Magnuson-Stevens Act Definitions and Required Provisions

Amendment 6 to the Bottomfish and Seamount Groundfish Fisheries Management Plan
Amendment 8 to the Pelagic Fisheries Management Plan
Amendment 10 to the Crustaceans Fisheries Management Plan
Amendment 4 to the Precious Corals Fisheries Management Plan

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Summary

This amendment adds new Magnuson-Stevens Act definitions to the fishery management plans (FMPs) of the western Pacific region and addresses the requirement of the Act that any FMP contain provisions regarding bycatch, fishing sectors, essential fish habitat (EFH), fishing communities and overfishing. The amendment compiles the best available scientific information pertaining to each of these new provisions and incorporates it directly or by reference into the Western Pacific Council's FMPs for bottomfish and seamount groundfish, pelagics, crustaceans and precious corals fisheries. In addition, the amendment identifies other scientific data that are needed to more effectively address the new provisions. A summary of the Council's response to each provision follows.

Establish Reporting Methodology for Bycatch (Section 4.1)

The combination of information collected from National Marine Fisheries Service (NMFS) observer programs and research cruises and the various catch reporting systems that comprise the Western Pacific Fishery Information Network (WPacFIN) is sufficient to estimate with some confidence the amount and type of bycatch in FMP fisheries. Although the current focus of catch reporting systems is on monitoring the volume and disposition of landed target species, detailed discard information on target catches is reported by certain vessel types, such as Hawaii-based longline vessels and Northwestern Hawaiian Islands (NWHI) bottomfish vessels. Modification of survey methodologies or catch report forms may enhance the ability of existing catch reporting systems to monitor discards for other gear types. However, it will continue to be important to supplement bycatch information collected by catch reporting systems with bycatch data gathered from observer programs or research cruises conducted by NMFS and other agencies, such as the Secretariat for the Pacific Community (SPC).

Scientific Data Needs:

- Field-testing of modified creel surveys or catch reporting forms to determine if additional information on the amount and type of bycatch in FMP fisheries can be collected without imposing an excessive reporting burden on fishermen.
- Continued and, if possible, expanded research cruises and observer programs to provide estimates of the type and amount bycatch that occurs with various gear types.

Minimize Bycatch and Bycatch Mortality (Section 4.1)

The prevalent gear types used in the region are variations of hook and line (with a small amount of trapping for lobster in Hawaii) that tend to be fairly selective. However, the amount of bycatch in the region's fisheries can be further reduced by developing and promoting uses for the fish that are generally discarded. For example, NMFS is currently sponsoring a study to determine whether markets exist (or can be developed) for the meat, hides, etc. of the sharks caught by domestic longline vessels. With regard to minimizing bycatch mortality, it would be difficult to reduce mortality with the gear types currently used in FMP fisheries.

Scientific Data Needs:

- Research on potential uses of and markets for fish that are currently discarded in order to minimize waste and encourage full utilization.
- Survival rate studies of live discards in order to more accurately estimate bycatch mortality.

Specify Data on Commercial, Recreational and Charter Fishing and Quantify Trends in Landings in These Sectors (Section 4.2)

Information contained in the FMPs and amendments is supplemented and updated by the annual reports prepared by the Council for each fishery. Included in the annual reports are data on total weight of fish landed by species, weight of fish sold, fishing effort, average price, revenue and annual catch per unit effort (CPUE). Such detailed information is collected for both the commercial and charter sectors in all four island areas except for the Northern Mariana Islands, where the fishery data collection system has been significantly reduced. Information on the size and composition of recreational catches of pelagic and bottomfish species in Hawaii is not collected by any ongoing data collection programs. Furthermore, no recreational fishing surveys have been recently conducted in the Pacific Island Areas to supplement information collected by current creel surveys. Currently, the unsold portion of reported catches is considered to be the recreational catch.

Scientific Data Needs:

- Marine recreational fishing surveys in order to more accurately quantify landings in the recreational sector.
- Assistance to the Northern Mariana Islands Division of Fish and Wildlife (DFW) to re-establish the creel survey program.

Describe Essential Fish Habitat and Minimize Adverse Effects (Section 4.3)

Because there are large gaps in scientific knowledge about the life histories and habitat requirements of many FMP species, the Council has adopted a precautionary approach in designating essential fish habitat (EFH). With the exception of the EFH for precious corals, the designations consist of the depth ranges within the exclusive economic zone (EEZ) of certain life stages of some FMP species. In addition, the Council identified habitat areas of particular concern (HAPC). For adult and juvenile bottomfish species, the water column and all bottom habitat from the shorelines of all islands to a depth of 400 m are designated EFH. For bottomfish eggs and larvae, the shoreline to the outer limit of the EEZ to a depth of 400 m are designated EFH. Slopes and escarpments at a depth of 40 to 280 m and three known areas of juvenile bottomfish habitat are designated HAPC. EFH for the adult life stage of the seamount groundfish complex is all waters and bottom habitat bounded by latitude 29°–35°N and longitude 171°E–179°W between 80–600 m. EFH for eggs, larvae and juveniles is the epipelagic zone of all waters bounded by latitude 29°–35°N and longitude 171°E–179°W. Pelagic species EFH is the shoreline to the outer limit of the EEZ to a depth of 1,000 m. In addition, areas outside the EEZ are considered important habitat. HAPC are all seamounts and banks around islands from the shoreline to the outer limit of the EEZ down to 2,000 m. Crustacean larvae EFH is the shoreline to the outer limit of the EEZ down to a depth of 150 m; adult and juvenile crustacean EFH extends to a depth of 100 m. HAPC are Maro Reef, Necker Island, Gardner Pinnacles and all other banks in the NWHI with summits less than or equal to 30 m deep. Precious corals EFH is confined to the Established, Conditional and Refugia Beds and three known beds for black corals. Precious corals HAPC include the Makapuu bed, Wespac bed, Brooks Bank bed and Auau Channel.

Scientific Data Needs:

- See Appendix 6.

Include Impacts on Fishing Communities (Section 4.4)

Given the reference in the Magnuson-Stevens Act to the economic importance of fishery resources to the island areas within the western Pacific region and taking into account these islands' distinctive geographic, demographic and cultural attributes, the Council concluded that it is appropriate to characterize each of the island areas within its region as a fishing community. The accompanying regulatory impact reviews for FMPs and amendments submitted to the Secretary after October 1, 1990, adequately address the effects of management measures on fishing communities in the western Pacific region.

Scientific Data Needs:

- Additional research on the economic and social importance of fishery resources in each island area in order to improve the depth and scope of impact statements for future proposed management measures. Specific areas where research is required include an estimation of the value of shark-fin landings in the western Pacific region; identification of economic or other barriers that have prevented full participation by indigenous island residents in western Pacific fisheries; and cost-earnings analyses of small-scale fishing enterprises in the Pacific Island Areas.

Specify Overfishing Criteria and Include Preventive Measures (Section 4.5)

The main control rule in the NWHI bottomfish fishery is a limited entry system. Minimum stock size threshold was determined by SPR proxy to range from 20% to 33% for bottomfish, based on an analysis of common Hawaiian species. Maximum fishing mortality threshold for MSY was determined as F=0.17-0.69 for bottomfish. Information is insufficient to quantify a value for OY at this time, however, a precautionary approach could be to allow a buffer for these MSY threshold values by setting a target level slightly higher until the precision and accuracy of the proxy estimator, and information on social, economic and ecological factors are better known. Results from recent genetic analyses and related studies, supporting archipelagic stock ranges, indicate that no BMUS are overfished based on either a recruitment-based or MSY-based definition of overfishing. Concurrent with the required change in definition of overfishing from a SPR-based threshold to a MSY-based threshold, overfishing (based on MSY or its SPR proxy) is now calculated based on the stock as a unit throughout its range, as determined by the best available information. Existing measures in the FMP are also sufficient to prevent overfishing at this time.

The Council manages its pelagic fisheries to prevent overfishng and achieve OY, as defined in Amendments 1 and 7, to the extent practicable. Any control rules to prevent overfishing for PMUS will require full international cooperation in assessment and management by Pacific fishing nations with the US. Methods to objectively measure MSY and assess overfishing for pelagics must all be applied on a Pacific-wide basis and be based on sufficient data. For only a few species are reasonable MSY estimates available. The threshold for F_{MSY} or MFMT, while unknown for most PMUS stocks, is estimated to be 0.2–1.5 per year, based on F_{MSY}=M. The threshold level for MSST, also not known for most pelagic stocks, is estimated by the proxy SPR=20–30% (35–45% for oceanic sharks). The Council maintains that MSY-related definitions of overfishing cannot be applied to the US Pacific island EEZs given the Pacific-wide distribution of most pelagic stocks and the current highly uncertain estimates of stock-wide MSYs. Information is also insufficient to quantify a value for OY at this time, until social, economic and ecological factors are better known. Existing measures in the FMP are sufficient to prevent overfishing and no pelagic stocks are known to be overfished at this time. The Council asserts that the new overfishing provision can best be addressed through US participation in international management initiatives in the Pacific.

The NWHI lobster fishery operates under a constant risk of overfishing with associated constant harvest rate control rule, through a fleet-wide harvest guideline, that has been effective in producing harvest levels that probably approach OY. The strategy is conservative and risk averse. The risk of overfishing is currently set at 10% whch translates to a 13% harvest rate and is a more conservative strategy than basing overfishing on MSY or MSST, since it maintains sustainable yield well away from the threshold limits. Minimum stock size threshold was determined by SPR proxy to be 20%. Maximum fishing mortality threshold for MSY was determined as F=0.21-1.25. Under the current control rule the expected SPR is 65%, significantly more conservative than the MSY thresholds. Until studies can be conducted on economic, social and ecological factors of the lobster fishery, a provisional estimate of OY may be the average annual yield associated with the 13% constant harvest rate. Measures contained in the FMP are sufficient to prevent overfishing, and no stocks are currently overfished.

The precious corals fishery is already managed based on OY quotas (i.e., control rule), calculated by downwardly adjusting MSY estimates. Values for OY quotas are listed as regulations for the main species of precious corals. The SPR proxy for minimum stock size threshold that corresponds to MSY is SPR=30%, and is already defined as such in the FMP. If one assumes F_{MSY}=M then the maximum fishing mortality threshold for MSY is F=0.066. As no harvesting has occurred for 20 years, and nearly full recovery has been attained, no species of precious coral is currently overfished in the western Pacific's EEZ.

Scientific Data Needs (Bottomfish Fishery):

- CPUE data for species targeted trips in the NWHI fishery.
- Improved estimates of the size at entry and natural mortality rate to obtain a more reliable MSY proxy.
- Estimates of MSY-based overfishing thresholds, or proxies, for BMUS in American Samoa, Guam and the Northern Mariana Islands.
- Monitoring and evaluation of the State of Hawaii's management plan to restore locally depleted bottomfish in the Main Hawaiian Islands (MHI).
- Detailed information on economic, social and ecological factors to quantify OY.

Scientific Data Needs (Pelagics Fishery):

- International assessments of PMUS stocks in the Pacific and improved estimates of parameters to determine MSY or proxies thereof, in order to prevent overfishing.
- More complete and accurate population dynamics data on PMUS.
- Determination of limiting or threshold values and the robustness of biological reference points that define overfishing through simulation models.
- Estimates of MSY from results of tagging studies in the Pacific.
- Improved database of time-series information to estimate SPR for PMUS Pacific-wide.
- Detailed information on economic, social and ecological factors to quantify OY.

Scientific Data Needs (Crustaceans Fishery):

- Rerunning the population dynamics simulation model using updated parameter values and a revised model structure based on current NWHI lobster fishery information.
- Studies of the stock-recruitment relationship in the NWHI lobster fishery.
- Studies on the feasibility of species-specific and area-specific modeling.
- Studies on economic and social factors in the fishery to improve the estimate of OY.

Scientific Data Needs (Precious Corals Fishery):

- Research on the distribution, abundance and status of precious corals in the Pacific Island Areas.
- MSY estimates for Conditional Beds and Exploratory Areas.
- MSY estimates for black corals.
- Surveys of Makapuu bed to better define the bed's boundaries, monitor the recovery of corals (particularly gold coral) and determine the impacts of fishing activity should it occur.
- Improved and updated information on economic, social and ecological factors to better quantify OY.

Contents

Appendices

1.0 INTRODUCTION

1.1 Responsible Agencies

The Council was established by the Magnuson Fishery Conservation and Management Act to develop fishery management plans for fisheries operating in the US exclusive economic zone (EEZ) around American Samoa, Guam, Hawaii, the Northern Mariana Islands and the other US Pacific Islands.[1] Once an FMP is approved by the Secretary of Commerce, it is implemented by Federal regulations that are enforced by the National Marine Fisheries Service (NMFS) and the US Coast Guard, in cooperation with state, territorial and commonwealth agencies. For further information, contact:

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1. Howland Island, Baker Island, Jarvis Island, Johnston Atoll, Midway Island, Kingman Reef, Palmyra Atoll and Wake Island.

1.3 List of Acronyms

B	Spawning biomass
BMUS	Bottomfish management unit species
C	Catch (in numbers)
CFR	Code of Federal Regulations
CMUS	Crustacean management unit species
CPUE	Catch per unit effort
DAWR	Guam Division of Aquatic and Wildlife Resources
DAH	Domestic allowable harvest
DFW	Northern Mariana Islands Division of Fish and Wildlife
DMWR	American Samoa Department of Marine and Wildlife Resources
EEZ	Exclusive economic zone
F	Fishing mortality
FL	Fork length
FMP	Fishery management plan
HAPC	Habitat areas of particular concern
HDAR	Hawaii Division of Aquatic Resources
HR	Harvest rate
M	Natural mortality rate
MFMT	Maximum fishing mortality threshold
MHI	Main Hawaiian Islands
MSST	Minimum stock size threshold
MSY	Maximum sustainable yield
MUS	Management unit species
MYPR	Maximum yield per recruit
SE-NHR	southern Emperor-northern Hawaiian Ridge
NMFS	National Marine Fisheries Service
NWHI	Northwestern Hawaiian Islands
OY	Optimum yield
PCMUS	Precious coral management unit species
PIAO	NMFS Pacific Islands Area Office
PMUS	Pelagic management unit species
RAIOMA	Resource Assessment and Investigation of the Mariana Archipelago
RSB	Relative spawning biomass
SPC	Secretariat of the Pacific Community (South Pacific Commission)
SPR	Spawning potential ratio
TALFF	Total allowable foreign fishing
UFA	United Fish Agency
WpacFIN	Western Pacific Fisheries Information Network
WPRFMC	Western Pacific Regional Fishery Management Council
Y	Yield or catch (in weight)
YPR	Yield per recruit

1.4 Managed Species in the Western Pacific Region

<u>Scientific Name</u>	<u>Common Name (*local name*)</u>
<u>Bottomfish</u>	
Aphareus rutilans	red snapper/silvermouth (*lehi*)
Aprion virescens	gray snapper/jobfish (*uku*)
Caranx ignobilis	giant trevally/jack (*ulua*)
C. lugubris	black trevally/jack (*ulua*)
Epinephelus fasciatus	blacktip grouper
E. quernus	sea bass (*hapuupuu*)
Etelis carbunculus	red snapper (*ehu*)
E. coruscans	red snapper (*onaga*)
Lethrinus amboinensis	ambon emperor
L. rubrioperculatus	redgill emperor
Lutjanus kasmira	blueline snapper (*taape*)
Pristipomoides auricilla	yellowtail snapper (yellowtail *kalekale*)
P. filamentosus	pink snapper (*opakpaka*)
P. flavipinnis	yelloweye snapper (yelloweye *opakapaka*)
P. sieboldii	pink snapper (*kalekale*)
P. zonatus	snapper (*gindai*)
Pseudocaranx dentex	thicklip trevally
Seriola dumerili	amberjack
Variola louti	lunartail grouper
Seamount Groundfish	
Beryx splendens	alfonsin
Hyperoglyphe japonica	ratfish/butterfish
Pseudopentaceros richardsoni	armorhead
Pelagic Species	
Coryphaena spp.	mahimahi
Acanthocybium solandri	wahoo
Makaira mazara; M. indica	Indo-Pacific blue marlin; black marlin
Tetrapterus audax	striped marlin
T. angustirostris	shortbill spearfish
Istiophorus platypterus	sailfish
Xiphias gladius	swordfish
Lampris spp.	moonfish
Ruvettus pretiosus; Lepidocybium flavobrunneum	oilfishes
Bramidae	pomfret
Alopiidae; Carcharinidae; Lamnidae; Sphyrnidae	oceanic sharks
Thunnus alalunga	albacore
T. obesus	bigeye tuna
T. albacares	yellowfin tuna

T. thynnus	northern bluefin tuna
Katsuwonus pelamis	skipjack tuna
Euthynnus affinis	kawakawa
Gymnosarda unicolor	dogtooth tuna
Auxis spp.; *Scomber* spp.; *Allothunnus* spp.	other tuna relatives
Crustaceans	
Panulirus marginatus,	
Panulirus pencicillatus;	
Panulirus sp.	spiny lobsters
Scyllaridae sp.	slipper lobster
Ranina ranina	Kona crab
Precious Corals	
Corallium secundum	pink coral
Corallium regale	red coral
Corallium laauense	red coral
Gerardia sp.	gold coral
Narella sp.	gold coral
Calyptrophora sp.	gold coral
Callogorgia gilberti	gold coral
Lepidisis olapa	bamboo coral
Acanella sp.	bamboo coral
Antipathes dichotoma	black coral
Antipathes grandis	black coral
Antipathes ulex	black coral

2.0 BACKGROUND AND PURPOSE OF AMENDMENT

2.1 Summary of Fishery Management Plans and Amendments

2.1.1 Bottomfish fishery

The FMP for bottomfish and seamount groundfish fisheries in the western Pacific region became effective in 1986. The FMP prohibits certain destructive fishing techniques, including explosives, poisons, trawl nets and bottom-set gillnets; establishes a moratorium on the commercial harvest of seamount groundfish stocks at the Hancock Seamounts; and implements a permit system for fishing for bottomfish in the EEZ around the NWHI. The plan also establishes a management framework that includes adjustments such as catch limits, size limits, area or seasonal closures, fishing effort limitation, fishing gear restrictions, access limitation, permit and/or catch reporting requirements and a rules-related notice system.

Amendment 1 includes the establishment of limited access systems for bottomfish fisheries in the EEZ surrounding American Samoa and Guam within the framework measures of the FMP.

Amendment 2 was developed to diminish the risk of biological overfishing and improve the economic health and stability of the bottomfish fishery in the NWHI. The amendment divides the EEZ around the NWHI into two zones: the Hoomalu Zone and Mau Zone. A limited access system was established for the Hoomalu Zone. Access to the Mau Zone remains unrestricted, except for excluding vessel owners permitted to fish in the Hoomalu Zone. The Mau Zone is intended to serve as an area where fishermen can gain experience fishing in the NWHI, thereby enhancing their eligibility for subsequent entry into the Hoomalu Zone.

Amendment 3 defines recruitment overfishing as a condition in which the ratio of the spawning stock biomass per recruit at the current level of fishing to the spawning stock biomass per recruit that would occur in the absence of fishing is equal to or less than 20%. Amendment 3 also delineates the process by which overfishing is monitored and evaluated.

Amendment 4 requires vessel owners or operators to notify NMFS at least 72 hours before leaving port if they intend to fish in a 50 nm “study zone” around the NWHI. This notification allows Federal observers to be placed on board bottomfish vessels to record interactions with protected species if this action is deemed necessary.

2.1.2 Pelagics fishery

The management plan for the pelagic fisheries of the western Pacific region was published in 1987. The FMP includes initial estimates of MSY for the stocks and set OY for these fisheries in the EEZ. The MUS at that time were billfish, wahoo, mahimahi and oceanic sharks. The FMP prohibits drift gillnet fishing within the region’s EEZ and foreign longline fishing within certain areas of the EEZ.

Amendment 1 was drafted in response to the Secretary of Commerce Guidelines for the Magnuson Act National Standards requiring a measurable definition of recruitment overfishing for each species or species complex in a FMP. The OY for PMUS was also defined as the amount of fish that can be harvested by domestic and foreign vessels in the EEZ without causing local overfishing or economic overfishing.

Amendment 2 requires domestic longline vessels to have Federal permits, to maintain Federal fishing logbooks and, if wishing to fish within 50 nm of the NWHI, to have observers placed on board. It also includes under the FMP pelagic fisheries in the EEZ around the Northern Mariana Islands.

Amendment 3 creates a 50 nm longline exclusion zone around the NWHI to protect endangered Hawaiian monk seals. It also contains framework provisions for establishing a mandatory observer program to collect information on interactions between longline fishing and turtles.

Amendment 4 establishes a three-year moratorium on new entries into the Hawaii-based domestic longline fishery. It also adds a provision for establishing a mandatory vessel monitoring system for domestic longline vessels fishing in the western Pacific region.

Amendment 5 creates a domestic longline vessel exclusion zone around the MHI ranging from 50 to 75 nm and a similar 50 nm exclusion zone around Guam and its offshore banks. The zones are intended to prevent gear conflicts and vessel safety issues arising form interactions between longline vessels and smaller fishing boats. A seasonal reduction in the size of the closure was implemented in October 1992; between October and January, longline fishing is prohibited within 25 nm of the windward shores of all islands except Oahu, where longline fishing is prohibited within 50 nm from the shore.

Amendment 6 specifies that all tuna species are designated as fish under US management authority. It also applies the longline exclusion zones of 50 nm around the island of Guam and the 50–75 nm zone around the MHI to foreign vessels.

Amendment 7 institutes a limited entry program for the Hawaii-based domestic longline fishery. The number of vessels allowed into the fishery is limited to 167, and the length of these vessels is limited to 94 feet or less.

2.1.3 Crustaceans fishery

Initial provisions of the FMP, adopted in 1983, include a minimum size limit, gear design requirement, ban on egg-bearing females and mandatory logbook program. The FMP has been amended nine times. Main actions include adoption of State of Hawaii regulations in the EEZ around the MHI (Amendment 1); specification of trap opening dimensions (Amendment 2); clarification of definitions for minimum size and tail length (Amendment 3); establishment of a 20-nm closed area (protected species zone) around Laysan Island (Amendment 4);

implementation of a minimum size for slipper lobster and requirement to include escape panels in traps (Amendment 5); definition of recruitment overfishing as SPR < 0.02 (Amendment 6); establishment in the NWHI fishery of a closed season (January–June) and a limited entry program (Amendment 7); elimination of "use-or-lose" landing requirement and development of a target CPUE for forecast quota (Amendment 8); and establishment of an annual harvest guideline based on constant harvest rate of population at a specified risk of overfishing and implementation of a "retain-all" fishery (Amendment 9).

2.1.4 Precious corals fishery

The management plan for the precious corals fishery of the western Pacific region was implemented in 1983. In the FMP, precious coral beds are treated as distinct management units because of their widely separated, patchy distribution and the sessile nature of individual colonies. The beds are classified as Established, Conditional, Refugia or Exploratory. Established Beds are ones for which appraisals of MSY are reasonably precise. To date, only Makapuu bed has been studied adequately enough to be classified as Established. Conditional Beds are ones for which estimates of MSY have been calculated by comparing the size of the beds to that of the Makapuu bed and then multiplying the ratio by the yield from the Makapuu bed. It is assumed that ecological conditions at the Makapuu bed are representative of conditions at all other beds. Five beds of precious corals are classified as Conditional, all of which are located in the EEZ around Hawaii. Refugia Beds are areas set aside for baseline studies and possible reproductive reserves. No harvesting of any type is allowed in those areas. The single Refugia Bed that has been designated—the Westpac bed—is also located in the EEZ surrounding Hawaii. Exploratory Areas are the unexplored portions of the EEZ. Separate Exploratory Permit Areas are established for Hawaii, American Samoa and Guam.

The FMP permits the use of only selective gear in the EEZ around the MHI, i.e., south and east of a line midway between Niihau and Nihoa Islands. Use of both selective and nonselective gear is permitted on the Conditional Beds of Brooks Bank and the 180 Fathom Bank and throughout the Exploratory Area of the NWHI. Quotas are established for pink, gold and bamboo coral populations in the Makapuu bed and in the Conditional Beds. Pink coral harvested from the Makapuu bed, the Keahole Point bed and the Kaena Point bed must have attained a minimum height of 10 inches. If tangle net dredges are employed, the weight quota is only 20% of that allowed for selective harvesting.

The FMP establishes a procedure for redesignating coral beds from Exploratory to Conditional and from Conditional to Established as new beds are located and more catch/effort data become available that will allow more precise determinations of sustainable yields.

Amendment 1 applies the management measures of the FMP to the Pacific Island Areas other than Guam, American Samoa and the Northern Mariana Islands by incorporating them into a single Exploratory Permit Area; expands the managed species to include Midway deep-sea coral; and outlines provisions for experimental fishing permits designed to stimulate the domestic fishery.

Amendment 2 defines overfishing with respect to Established Beds as follows: An Established Bed shall be deemed overfished with respect to recruitment when the total spawning biomass (all species combined) has been reduced to 20% of its unfished condition. This definition applies to all species of precious corals and is based on cohort analysis of the pink coral, *Corallium secundum*.

2.2 Purpose of Amendment

The Magnuson-Stevens Act requires that FMPs contain provisions regarding bycatch, fishing sectors, EFH, fishing communities and overfishing. This amendment compiles the best available scientific information pertaining to each of these new provisions and incorporates it directly or by reference into the Western Pacific Council's management plans for bottomfish and seamount groundfish, pelagics, crustaceans and precious corals fisheries. In addition, the amendment identifies other scientific data that are needed to more effectively address the new provisions. The Magnuson-Stevens Act also contains a number of new definitions. This amendment adds those definitions that are pertinent to western Pacific fisheries to the Council's four management plans.

2.3 Amendment Coordination

This amendment was prepared through an iterative process consisting of a series of meetings of the Council, SSC, FMP teams and fishing industry advisory panels. In addition, the Council worked in close cooperation with scientists in the NMFS Southwest Fisheries Service Center, Honolulu Laboratory, Pacific Islands Area Office and Southwest Regional Office. Notice of the availability of a draft amendment for public review and comment was published in the Federal Register on July 15, 1998. Public meetings and hearings at which this amendment was discussed are listed below:

Public Hearing on Amendment: July 20, 1998
Council: August 19–21, 1997; Nov. 12–14, 1997; April 13–17, 1998; July 27–29, 1998
SSC: August 5–7, 1997; Nov. 10–11, 1997; March 24–26, 1998; July 21–23, 1998
Bottomfish and Seamount Groundfish Fishery Plan Team: July 28, 1997; March 11–13, 1998
Pelagics Fishery Plan Team: July 30–31, 1997; May 6–7, 1998
Precious Corals Fishery Plan Team: July 29, 1997; Jan. 30, 1998; June 4, 1998
Crustaceans Fishery Plan Team: July 24–25, 1997; March 17–19, 1998
Ecosystem and Habitat Advisory Panel: July 29, 1997; March 20, 1998
Pelagics Fishery Advisory Panel: July 30–31, 1997
Bottomfish and Seamount Groundfish Fishery Advisory Panel: July 28, 1997

3.0 NEW DEFINITIONS

3.1 Bycatch

Bycatch means fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Such term does not include fish released alive under a recreational catch and release fishery management program.

3.2 Recreational, Charter and Commercial Fishing

Charter fishing means fishing from a vessel carrying a passenger for hire (as defined in section 2101(21a) of title 46, United States Code) who is engaged in recreational fishing. Commercial fishing means fishing in which the fish harvested, either in whole or in part, are intended to enter commerce or enter commerce through, sale, barter or trade. Recreational fishing means fishing for sport or pleasure.

3.3 Economic Discards and Regulatory Discards

Economic discards mean fish which are the target of a fishery, but which are not retained because they are of an undesirable size, sex or quality or for other economic reasons. Regulatory discards mean fish harvested in a fishery which fishermen are required by regulation to discard whenever caught or are required by regulation to retain but not sell.

3.4 Essential Fish Habitat

Essential fish habitat means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.

3.5 Fishing Community

Fishing community means a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators and crews and US fish processors that are based in such community.

3.6 Individual Fishing Quota

Individual fishing quota means a Federal permit under a limited access system to harvest a quantity of fish, expressed by a unit or units representing a percentage of the total allowable catch of a fishery that may be received or held for exclusive use by a person.

3.7 Optimum

Optimum, with respect to the yield from a fishery, means the amount of fish that (a) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; (b) is prescribed as such on the basis of the MSY from the fishery, as reduced by any relevant economic, social or ecological factor; and (c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the MSY in such fishery.

3.8 Overfished and Overfishing

Overfishing and Overfished mean a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce the MSY on a continuing basis.

3.9 Pacific Insular Area

Pacific Insular Area means American Samoa, Guam, the Northern Mariana Islands, Baker Island, Howland Island, Jarvis Island, Johnston Atoll, Kingman Reef, Midway Island, Wake Island or Palmyra Atoll, as applicable, and includes all islands and reefs appurtenant to such island, reef or atoll.

4.0 NEW FISHERY MANAGEMENT PLAN PROVISIONS

4.1 Establish Reporting Methods to Assess Bycatch and Minimize Bycatch and Bycatch Mortality

Establish a standardized reporting methodology to assess the amount and type of bycatch occurring in the fishery, and include conservation and management measures that, to the extent practicable and in the following priority—

(A) minimize bycatch; and

(B) minimize the mortality of bycatch which cannot be avoided.

This section presents an overview of the type and amount of bycatch in each managed fishery and assesses the adequacy of bycatch reporting in terms of the required provision. It also examines existing and possible new measures to minimize bycatch and mortality of bycatch in each FMP fishery.

4.1.1 Bottomfish fishery

This fishery is managed under the Bottomfish and Seamount Groundfish FMP, implemented in 1986. Commercial and recreational bottomfish fishing occurs in the EEZ around all of the occupied islands in the Council's area.

Gear Types

In Hawaii commercial and recreational bottomfish fishing are conducted with handlines that are set and hauled on electric-, hydraulic- or hand-powered reels. Vessels are usually equipped with depth sounders, fish echo sounders and satellite navigational devices. Two separately managed bottomfish fisheries occur in Hawaii. In the NWHI all participants fish commercially on a full- or part-time basis while in the MHI fishery there are also recreational fishermen. Available data suggests that the magnitude of the effort in the MHI fishery has been declining since the late 1980s. In American Samoa small skiffs and *alia* catamarans equipped with handlines and hand-powered reels fish on the deep outer-reef slope. As in Hawaii, this method is relatively selective, targeting a mix of snappers, groupers, jacks and emperors. In the EEZ around Guam and the Northern Mariana Islands deep-water bottomfish fishing is conducted mainly by commercial vessels equipped with electric-powered reels.[2] Shallow-water BMUS are also caught on seamounts using rod and reel.

[2] Bottomfish fisheries occurring in the EEZ around the Northern Mariana Islands are not managed under the FMP.

Data Collection

In Hawaii landings data for the commercial bottomfish fishery in the MHI and in the EEZ around the uninhabited islands in the Pacific Island Areas are collected on the Fish Catch Report (referred to as the C3 form) administered by the HDAR. (See Appendix 1 for a description of regional data collection systems and Appendix 2 for copies of the data forms. The C3 form is reproduced on p. A2-17). The form requires commercial marine license holders to report the number and weight of each species caught and the weight of each species sold. The form does not require fishermen to provide information on the disposition of unsold catch.

Participants in the NWHI fishery are required to complete the HDAR NWHI Bottomfish Trip Daily Log (p. A2-22). The daily log requires fishermen to report the number and weight of various bottomfish and non-bottomfish species kept, the number released and the number damaged or stolen by marine mammals and sharks. There is also limited space provided for recording the type and number of other fish kept, released or stolen.

In American Samoa landings data are collected from creel surveys administered by the DMWR. The Offshore Survey form (p. A2-1) used in the creel surveys records the numbers and weight of each species caught during a trip as well as the disposition of the catch. However, fishermen have not been specifically asked to provide information on the disposition of fish that are not sold.

In Guam landings data are collected from creel surveys administered by the DAWR. The Offshore Creel Census (p. A2-4) form records the number and weight of each species caught during a trip and percentage of the total catch that is kept or sold. However, fishermen have not been specifically asked to provide information on the disposition of fish that are not sold.

In the Northern Mariana Islands from 1988 to 1996 the DFW collected landings data in a creel survey program. The CNMI Offshore Creel Census and CNMI Inshore Creel Census forms (p. A2-25 and A2-27) recorded the number and weight of each species caught during a trip and percentage of the total catch that was kept or sold. However, fishermen were not specifically asked to provide information on the disposition of fish that were not sold. Commercial bottomfish landings in the Northern Mariana Islands are currently recorded in the DFW's Commercial Purchase Database (p. A2-29).

Several research cruises in the Hawaiian Islands and other parts of the western Pacific conducted by NMFS and other fishery agencies have collected detailed information on bottomfish stocks. These fishery-independent records are also useful in providing information on the likely volume of bycatch.

Bycatch

In all cases bottomfish are caught on gear that is relatively selective, targeting the snapper/grouper/emperor complex on outer reef slopes and seamounts. However, the ability to target particular species varies widely depending on the skill of each captain. Experienced bottomfish fishermen have the capability to catch desired species with little bycatch or incidental catch. However, it is impossible to completely avoid non-target species.

Table 4.1.a presents HDAR logbook data on the number of fish caught and kept, the number of fish discarded and number of fish discarded during 1997. Releases and damaged fish might reasonably be designated bycatch; these amounted to only 8% of the total catch of NWHI handline-caught bottomfish. No details were provided about the numbers of fish stolen, as these are usually grouped in the ‘damaged’ category by fishermen. Sharks, oilfish, snake mackerel, pufferfish and moray eels are important bycatch species, discarded because they are normally not considered food fish. In contrast, ulua (Caringidae) and kahala are discarded despite being palatable (Kasaoka 1990). Ulua are discarded because of their short shelf-life and low market value. Kahala, once a major component of commercial and recreational landings, are now seldom retained as they have been implicated in incidents of ciguatera. In Hawaii a recent increase in the market demand for shark fins has meant that more sharks are being “finned” (the practice of cutting off a shark’s fins and returning the remainder of the fish to the sea) and fewer are being discarded as bycatch.

Data collected during NMFS research cruises in Hawaii indicate that species generally regarded as bycatch represent about 19% of the total catch (Figure 4.1.a).

Fishery independent data collected during surveys in American Samoa in 1978 and 1988 by the SPC suggest that the catch of non-target species amounts to less than 1% of the total catch and consists mainly of snake mackerel (*Promethichthys prometheus*). Information gathered during the NMFS Resource Assessment and Investigation of the Mariana Archipelago (RAIOMA) project suggest that in Guam and the Northern Mariana Islands pufferfish, gurnards, beardfish and sharks are the main bycatch species (Figure 4.1.b). Total potential bycatch comprises only about 1% of the total catch.

Hawaiian Name	Scientific Name	No. Kept	No. Released	No. Damaged
Misc. shark,	Carcharhinidae	0	166	0
Tiger shark	*Galeocerdo cuvier*	0	5	0
Kahala	*Seriola dumerilli*	25	2,114	6
Ahi	*Thunnus alabacares*	16	7	0
Ulua butaguchi	*Caranx ignobilis*	4,396	1,177	121
Uku	*Aprion virescens*	3,500	16	50
Hapuupuu	*Epinephelus quernus*	4,586	17	97
Kalekale	*Pristopomoides auricilla*	6,312	12	7
Opakapaka	*Pristipomoides filamentosus*	16,554	2	213
Ehu, ulaula	*Etelis carbunculus*	6,070	0	98
Gindai	*Pristipomoides zonatus*	2,133	0	98
Onaga	*Aprion virescens*	8,207	0	37
Ulua	Carangidae	231	0	7
Lehi	*Aphareus rutilans*	123	0	2
Kawakawa	*Euthynnus affinis*	29	0	0
Mahimahi	*Coryphaena hippurus*	16	0	0
Omilu	Carangidae	49	0	0
Misc. ulua/papio	Carangidae	1	0	0
Weke ula,		11	0	0
Aawa	Labridae	9	0	0
Aweoweo		4	0	0
Wahanui		23	0	0
Kaku	Sphyraenidae	10	0	0
Kamano	Elegatis bipnnulatis	3	0	0
Kumu	Mullidae	1	0	0
Mu		2	0	0
Nohu,	Scorpaenidae	1	0	0
Ulua kagami	Carangidae	5	0	0
Opelu	Decapterus spp	5	0	0
Taape	Lutjanus kasmira	24	0	0
Pomfret	Bramidae	17	0	0
Ulua dobe	Carangidae	2	0	0
Ulua gunkan	Carangidae	46	0	0
Ulua papa	Carangidae	224	0	0
Hogo	Scorpaenidae	193	0	0
Others		4	0	0
Total		52,832	3,516	736

Table 4.1.a: Logbook estimates of disposition of catches in the NWHI bottomfish fishery, 1997 (Source: NMFS Honolulu Laboratory)

4.1.2 Pelagics fishery

Pelagic fish species are managed under the FMP for pelagic fisheries, implemented in 1986. Commercial pelagic fisheries are found primarily in Hawaii, but there are recreational, subsistence and small-scale commercial fisheries in the other island areas.

Gear Types

PMUS are caught by longline, troll and handline, pole- and-line and purse seine.

The number of longline vessels based in Hawaii are restricted by a license limitation program to 167. Currently, about 105 vessels are active. These vessels are typically 50–100 ft in length and employ a monofilament mainline 18–60 nm long, with 400–2,000 baited hooks. Longline fishing is prohibited in a 50–75 nm exclusion zone around the MHI to prevent competition and gear conflicts with troll and handline vessels and in a 50 nm exclusion zone around the NWHI to prevent interactions with protected species. In American Samoa the domestic longline fleet mainly consists of small (28–32 ft) catamarans from which a 300-hook longline is set and retrieved by hand. In Guam and the Northern Mariana Islands there is no commercial longline fleet.

Hand troll gear is used by commercial, recreational and charter vessels to fish for pelagic species throughout Hawaii. Commercial albacore troll vessels occasionally fish in the waters around Hawaii. In American Samoa, Guam and the Northern Mariana Islands trolling with baited hooks and lures is conducted from catamarans and other small commercial, recreational and charter vessels in coastal waters, near seamounts or around fish aggregating devices. Handline fishing from stationary or drifting vessels is also common in Hawaii.

A small pole-and-line fleet, which principally targets surface schools of skipjack tuna, operates in Hawaii.

US purse seine vessels operating in the central and western Pacific occasionally fish in the EEZ around the uninhabited islands of the Pacific Island Areas.

Data Collection

Longline vessels based in Hawaii and American Samoa and those fishing in the waters of Guam, the Northern Mariana Islands and the uninhabited islands of the Pacific Island Areas are required to record catches in the NMFS Western Pacific Daily Longline Fishing Log (p. A2-18). Vessels are required to record the number of various PMUS kept during a set and the number not kept/released. The form also requires longline fishermen to report the number of sharks finned, kept whole and not kept/released. There is also limited space for recording the number of non-PMUS kept or not kept/released.

In addition, Hawaii-based longline vessels are required to complete the HDAR Longline Trip Report (p. A2-19), which records the number and weight of particular pelagic species caught and the weight of each type sold. There is also limited space for reporting the number and weight of other species caught and the weight of those sold. Fishermen are not required to report the disposition of unsold fish. Finally, the form requires fishermen to record the number of dolphins, monk seals, humpback whales, turtles (by species), albatrosses and other protected species released alive, injured or dead.

Since 1994, NMFS observers have also been deployed on Hawaii-based longline vessels, principally to document the interactions between longline gear and marine turtles. The Magnuson-Stevens Act classifies turtles that are captured and discarded as bycatch. The observers record whether each turtle is alive or dead when released. They have also fitted a number of live released turtles with satellite tags that transmit information on the location and depth of the animal. This information is also being used to determine the post-hooking mortality rate of turtles. Observers also record the type and number of all fish captured in a set.

Landings data for commercial troll and handline vessels in Hawaii are collected on the state's Fish Catch Report (refer to Section 4.1.1 and see p. A2-17). Holders of Hawaii commercial marine fishing licenses fishing in the uninhabited islands and landing their catch in Hawaii are also required to used this form. Some charter and recreational vessels also routinely participate in the NMFS Cooperative Billfish Tagging Program on a voluntary. The troll fleet in American Samoa employs the Offshore Survey (p. A2-1) to record catches, while in Guam the Offshore Creel Census, which includes an Offshore Vehicle Trailer Participation Census (p. A2-4 and A2-5), is used. The Offshore Creel Census, which included both interview and participation forms, was also used in the Northern Mariana Islands from 1988 until it was discontinued in 1996 (refer to Section 4.1.1.2 and see p. A2-24 and A2-25). Commercial troll landings in the Commonwealth are currently recorded on the DFW's Commercial Sales Data form (p. A2-29).

Commercial albacore troll vessels that land their catch in Hawaii are required to complete the HDAR Albacore Trolling Trip Report (p. A2-21). This form requires fishermen to report the number and weight of albacore, skipjack, yellowfin and bigeye tuna, yellowtail snapper and mahimahi caught during a trip and the weight of each type sold. There is also limited space for recording the number and weight of other species caught and the weight of those sold. The form does not require fishermen to report on the disposition of unsold fish.

Pole-and-line catches are recorded on the HDAR Aku Catch Report (p. A2-20). The form requires fishermen to report the number and weight of skipjack tuna and mahimahi caught and the weight of these species that are sold. The form also requires fishermen to record the number and weight of other fish species caught and the weight of these species sold. There is no space for reporting how unsold fish are disposed of.

Purse-seine vessels complete the South Pacific Regional Purse-Seine Logsheet (p. A2-30) developed under the Multilateral Treaty on Fisheries between Pacific Island States and the United States. The form requires fishermen to report the number of yellowfin, skipjack and bigeye tuna and other species caught during each set and the number of tuna, marlin and other species discarded. In addition, observers on US purse seiners from member nations of the South Pacific Forum complete the South Pacific Regional Purse Seine Observer Set Details form (p. A2-31), which records details of the catch including species and condition of discards.

Bycatch

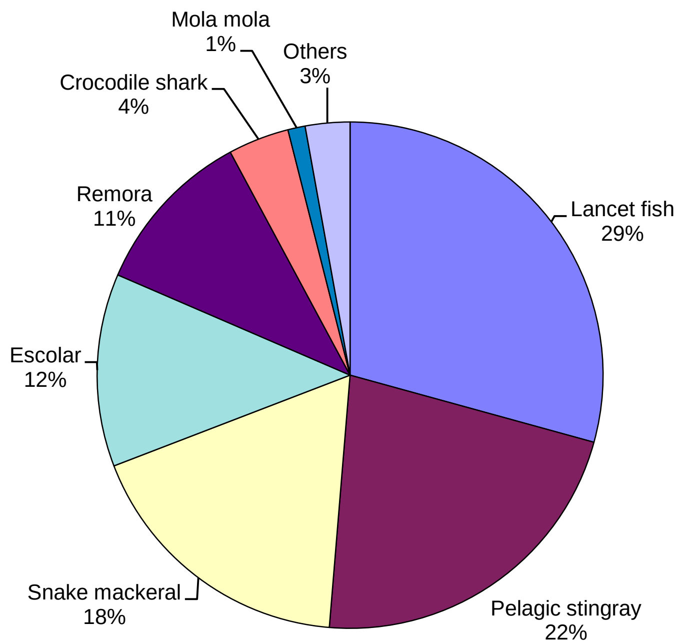
NMFS observers recorded more 60 different species caught by the Hawaii-based longline fleet between 1994 and 1997. Data collected on the catch and discards of PMUS by Hawaii-based longline fleet in 1997 are presented in Table 4.1.b. Of significance are the 85,523 sharks, of which the majority were blue sharks, caught by the fleet. Up until about five years ago, most sharks caught by longline gear were released alive. However, as a result of the growing demand for shark fins in Asian markets the practice of shark finning has increased. Presently, more than half of the caught sharks, including species other than the blue shark, are finned. About 1% of the sharks, mainly mako and thresher, are headed and gutted and retained for later sale. However, the majority of longline vessels do not retain blue shark carcasses because they cannot be profitably sold. Aside from sharks, there is a small fraction of the total catch that could be sold but is not retained for economic reasons. For example, marlins are often discarded at the beginning of a trip to leave hold space for more valuable species. Most of these economic discards are released alive.

Non-PMUS species captured by the longline fleet are mostly discarded and represent about 6% of the total number of fish caught. Based on NMFS observer data for 1994–1997, which amounts to between 4% and 5% of the annual total number of longline fishing trips, the discarded non-PMUS

Species	**Number Caught**	**Number Finned**	**Number Kept**	**Number Released**	**Discards as % of Total Catch**
Blue marlin	8249		8032	217	2.63
Spearfish	7302		7028	274	3.75
Striped marlin	12614		11925	689	5.46
Swordfish	39500		38164	1336	3.38
Other billfish	1708		1587	121	7.08
Blue sharks	79712	45,608	217	33,887	42.51
Mako sharks	1164	523	344	297	25.52
Thresher sharks	2321	550	212	1,559	67.17
Other sharks	2326	1769	16	541	23.26
Albacore	71051		66424	4627	6.51
Bigeye	79602		77220	2382	2.99
Bluefin	242		221	21	8.68
Skipjack	12058		11760	298	2.47
Yellowfin	28983		28281	702	2.42
Mahimahi	49311		40995	8316	16.86
Moonfish	8241		8068	173	2.10
Oilfish	1746		637	1109	63.52
Pomfret	10423		10345	78	0.75
Wahoo	8304		8132	172	2.07
Non-PMUS	1152		1073	79	6.86

species include lancet fish, pelagic stingray, snake mackerel, escolar, remora, crocodile shark and mola mola,, among others (Figure 4.1.c).

NMFS observers report that loggerhead, olive ridley, leatherback and green turtles are caught by longline gear, and about 40 turtle interactions are recorded per year. These encounters can be expanded statistically to estimate fleet-wide take and kill for individual species (Table 4.1.c).


Mola mola
1%
Others
3%
Crocodile shark
4%
Remora
11%
Lancet fish
29%
Escolar
12%
Snake mackeral
18%
Pelagic stingray
22%

The use of a statistically stratified expansion process to generate kill and take estimates means that variables obtained from logbook data prior to the implementation of the observer program can be used to estimate kill and take levels for those years.

As for the troll and handline fishery, there is relatively little information on the nature and amount of bycatch because of current reporting requirements. However, as the gear in use tend to be selective, bycatch probably constitutes a small part of the catch. Almost all the fish caught by troll and handline vessels, including charter boats, in Hawaii, American Samoa, Guam and the Northern Mariana Islands are either sold or kept for personal consumption. In recent years, fishing tournaments, such as the Hawaii International Billfish Tournament, have provided various incentives for participants to release their catch. These catch-and-release tournament fish are not part of a recreational catch and release fishery management program within the FMP and should be considered bycatch.

The albacore troll fishery occurring in the North and South Pacific outside the EEZ has reported incidental catches of skipjack tuna, striped marlin, mahimahi and louvars. However, the largest bycatch component in this fishery is probably small (< 60 cm) albacore, which are discarded for economic reasons (N. Bartoo, NMFS SW Fisheries Science Center, pers. comm.). The volume of discards is estimated to be about 10% of the catch.

The pole-and-line gear used by that fishery in Hawaii is highly selective. Non-target species that are occasionally caught, such as kawakawa, blue and striped marlin and rainbow runner, are usually either sold or retained for personal consumption by the crew.

According to Catch Report Form data collected by purse-seine vessels in US EEZ waters in 1997 (Table 4.1.d), discards amounted to less than 0.5% of the total volume of catch. Purse-seine logbooks indicate that skipjack tuna forms the largest fraction of the discard volume by weight. This data is confirmed by the weight and numbers of discards recorded by observers aboard US purse seiners operating within the US EEZ waters between 1994 and 1997 (Table 4.1.e). Rainbow runner, triggerfish and mackerel also make significant contributions to purse-seine discards in terms of numbers.

Quantity Discarded (mt)					
Species	**Howland & Baker**	**Jarvis**	**Palmyra**	**All Islands**	**Percent of Total Discards**
Skipjack tuna	68.19	18.72	1.00	87.91	63.64
Yellowfin tuna	1.55	1.92		3.47	2.51
Mixed	13.89	1		14.89	10.78
Marlin	3.07	0.7		3.77	2.73
Blue marlin	0.35			0.35	0.25
Sailfish	0.05			0.05	0.04
Swordfish		0.09		0.09	0.07
Shark	9.8	1.79		11.59	8.39
Albacore	0.02			0.02	0.01
"Baitfish"	7.66	0.56		8.22	5.95
Barracuda	0.05			0.05	0.04
Dolphinfish	0.03	0.13		0.16	0.12
Mackerel	0.46	0.52		0.98	0.71
Manta ray	0.15			0.15	0.11
Mixed species		0.07		0.07	0.05
Rainbow Runner	1.02	5.1		6.12	4.43
Wahoo	0.05			0.05	0.04
Unknown species	0.19			0.19	0.14
TOTAL	106.53	30.6	1.00	138.13	100.00

Species	Weight (mt)	Numbers	% wt	% no
Skipjack Tuna	124.50	1765	82.33	36.07
Rainbow runner	7.91	1672	5.23	34.17
Triggerfish	2.65	661	1.75	13.51
Mackerel	3.27	365	2.16	7.46
Bigeye Tuna	1.48	149	0.98	3.05
Yellowfin Tuna	7.07	130	4.67	2.66
Mahimahi	0.09	73	0.06	1.49
Black marlin	0.22	14	0.14	0.29
Shark	0.22	14	0.14	0.29
Blue marlin	1.73	12	1.14	0.25
Wahoo	0.00	8	0.00	0.16
Sailfish	0.03	2	0.02	0.04
Manta ray	0.13	1	0.09	0.02
Other Tuna	1.84	0	1.21	0.00
Barracuda	0.02	27	0.01	0.55
Unspecified species	0.08	0	0.05	0.00

Table 4.1.e: Observer estimates of volume of discards by US purse seiners operating in the EEZ around the uninhabited islands of the Pacific Island Areas, 1994–1997 (Source: Forum Fisheries Agency, Honiara)

4.1.3 Crustaceans fishery

The FMP for the crustacean fisheries of the western Pacific establishes management measures for the spiny and slipper lobster fishery in the NWHI and establishes permit and data reporting requirements for commercial fishing in the EEZ around other islands in the Council's area. The NWHI fishery is managed under a limited access program with a maximum of 15 participants and subject to an annual harvest quota, closed season and gear restrictions.

Gear Type

Commercial fishing for lobster in the NWHI is restricted to traps. Each trap must have eight escape vents of specified dimensions. These vents facilitate the escape of small lobster, which may have a relatively low market value, and reduce the catch of non-target species. Lobster fisheries in Guam, American Samoa and the Northern Mariana Islands target mainly reef lobster (*Panulirus penicillatus*), a species that does not readily enter traps.[3] Consequently, these fisheries depend on spearing of lobsters or collection by hand.

[3]Crustacean fisheries occurring in the EEZ around the Northern Mariana Islands are not managed under the FMP.

Data Collection

Participants in the NWHI fishery are required to complete the NMFS Daily Lobster Catch Report (p. A2-13) after each set. The form includes space for recording the number of spiny lobsters, slipper lobsters, Kona crab and octopus kept and the number discarded, but no distinction is made between animals discarded alive or dead. There is also limited space for recording the number of other animals kept or discarded. Finally, the form includes a space for recording the number of monk seals, turtles and other protected species observed in the area, observed in the vicinity of the gear, interfering with fishing operations, preying on released lobsters, entangled and released alive and entangled and released dead.

Participants in the NWHI fishery are also required to complete the HDAR Crustaceans Trip Report (p. A2-14). This form provides a trip summary of the number and weight caught and weight sold of spiny and slipper lobsters, Kona crabs, "7-11" crabs, pandalid shrimp and octopus. There is also limited space for recording the number and weight caught and weight sold of fish and other organisms.

The type and amount of the non-target catch in the NWHI trap fishery can also be estimated from experimental trap fishing information collected during NMFS research cruises in the NWH and by observers deployed on fishing vessels.

Bycatch

Data gathered by NMFS experiment traps from 1984 to 1996 indicate that the non-target species taken in traps are principally other small crustaceans—such as hermit crabs— and molluscs and reef fish (Figure 4.1.d). However, unlike the traps used in the commercial fishery, research traps do not contain escape vents. Thus, the amount of bycatch in the research traps is probably higher than the bycatch in commercial traps. Similar results were recorded by observers deployed on fishing vessels to record the number of lobsters discarded during the 1997 NWHI lobster season (Table 4.1.f).

Species	**Retained**	**Discarded**
Spiny Lobster	174,532	434
Slipper Lobster	254,720	3
Kona Crab	7	
Octopus	48	
Others		117

Because lobster fisheries in Guam, American Samoa and the Northern Mariana Islands depend on spearing of lobsters or collection by hand—both of which are highly selective methods—the amount of bycatch is likely to be negligible.

4.1.4 Precious corals fishery

The FMP for Precious Corals Fisheries, implemented in 1979, defines selective gear as any gear used for harvesting corals that can discriminate between type, size, quality or characteristics of living or dead corals. Non-selective gear is defined as any gear that cannot make this discrimination or differentiation. Only selective gear may be used in the EEZ seaward of the MHI.

Gear Type

The precious coral fishery has been dormant for several years. However, in June 1997 a firm received a permit to harvest the Makapuu bed in the EEZ around the MHI. The firm has indicated that it intends to employ only selective gear, such as manned and unmanned submersibles.

Data Collection

All permit holders in the fishery are required to complete the NMFS Daily Precious Coral Harvest Log (p. A2-15). The form contains a provision for reporting the weight of various species of pink, gold and bamboo coral harvested during a fishing day. The form does not require harvesters to report how they dispose of harvested coral or the type, amount and disposition of other organisms that may be harvested.

Bycatch

Since FMP implementation in 1979 precious corals have not been commercially exploited in the management area. Thus the type and amount of bycatch cannot be assessed at this time. However, if selective gear is used, bycatch is likely to be negligible. The use of non-selective gear would result in a greater level of bycatch. It is estimated that dredges recover only about 40% of what is initially “knocked down.” The overall recovery rate may be increased if dredges are repeatedly dragged over the same area. In addition, other benthic organisms may be disturbed by dredging. The Council took this lower recovery rate into account by setting the weight quota for non-selective harvesting to be 20% of the quota that would apply if selective gear is used.

4.1.5 Discussion and conclusions

Standardized Reporting Methodologies

Most of the data collection systems of the WPacFIN program collect sufficient information on the main target and incidental species in the managed fisheries. (See Appendix 1 for a description of these systems.) However, because these systems focus on commercial landings, which have relatively minor amounts of bycatch, they may in varying degrees inadequately document the amount and type of bycatch.

It may be possible to improve documentation of bycatch through relatively minor changes in current survey methodologies. Currently, creel surveys administered in American Samoa and Guam do not ask fishermen to provide information on the disposition of fish that are not sold. In Hawaii, the space provided on the self-administered catch report forms for recording the type and number of fish released or discarded in the commercial fisheries is generally very limited. Including a question regarding bycatch in the creel survey forms and expanding the space for released or discarded fish in the catch report forms would require only relatively minor changes in survey methodology. On the other hand, it is important that both forms be kept as brief as possible to minimize the reporting burden placed on fishermen. Increasing the amount of requested data may reduce the quality and quantity of information fishermen provide on the landings of target species.

HDAR is currently developing a series of new catch report forms that require fishermen to record the number of fish released. These new forms are currently being evaluated in trials with commercial fishermen and should be finalized by early 1999. It is uncertain, however, whether the revised forms will provide more reliable estimates of the type and amount of bycatch. A report on Hawaii's commercial fish catch reporting system notes that none of the fishermen interviewed for the report keep detailed records of their catches while at sea (Kasaoka 1990). Generally, fishermen wait until after they have sold their catches and then transcribe information from sales records to the catch report form. Fishermen stated that it is not possible to remember the amount and type of species that were discarded, eaten or given away.

Given the possible shortcomings of relying on creel surveys and fish catch reports to assess the type and amount of bycatch in some fisheries, other existing reporting methodologies are used when possible. For example, bycatch data is also obtained from observer programs and fishery-independent data collection methods, such as research cruises. Data currently gathered during NMFS research cruises provide a means of assessing levels of bycatch in the bottomfish and NWHI lobster fisheries. To more accurately estimate bycatch in the lobster fishery, NMFS might consider including a sampling component using traps with escape vents as are used in the commercial fishery. Similarly, data collected by observers deployed on purse seine and Hawaii longline vessels can be used to supplement data collected by logbooks. To date, NMFS observers have been deployed on longline vessels principally to document the interactions between longline gear and marine turtles. NMFS should expand the scope of the longline observer program to emphasize the monitoring of all types of bycatch. In addition, NMFS should examine the feasibility of establishing observer programs for other gear types, such as troll and handline in the pelagics fishery. Estimates of bycatch obtained from logbooks, observer programs and research cruises should be summarized in the Council's FMP annual reports.

Because many of the gear types used in pelagic fisheries throughout the central and western Pacific target highly migratory species, it is important that bycatch issues be addressed at an international level. Some progress has been made in this area. For example, data collected by SPC's Oceanic Fisheries Program and by observer programs of several SPC member countries are being analyzed to estimate annual catches of non-target species by longline and purse-seine vessels fishing in the SPC statistical area. Future work will consider the effect of various fishing-related factors (e.g., latitude, longitude, year, quarter, target species, etc.) on catch rates of non-target species.

Discards can be returned to the sea either alive or dead. However, it may be unreasonable to request fishermen to distinguish between live and dead discards. Although a captured fish may appear to a fisherman to be alive at the time of release, the fish may die soon after due to trauma or consumption by predators that take advantage of its weakened or vulnerable condition. There is currently little scientific information available on the survival rates of live discards in the FMP fisheries. The survival rate for a particular species will depend partly on the gear used, onboard handling and the depth and area in which it is caught. Additional research on survival rates of live discards under various fishing conditions would be beneficial.

Measures to Minimize Bycatch and Bycatch Mortality

The prevalent gear types used in the region to catch BMUS and PMUS are variations of hook and line, which tend to be fairly selective. In addition, discussions with bottomfish fishermen revealed that fishermen usually move to another fishing ground if catches of sharks, oilfish, kahala or other undesirable fish become excessive, thereby minimizing bycatch. With regard to minimizing bycatch in the lobster trap fishery, NMFS evaluated the effectiveness of escape vents of various sizes, shapes and placement on the trap, in the laboratory, on research vessels and on commercial fishing vessels. Everson et al. (1992) concluded that the current escape vent configuration is optimal for reducing the catch of small lobsters and retaining larger lobsters. Only selective gear can be used to harvest coral from the EEZ around the MHI. Consequently, the amount of bycatch from harvest operations in this area is minimized. The FMP allows either selective or non-selective gear to be used to harvest coral from Brooks Bank and 180 Fathom Bank in the NWHI and from exploratory areas other than the EEZ off the MHI. However, the only firm that has recently expressed an interest in harvesting precious corals in these areas has indicated that it will employ only selective gear.

Complete avoidance of non-target species is not possible using current fishing techniques, but the amount of bycatch in the region's fisheries can be further reduced by developing and promoting uses for the fish that are usually discarded. For example, moonfish and pomfrets captured by Hawaii-based longline vessels were formerly discarded but are now retained. NMFS is currently sponsoring a study to determine whether markets exist (or can be developed) for meat, hides and other parts of the sharks caught by domestic longline vessels.

It would be difficult to develop bottomfish fishing techniques that would reduce the mortality of bycatch. Teleost bottomfish brought to the surface typically suffer from swelling of the swim bladder, eversion of the stomach and sometimes swelling and extrusion of the eyes. It is possible with some fish to puncture and deflate the swim bladder and to re-insert the stomach. However, it is unlikely that this would be a practical option during a commercial fishing operation. Captured sharks stand a better chance of survival if released, as they lack a swim bladder and are generally more robust than other types of fish.

It also would be difficult to reduce bycatch mortality with the gear types currently used to harvest pelagic species. With pole-and-line gear, fish are flung clear of the water and land on the deck, where they sustain serious injury from the impact. In troll fishing, fish may fight on the end of the line for an extended period of time before being reeled in. This is particular true if light tackle is used to enhance the sporting element of the fishing experience. The survival rate of fish that are released is uncertain, but tagging data suggests that it may be relatively low. For example, tag recoveries in the NMFS tagging program are 0.9% and 1.6% for 4,410 blue marlin and 19,534 striped marlin, respectively.

The post-release mortality of sharks and turtles released by longline vessels is uncertain. As noted above, additional research on survival rates of live discards under various fishing conditions would be beneficial. This research should include an evaluation of on-board handling techniques intended to minimize the mortality of live discards.

4.2 Commercial, Recreational and Charter Fishing Sectors

> *Specify the pertinent data which shall be submitted to the Secretary with respect to commercial, recreational, and charter fishing in the fishery, including, but not limited to, information regarding the type and quantity of fishing gear used, catch by species in numbers of fish or weight thereof, areas in which fishing was engaged in, time of fishing, number of hauls, and the estimated processing capacity of, and the actual processing capacity utilized by, United States fish processors.*
>
> *Include a description of the commercial, recreational, and charter fishing sectors which participate in the fishery and, to the extent practicable, quantify trends in landings of the managed fishery resource by the commercial, recreational, and charter fishing sectors.*

4.2.1 Bottomfish fishery

<u>Data Reporting Systems</u>

In Hawaii fishermen who hold a commercial marine license are required to complete a HDAR Fish Catch Report. (For a description of regional data collection systems see Appendix 1. For a reproduction of data forms, see Appendix 2. For this form, see p. A2-17.) The form requires fishermen to report the type of fishing gear used (e.g., deep-sea handline, trolling, etc.), area fished, number and weight of each species caught and the weight sold.

Commercial fishermen participating in the Federally regulated NWHI bottomfish fishery are required to complete the HDAR NWHI Bottomfish Trip Daily Log (p. A2-22). The daily log contains provisions for reporting the gear used, number of lines, number of hooks, number and weight of various bottomfish and non-bottomfish species kept, number released, number damaged or stolen by marine mammals and sharks, area fished, length of trip, specific effort information and weather conditions. Sales information is reported on the HDAR NWHI Bottomfish Trip Sales

Report (p. A2-23). Additional commercial landings information on both the MHI and NWHI bottomfish fisheries is collected by the NMFS market monitoring program.

No routine reporting system exists for collecting data on the recreational component of the bottomfish fishery in Hawaii. Surveys have been undertaken to estimate the extent of recreational fisheries, but these have been sporadic and limited in scope due to a lack of funds.

In American Samoa the Offshore Survey (p. A2-1) administered by the DMWR collects information on the number and weight of each species caught during commercial and recreational fishing trips, method of fishing (troll, bottom, etc.), time fished and the area fished. In addition, the survey requests information on the disposition of the catch. DMWR applies a set of algorithms to estimate the commercial landings based on the estimate of total landings and catch disposition information derived from the surveys.

In Guam the Offshore Creel Census administered by the DAWR (p. A2-4) records the number and weight of each species caught during commercial, charter and recreational fishing trips, method of fishing (e.g., trolling, bottom, etc.), number of gear used, area fished, weather conditions and percentage of the total catch that is kept or sold. The survey also asks fishermen if they participated in charter fishing and if so the number of guests taken. The survey does not specifically request fishermen to provide information on the disposition of fish that are kept. DAWR collects additional data on commercial landings through the voluntary trip ticket receipt program.

In Guam total commercial landings are calculated by summing the weight and value fields in the commercial landings database and then multiplying by an estimated percent coverage expansion factor. This annual expansion factor is based on an analysis of "disposition of catch" data from the creel survey, vessel entry and exit patterns, general dock-side knowledge of the fishery, status of market conditions and overall number of records in the data base.

In the Northern Mariana Islands data on commercial landings are collected by the DFW from the Commercial Sales Data, or "trip ticket," form (A2-29), which records local fish sales to commercial establishments.[4] Landings, species composition, revenue and the number of fishermen or boats selling catch are estimated from information provided on the forms.

[4]Bottomfish fisheries occurring in the EEZ around the Northern Mariana Islands are not managed under the FMP.

Until the creel survey program was discontinued in 1996, the Offshore Creel Census and Inshore Creel Census (p. A2-24 and A2-26) administered by DFW recorded the number and weight of each species caught during commercial and recreational fishing trips, fishing method used, number of gear used, area fished, weather conditions and percentage of the total catch that is kept or sold.

The *Bottomfish and Seamount Groundfish Fisheries Annual Report* summarizes information collected on the bottomfish fisheries in Hawaii, American Samoa, Guam and Northern Mariana Islands. For Hawaii, this information includes landings by species, fishing effort (number of vessels and trips), average price, revenue, annual catch per unit effort and the estimated spawning potential ratio by species. Information from American Samoa includes total weight of bottomfish landed (differentiated by species), weight of bottomfish sold, fishing effort (number of hours and trips), catch rates, average price, revenue and the estimated spawning potential ratio for the bottomfish complex. Information from Guam includes total weight of bottomfish landed (differentiated by species), weight of bottomfish sold, fishing effort (number of hours, trips and boats), average price, revenue and annual CUE. Information from the Northern Mariana Islands includes estimated landings, species composition, revenue and the number of fishermen or boats selling catch.

Information collected by HDAR Fish Catch Reports (p. A2-17) on the weight and composition of the unsold portion of the catch is summarized in *Fishery Statistics of the Western Pacific,* which is published annually by NMFS.

Commercial and Recreational Fishing

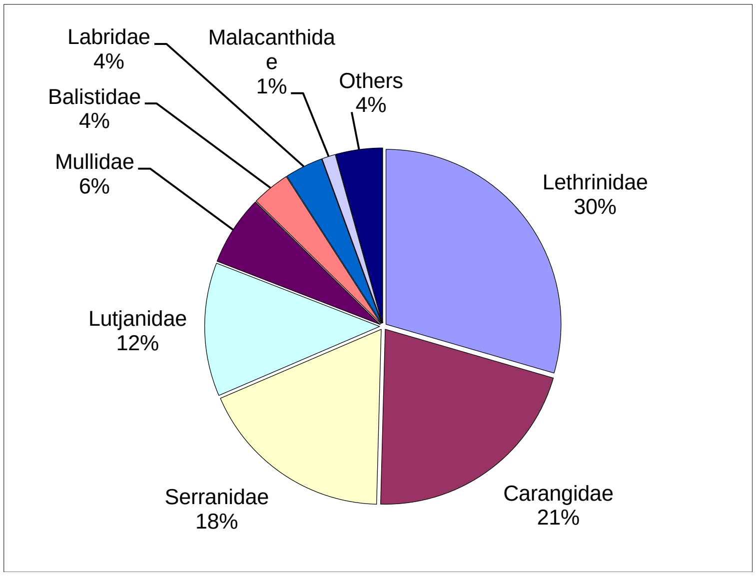
As noted in the FMP, throughout the western Pacific region there are few fishermen who specialize in harvesting bottomfish. Most fishermen shift from fishery to fishery in response to weather conditions, seasonal abundance or fluctuations in price. Furthermore, most of the vessel operators are part-time commercial fishermen and may combine commercial, recreational or subsistence effort in a single fishing trip.

The most reliable data for Hawaii come from a creel survey conducted on Oahu by NMFS in 1990–91 and indicate that 66% of the bottomfish landed were not sold and thus can be considered the recreational catch. For American Samoa and Guam information in the *Bottomfish and Seamount Groundfish Fisheries Annual Report* can be used to estimate the recreational catch. Reported landings are sub-divided into sold and unsold components. Because of the prevalence of fishermen who combine commercial and recreational effort, the unsold percentage of landings is used as a proxy for the recreational component of the fishery. In American Samoa 1985–1996 creel survey data indicate that the unsold—or recreational—catch fluctuates between 14% and 1% with an overall average of 4%. In Guam 1980–1996 creel survey suggests that 60% of landed bottomfish are caught for recreation. Since the termination of creel surveys in the Northern Mariana Islands, landings have not been recorded unless the catch is sold.

Charter Fishing

Charter vessels in Hawaii and American Samoa do not typically fish for bottomfish. In recent years, some charter vessels in Guam have started targeting bottomfish. The vessels range from typical trolling charter vessels involving three to six patrons who opt to fish for bottomfish, to larger bottomfish-fishing–only party boats accommodating up to 30 persons. At present, DAWR is refining the algorithms used to estimate the amount and composition of the charter component of bottomfish landings. Table 4.2.a and Figure 4.2.a summarize this data for 1996 and 1997. Several of the dozen or so charter vessels in Northern Mariana Islands have also started targeting bottomfish in the last few years. Since the termination of creel surveys, the landings from these boats have not been recorded unless the catch is sold, in which case the catch is reported on the Commercial Sales Data form. Catch and effort information on charter trips is not reported separately in the *Bottomfish and Seamount Groundfish Fisheries Annual Report*.

	Year	
	1996	**1997**
Total trips	1716	1803
Total catch	9907	10138
Total hours	4300	4001
Total no. persons	24044	24443
Person-hrs	60427	53871
Gear-hrs	47660	38674
CPUE (lb/trip	5.77	5.62
CPUE (lb/hr)	203	2.53
CPUE (lb/gr-hr)	0.21	0.26



4.2.2 Pelagics fishery

Data Reporting Systems

As described above, fishermen in Hawaii who hold a commercial marine license are required to complete a HDAR Fish Catch Report (p. A2-17). In addition to this report, HDAR administers specific data collection systems for the commercial longline, albacore troll and pole-and-line fisheries. Additional commercial landings information is collected by the NMFS market monitoring program. Information collected by HDAR Fish Catch Reports on the weight and composition of the unsold portion of the catch is summarized in *Fishery Statistics of the Western Pacific* which is published annually by NMFS.

In American Samoa data on the domestic longline fleet is collected by the NMFS Western Pacific Daily Longline Fishing Log (p. A2-18). The log records number of hooks, number of sets, fishing time and location, number of species caught and weather. The Offshore Survey (p. A2-1) administered by DMWR also collects data on longline fishing, including the weight of the fish landed by species, and collects information on troll gear landings.

In Guam the Offshore Creel Census (p. A2-4) collects information on commercial and recreational landings of pelagic species.

In the Northern Mariana Islands data on commercial landings and the portion of the catch that is sold by charter vessels are collected by the DFW from the Commercial Sales Data form (A2-29). Landings, revenue and the number of fishermen or boats selling catch are estimated by summing the information from the forms. Until the creel survey program was discontinued in 1996, the Offshore Creel Census (p. A2-24 and A2-25) and Inshore Creel Census (p. A2-26 and A2-27) recorded catch and effort data on commercial and recreational fishing trips.

The *Pelagic Fisheries Annual Report* summarizes information provided by the various data collection systems for different areas and gear types. For Hawaii commercial catch data includes landings by species, fishing effort (number of vessels and trips), average price, revenue and annual catch per unit effort. For American Samoa information on total weight of fish landed by longline and troll gear (differentiated by species), weight of fish landed by longline and troll gear that is sold (differentiated by species), fishing effort (number of hours, trips and boats), average price, revenue and annual catch per unit effort is summarized. The weight of skipjack, yellowfin and albacore tuna landed at the two fish canneries in Pago Pago by US and foreign vessels is collected by the PIAO and is also presented in the *Pelagic Fisheries Annual Report*. For Guam information on total weight of pelagic fish landed (differentiated by species), weight of pelagic fish sold (undifferentiated by species), fishing effort (number of hours, trips and boats), average price, revenue and annual catch per unit effort is summarized. For the Northern Mariana Islands information on total weight of pelagic fish landed (differentiated by species), weight of pelagic fish sold (differentiated by species), fishing effort (number of trips and boats), average price, revenue and annual catch per unit effort is summarized. Catch, and effort information on charter trips in the Northern Mariana Islands is not reported separately in the *Pelagic Fisheries Annual Report*.

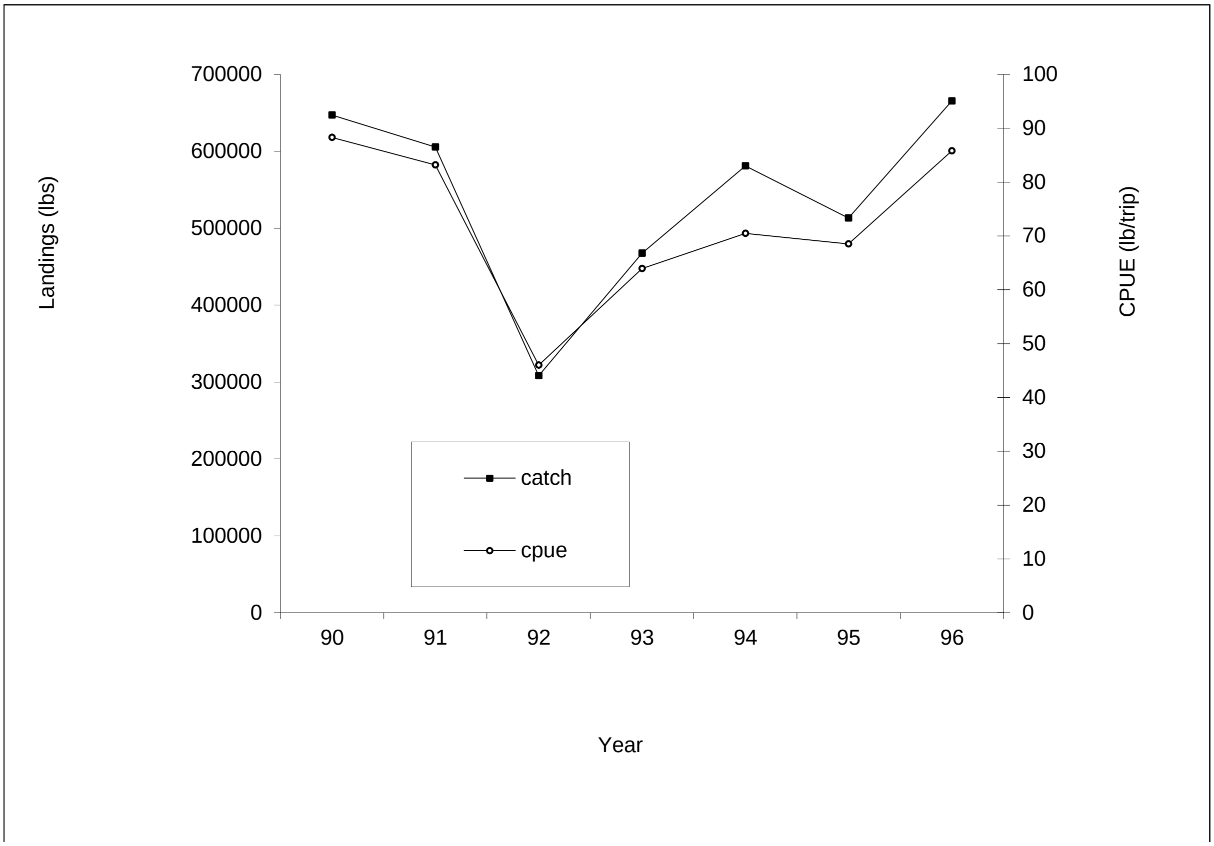
Commercial and Recreational Fishing

As the FMP states, there is no clear distinction between recreational and commercial troll fisheries; therefore, it is difficult to identify the recreational component of the troll fleet's total effort. Furthermore, in Hawaii no routine reporting system exists for collecting data on the recreational component of the pelagics fishery. A creel survey conducted on Oahu by NMFS in 1990–91 indicated that 60% of the fish caught with troll gear are not sold.

In American Samoa and Guam the reported unsold portion of the total catch is considered to be the recreational catch. For American Samoa creel survey data collected 1982–1996 indicate that 11% of all pelagic species landed are not sold. In Guam creel survey data collected 1980–1996 indicate that 59% of landed fish are unsold and is considered the recreational harvest. Since the termination of creel surveys in the Northern Mariana Islands, landings have not been recorded unless the catch is sold.

Charter Fishing

A large fleet of charter vessels in Hawaii harvests pelagic species. Fish caught by charter boat patrons are generally sold by the captain and crew. HDAR began differentiating catch report data for the charter sector in 1985. Charter vessels are identified on the annual application form for a commercial marine license, and HDAR can cross-reference the numbers on the license applications submitted by charter vessels with license numbers recorded on the Fish Catch Reports (p. A2-17). Catch and effort information on charter trips for 1990–1996 is provided in Figure 4.2.b. Composition of charter pelagic species catches in Hawaii for 1996 is provided in Table 4.2.b:


700000
600000
500000
400000
300000
200000
100000
0
Landings (lbs)
100
90
80
70
60
50
40
30
20
10
0
CPUE (lb/trip)
catch
cpue
90
91
92
93
94
95
96
Year

Species	Numbers	Weight (lbs)	Weight sold (lbs)	Value ($)
Mahimahi	3033	62,846	47,649	125,635
Aku	2,261	19,405	13,114	25,620
Ono	1,903	43,088	32,009	77,991
Blue marlin	1,880	390,516	304,596	211,674
Yellowfin tuna	1,770	70,113	60,130	119,272
Striped malin	745	48,130	26,966	26,451
Spearfish	381	12,174	6,611	7,649
Mano	207	12,034	6,545	6,113
Kawakawa	58	466	294	534
Ulua	57	1,329	496	644
Bigeye tuna	31	152	0	0
Kaku	21	422	92	92
Uku	19	202	70	197
Kamano	16	152	69	66
Black marlin	13	2,279	2,279	1,819
Broadbill	5	755	755	1,723
Kahala	4	78	0	0
Mako	1	93	93	88
Total	12,405	664,234	501,768	605,574

Table 4.2.b: Composition of charter pelagic species catches in Hawaii, 1996 (Source: WPacFIN)

In American Samoa the charter fleet consists of one or two boats that target pelagic species, but it is not possible to separate the size and composition of charter vessel catches from total landings by troll gear.

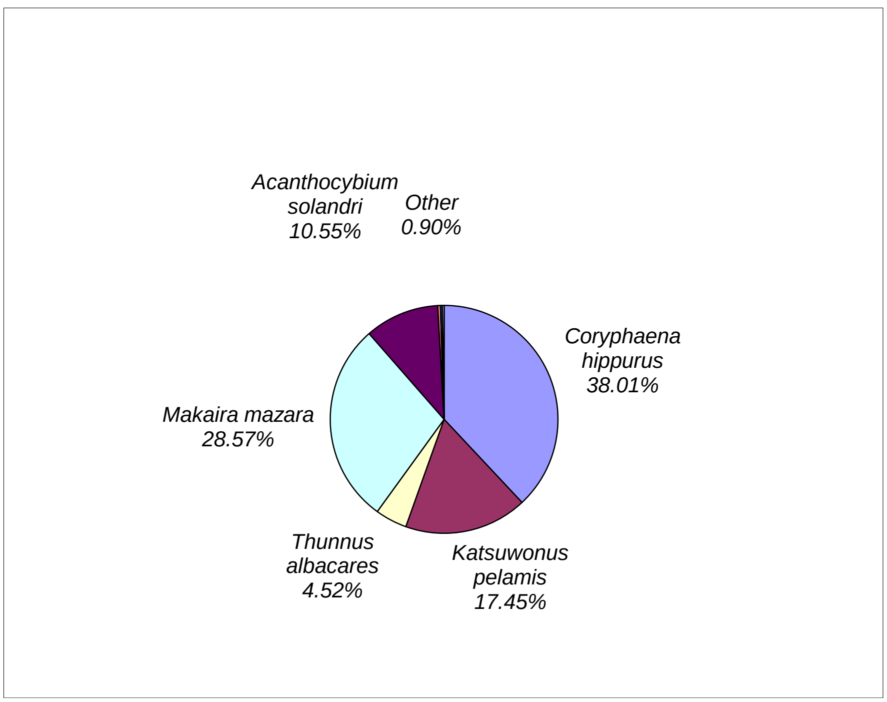
In Guam a small but significant segment of the troll fleet consists of charter vessels. Fishermen must report participation in charter fishing on the Offshore Creel Census form (p. A2-4) and report the number of guests taken on a charter trip. At present, DAWR is refining the algorithms used to estimate the amount and composition of the charter component of pelagic species landings. Table 4.2.c shows Guam charter troll catch and effort for 1996 and 1997, and Figure 4.2.c summarizes the composition of the catch in 1996.

The small fleet of charter vessels in Northern Mariana Islands frequently targets pelagic species.

	Year	
	1996	**1997**
Total trips	5745	4751
Total catch	205948	164696
Total hours	19420	14621
Total no. persons	35170	27683
Person-hrs	117784	83979
Gear-hrs	85138	64885
CPUE (lb/trip	35.85	34.67
CPUE (lb/hr)	10.6	11.26
CPUE (lb/gr-hr)	2.42	2.54

These vessels generally retain half or more of their catches for sale in local markets.

4.2.3 Crustaceans fishery



Data Reporting Systems

Participants in the NWHI commercial fishery are required to complete the NMFS Daily Lobster Catch Report (p. A2-13) and HDAR Crustaceans Trip Report (p. A2-14). The catch report records the number of lobsters caught, area fished, weather condition and date and time of gear set and haul. The trip report summarizes the number and weight of lobsters caught and weight sold. Data on landings, revenue, fishing effort (number of vessels, trips and trap-hauls) and CPUE are summarized in annual reports prepared by NMFS. Should commercial lobster fishing ventures operate in the EEZ around the MHI, American Samoa, Guam or the uninhabited islands of the Pacific Island Area[5], they would also be required to obtain a NMFS permit and complete the NMFS Daily Lobster Catch Report (p. A2-13).

Commercial and Recreational Fishing

The NWHI fishery is the only regionally significant commercial lobster fishery. No significant recreational lobster fishing occurs in the EEZ around the MHI or NWHI. No significant commercial or recreational lobster fishing occurs in the EEZ around American Samoa, Guam or the uninhabited islands of the Pacific Island Areas. Recently, two permits have been issued to fishermen interested in harvesting lobster in the waters around American Samoa, but no fishing activity has taken place.

Charter Fishing

Charter vessels in Hawaii do not target lobsters. No significant charter lobster fishing occurs in the EEZ around American Samoa, Guam or the uninhabited islands of the Pacific Island Areas.

4.2.4 Precious corals fishery

Data Reporting Systems

Commercial coral harvesting ventures operating in the EEZ around Hawaii and the Pacific Island Areas are required to obtain a NMFS permit and complete the NMFS Daily Precious Coral Harvest Log (p. A2-15).

[5]Crustacean fisheries occurring in the EEZ around the Northern Mariana Islands are not managed under the FMP.

Commercial and Recreational Fishing

No significant commercial or recreational harvesting of precious corals occurs in the EEZ around Hawaii or the Pacific Island Areas.[6] Recently, a permit to harvest the Makapuu bed in Hawaii has been issued to a firm, but harvesting has not begun.

Charter Fishing

No significant harvesting of precious corals occurs in the EEZ around Hawaii or the Pacific Island Areas through charter fishing.

4.2.5 Discussion and conclusions

As has been discussed, in the case of bottomfish fishing and trolling for pelagic species there is generally no clear distinction between recreational and commercial fishing. It is not possible to label the majority of fishermen or fishing vessels that participate in these fisheries as "commercial" or "recreational." In all of the island areas it is more appropriate to categorize as commercial or recreational the fish caught during a particular trip than the fishermen or fishing vessels catching them. Thus, in the annual reports the part of the catch that is reported as sold is considered the commercial component while the unsold portion represents the recreational catch. According to the Magnuson-Stevens Act, unsold fish should be classified as commercial if traded or bartered. However, it is not practical or appropriate for data collection systems in the region to make this distinction, as the customary exchange of fish with no immediate expectation of return is not regarded in Pacific island societies as a commercial activity.

Information on the size and composition of recreational catches of pelagic and bottomfish species in Hawaii is not collected by any ongoing data collection programs. Furthermore, no recreational fishing surveys have been recently conducted in the Pacific Island Areas to supplement information collected by current creel surveys. The Council fully supports proposals by NMFS to conduct such marine recreational fishing surveys.

If charter fishing develops in American Samoa, the Offshore Survey and Participation forms (p. A2-1 and A2-2) will be modified to specifically collect information that will allow DMWR to separately report charter catch and effort.

4.3 Describe Essential Fish Habitat

> *Describe and identify essential fish habitat for the fishery based on the guidelines established by the Secretary under section 305(b)(1)(A), minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat.*

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[6]Precious coral fisheries occurring in the EEZ around the Northern Mariana Islands are not managed under the FMP.

The NMFS guidelines intended to assist Councils in implementing the EFH provision of the Magnuson-Stevens Act set forth the following four broad tasks:

- Identify and describe EFH for all species managed under an FMP;
- Describe adverse impacts to EFH from fishing activities;
- Describe adverse impacts to EFH from non-fishing activities; and
- Recommend conservation and enhancement measures to minimize and mitigate the adverse impacts to EFH resulting from fishing and non-fishing related activities

The designation of EFH was based on the best available scientific information. This information was obtained through an iterative process consisting of a series of public meetings of the Council, SSC, FMP teams and fishing industry advisory panels (Section 2.3). In addition, the Council worked in close cooperation with scientists in the NMFS Southwest Fisheries Service Center, Honolulu Laboratory, PIAO and Southwest Regional Office.

The guidelines suggest that each Council prepare a preliminary inventory of available environmental and fisheries information on managed species. Such an inventory is useful in describing and identifying EFH, and it helps to identify missing information about the habitat of particular species. The guidelines note that a wide range of basic information is needed to identify EFH. This includes data on current and historic stock size, the geographic range of the managed species, the habitat requirements by life history stage and the distribution and characteristics of those habitats. Since EFH has to be identified for each major life history stage, information about a species' distribution, density, growth, mortality and production within all the habitats it occupies, or formerly occupied, is also necessary.

The guidelines state that the quality of available data should be rated using the following four-level system:

Level 1: All that is known is where a species occurs based on distribution data for all or part of the geographic range of the species.
Level 2: Data on habitat-related densities or relative abundance of the species are available.
Level 3: Data on growth, reproduction or survival rates within habitats are available.
Level 4: Production rates by habitat are available.

With higher quality data those habitats most highly valued by a species can be identified, allowing a more precise designation of EFH. Habitats of intermediate and low value may be essential depending on the health of the fish population and the ecosystem. For example, if a species is overfished, and habitat loss or degradation is thought to contribute to its overfished condition, all habitats currently used by the species may be essential.

At present, there is not enough data on the relative productivity of different habitats to develop EFH designations based on Level 3 or Level 4 data for any of the Western Pacific Council's MUS. The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a particular managed species' life stage.

The Council used the best available scientific information to describe EFH in text and tables that provide information on the biological requirements for each life stage (egg, larvae, juvenile, adult) of all MUS (Appendix 3). Careful judgement was used in determining the extent of the essential fish habitat that should be designated to ensure that sufficient habitat in good condition is available to maintain a sustainable fishery and the managed species' contribution to a healthy ecosystem. Because there are large gaps in scientific knowledge about the life histories and habitat requirements of many MUS in the western Pacific region, the Council adopted a precautionary approach in designating EFH to ensure that enough habitat is protected to sustain managed species.

In addition to the narratives, the general distribution and geographic limits of EFH for each life history stage are presented in the forms of maps (Appendix 4). The Council incorporated these data into a geographic information system to facilitate analysis and presentation. More detailed and informative maps will be produced as more complete information about population responses to habitat characteristics (e.g., growth, survival or reproductive rates) becomes available.

In addition to EFH, the Council identified habitat areas of particular concern (HAPCs) within EFH for all FMPs. In determining whether a type or area of EFH should be designated as a HAPC, one or more of the following criteria was met: ecological function provided by the habitat is important; habitat is sensitive to human-induced environmental degradation; development activities are or will be stressing the habitat type; or habitat type is rare.

4.3.1 Essential fish habitat designations

Bottomfish Habitat

Identification of BMUS EFH

Except for several of the major commercial species, very little is known about the life histories, habitat utilization patterns, food habits or spawning behavior of most adult bottomfish and seamount groundfish species. Furthermore, very little is known about the distribution and habitat requirements of juvenile bottomfish.

Generally, the distribution of adult bottomfish in the western Pacific region is closely linked to suitable physical habitat. Unlike the US mainland with its continental shelf ecosystems, Pacific islands are primarily volcanic peaks with steep drop-offs and limited shelf ecosystems. The BMUS under the Council's jurisdiction are found concentrated on the steep slopes of deepwater banks. The 100-fathom isobath is commonly used as an index of bottomfish habitat. Adult bottomfish are usually found in habitats characterized by a hard substrate of high structural complexity. The total extent and geographic distribution of the preferred habitat of bottomfish is not well known. Bottomfish populations are not evenly distributed within their natural habitat; instead they are found dispersed in a non-random, patchy fashion. Deepwater snappers tend to aggregate in association with prominent underwater features, such as headlands and promontories.

There is regional variation in species composition, as well as a relative abundance of the MUS of the deepwater bottomfish complex in the sestern Pacific region. In American Samoa, Guam and the Northern Mariana Islands the bottomfish fishery can be divided into two distinct fisheries, a shallow- and a deep-water bottomfish fishery, based on species and depth. The shallow-water (0–100 m) bottomfish complex is comprised of groupers, snappers and jacks in the genera *Lethrinus*, *Lutjanus*, *Epinephelus*, *Aprion*, *Caranx*, *Variola* and *Cephalopholis.* The deep-water (100–400 m) bottomfish complex is primarily comprised of snappers and groupers in the genera *Pristipomoides, Etelis, Aphareus, Epinephelus* and *Cephalopholis*. In Hawaii the bottomfish fishery targets several species of eteline snappers, carangids and a single species of groupers. The target species are generally found at depths of 50–270 m.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for bottomfish assemblages pursuant to Section 600.805(b) of 62 FR 66551. The species complex designations include deep-slope bottomfish (shallow- and deep-water) and seamount groundfish complexes. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. These species complexes are grouped by the known depth distributions of individual BMUS. These are summarized in Table 4.3.a. For a broader description of the life history and habitat utilization patterns of individual BMUS see Appendix 3.

Bottomfish	**Shallow-water species (0–100 m)** Uku (*Aprion virescens*), Thicklip trevally (*Pseudocaranx dentex*), Lunartail grouper (*Variola louti*), Blacktip grouper (*Epinephelus fasciatus*), Ambon emperor (*Lethrinus amboinensis*), Redgill emperor (*Lethrinus rubrioperculatus*), Giant trevally (*Caranx ignoblis*), Black trevally (*Caranx lugubris*), Amberjack (*Seriola dumerili*), Taape (*Lutjanus kasmira*)
	Deep-water species (100–400 m) Ehu (*Etelis carbunculus*), Onaga (*Etelis coruscans*), Opakapaka (*Pristipomoides filamentosus*), Yellowtail Kalekale (*P. auricilla*), Yelloweye opakapaka (*P. flavipinnis*), Kalekale (*P. sieboldii*), Gindai (*P. zonatus*), Hapupuu (*Epinephelus quernus*), Lehi (*Aphareus rutilans*)
Seamount Groundfish	Armorhead (*Pseudopentaceros richardsoni*), Ratfish/butterfish (*Hyperoglyphe japonica*), Alfonsin (*Beryx splendens*)

Table 4.3.a: Management unit species complexes for bottomfish

At present, there is not enough data on the relative productivity of different habitats to develop EFH designations based on Level 3 or Level 4 data. Given the uncertainty concerning the life histories and habitat requirements of many BMUS, the Council designated EFH for adult and juvenile bottomfish as the water column and all bottom habitat extending from the shoreline to a depth of 400 m (200 fathoms) encompassing the steep drop-offs and high relief habitats that are important for bottomfish.

The eggs and larvae of all BMUS are pelagic, floating at the surface until hatching and subject thereafter to advection by the prevailing ocean currents. There have been few taxonomic studies of these life stages of snappers (lutjanids) and groupers (epinepheline serranids). Presently, few larvae can be identified to species. As snapper and grouper larvae are rarely collected in plankton surveys, it is extremely difficult to study their distribution. Because of the existing scientific uncertainty about the distribution of the eggs and larvae of bottomfish, the Council designated the water column extending from the shoreline to the outer boundary of the EEZ to a depth of 400 m as EFH for bottomfish eggs and larvae.

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. The seamount groundfish complex consists of three species (pelagic armorheads, alfonsins and ratfish). These species dwell at 200–600 m on the submarine slopes and summits of seamounts. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

The life histories and distributional patterns of seamount groundfish are also poorly understood. Data are lacking on the effects of oceanographic variability on migration and recruitment of individual management unit species. Based upon the best available data, the Council designated the EFH for the adult life stage of the seamount groundfish complex as all waters and bottom habitat bounded by latitude 29°–35°N and longitude 171°E–179°W between 80–600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all waters bounded by latitude 29°–35°N and longitude 171°E–179°W. This EFH designation encompasses the Hancock Seamounts, part of the northern extent of the Hawaiian Ridge, located 1,500 nautical miles northwest of Honolulu.

Habitat Areas of Particular Concern

Based on the known distribution and habitat requirements of adult bottomfish, the Council designated all escarpments/slopes between 40–280 m as HAPC. In addition, the Council designated the three known areas of juvenile opakapaka habitat (two off Oahu and one off Molokai) as HAPC. The basis for this designation is the ecological function these areas provide, the rarity of the habitat and the susceptibility of these areas to human-induced environmental degradation. Off Oahu juvenile snappers occupy a flat, open bottom of primarily soft substrate in depths ranging from 40 to 73 m. This habitat is quite different from that utilized by adult snappers. Surveys suggest that the preferred habitat of juvenile opakapaka in the waters around Hawaii represents only a small fraction of the total habitat at the appropriate depths. Areas of flat featureless bottom have typically been thought of as providing low value fishery habitat. It is possible that juvenile snappers occur in other habitat types but in such low densities that they have yet to be observed.

The recent discovery of concentrations of juvenile snappers in relatively shallow water and featureless bottom habitat indicates the need for more research to help identify, map and study nursery habitat for juvenile snapper.

Pelagic Habitat

Identification of PMUS EFH

PMUS under the Council's jurisdiction are found in tropical and temperate waters throughout the Pacific Ocean. Variations in the distribution and abundance of PMUS are affected by ever changing oceanic environmental conditions including water temperature, current patterns and the availability of food. There are large gaps in the scientific knowledge about basic life histories and habitat requirements of many PMUS. The migration patterns of PMUS stocks in the Pacific Ocean are poorly understood and difficult to categorize despite extensive tagging studies for many species. Little is known about the distribution and habitat requirements of the juvenile life stages of tuna and billfish after they leave the plankton until they recruit to fisheries. Since spawning and larvae occur only in tropical temperatures (including temperate summer), the pre-recruit sizes are probably more tropically distributed than recruits, and juvenile tunas of this size (1–15 cm) are only caught in large numbers around tropical archipelagoes. Very little is known about the habitat of different life history stages of PMUS that are not targeted by fisheries (i.e., sharks, Gempylids, etc). For these reasons, the Council has adopted a precautionary approach in designating EFH for PMUS.

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for pelagic species assemblages pursuant to Section 600.805(b) of 62 FR 66551. The species complex designations for the PMUS are marketable species, non-marketable species and sharks (Table 4.3.b). The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. The marketable species complex has been subdivided into tropical and temperate assemblages. The temperate species complex includes those PMUS that are found in greater abundance in higher latitudes such as swordfish and bigeye, bluefin and albacore tuna. In reality all PMUS are tropical. For a broader description of the life history and habitat utilization patterns of individual PMUS see Appendix 3.

Marketable	**Temperate species** Striped Marlin (*Tetrapurus audax*); Bluefin Tuna (*Thunnus thynnus*);

	Swordfish (*Xiphias gladius*); Albacore (*Thunnus alalunga*); Mackeral (*Scomber* spp); Bigeye (*Thunnus obesus*); Pomfret (family Bramidae) **Tropical species** Yellowfin (*Thunnus albacares*); Kawakawa (*Euthynnus affinis*); Skipjack (*Katsuwonus pelamis*); Frigate and bullet tunas (*Auxis thazard*, *A. rochei*); Blue marlin (*Makaira nigricans*); Slender tunas (*Allothunnus fallai*); Black marlin (*Makaira indica*); Dogtooth tuna (*Gymnosarda unicolor*); Spearfish (*Tetrapturus spp*); Sailfish (*Istiophorus platypterus*); Mahimahi (*Coryphaena hippurus, C. equiselas*); Ono (*Acanthocybium solandri*); Opah (*Lampris* sp)
Unmarketable	Oilfish (family Gempylidae); Pomfret (family Bramidae); Crocodile shark
Sharks	Requiem sharks (family Carcharinidae); Thresher sharks (family Alopiidae); Mackeral sharks (family Lamnidae); Hammerheads sharks (family Sphyrnidae)

Table 4.3.b: Species complexes for pelagic management unit species

Because of the uncertainty about the life histories and habitat utilization patterns of many PMUS, the Council has taken a precautionary approach by adopting a 1,000 m depth as the lower bound of EFH for PMUS. Although many of the PMUS are epipelagic, bigeye tuna are abundant at depths in excess of 400 m and swordfish have been tracked to depths of 800 m. One thousand meters is the lower bound of the mesopelagic zone. The vertically migrating mesopelagic fishes and squids associated with the deep scattering layer are important prey organisms for PMUS and are seldom abundant below 1,000 m. This designation is also based on anecdotal reports of fishermen that PMUS aggregate over raised bottom topographical features as deep as 2,000 m (1,000 fathoms) or more. This belief is supported by research that indicates seabed features such as seamounts exert a strong influence over the superadjacent water column. An example of this type of influence is the doming of the thermocline that has been observed over seamounts.

The eggs and larvae of all teleost PMUS are pelagic. They are slightly buoyant when first spawned, are spread throughout the mixed layer and are subject to advection by the prevailing ocean currents. Because the eggs and larvae of the PMUS are found distributed throughout the tropical (and in summer, the subtropical) epipelagic zone, EFH for these life stages has been designated as the epipelagic zone (~200 m) from the shoreline to the outer limit of the EEZ. The only generic variation in this distribution pattern occurs in the northern latitudes of the Hawaii EEZ, which extends farther into the temperate zone than any other EEZ covered by the plan. In these higher latitudes, eggs and larvae are rarely found during the winter months (November–February).

Habitat Areas of Particular Concern

For HAPC the Council designated the water column down to 1,000 m that lies above all seamounts and banks within the EEZ shallower than 2,000 m (1,000 fathoms). The EFH relevance of topographic features deeper than 1,000 m is due to the influence they have on the overlying mesopelagic zone. These deeper features themselves do not constitute EFH, but the waters from the surface to 1,000 m deep superadjacent to these features are designated as HAPC within the EFH. The 2,000-m depth contour captures the summits of most seamounts mentioned by fishermen, and all banks within the EEZ waters under the Councils jurisdiction. The basis for designating this areas as HAPC is the ecological function provided, the rarity of the habitat type, the susceptibility of these areas to human-induced environmental degradation and proposed activities that may stress the habitat type.

As noted above, localized areas of increased biological productivity are associated with seamounts, and many seamounts are important grounds for commercial fishing in the western Pacific region. There have been proposals to mine the manganese rich summits of the off-axis seamounts in the Hawaii EEZ. The possible adverse impacts of this proposed activity on fishery resources are of concern to the Council.

Because the PMUS are highly migratory, the areas outside the EEZ in the western Pacific region are designated by the Council as "important habitat." Vast areas outside of EEZ waters provide essential spawning, breeding and foraging habitat. The EEZ under the Council's jurisdiction represents only a small fraction of the waters in which PMUS are distributed. The Council believes that any attempt to manage PMUS stocks and protect their habitat on anything less than a Pacific basin-wide scale would be ineffective. Hence, the Council will continue its participation in all appropriate international forums and bodies involved in the management of highly migratory species.

Crustaceans Habitat

Identification of CMUS EFH

Spiny lobsters are found throughout the Indo-Pacific region. All spiny lobsters in the western Pacific region belong to the family Palinuridae. The slipper lobsters belong to the closely related family, Scyllaridae. There are 13 species of the genus *Panulirus* distributed in the tropical and subtropical Pacific between 35^0N and 35^0S. *P. penicillatus* is the most widely distributed, the other three species are absent from the waters of many island nations of the region. The Hawaiian spiny lobster (*P. marginatus*) is endemic to Hawaii and Johnston Atoll and is the primary species of interest in the NWHI fishery, the principal commercial lobster fishery in the western Pacific region. This fishery also targets the slipper lobster *Scyllarides squammosus*. Three other species of lobster—pronghorn spiny lobster (*Panulirus pencillatus*), ridgeback slipper lobster (*Scyllarides haanii*) and Chinese slipper lobster (*Parribacus antarticus*)—and the Kona crab, family *Raninidae*, are taken in low numbers in the NWHI fishery.

In the NWHI there is wide variation in lobster total density, size and sex ratio between the different islands. Neither the extent of species interaction between *P. marginatus* and *Scyllarides squammosus* nor the role of density dependent factors in controlling population abundance is known.

In the MHI most of the commercial, recreational and subsistence catches of spiny lobster are taken from waters under State jurisdiction. *P. maginatus* and *P. pencillatus* are taken in nearly equal numbers in trap samples around the island of Oahu. However, the species composition or the magnitude of the subsistence, recreational and commercial catch is not known. In America Samoa, the Northern Mariana Islands and Guam the species composition or the magnitude of the subsistence, recreational and commercial catch is also unknown.

In Hawaii adult spiny lobsters are typically found on rocky substrate in well protected areas, in crevices and under rocks. Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another. Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters. Similarly, juvenile and adult *P. pencillatus* also share the same habitat. *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands.

The reported depth distribution of *P. marginatus* is 3–200 m. While this species is found down to depths of 200 m it usually inhabits shallower waters. *P. marginatus* is most abundant in waters of 90 m or less. Large adult spiny lobsters are captured at depths as shallow as 3 m.

In the southwestern Pacific spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items. *Panulirus pencillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs and moves on to the reef flat at night to forage.

Very little is known about the planktonic phase of the phyllosoma larvae of *Panulirus marginatus*. The oceanographic and physiographic features that result in the retention of lobster larvae within the Hawaiian archipelago are poorly understood. Evidence suggests that fine scale oceanographic features, such as eddies and currents, serve to retain phyllosoma larvae within the Hawaiian Island chain. While there is a wide range of lobster densities between banks within the NWHI, the spatial distribution of phyllosoma larvae appears to be homogenous (Polovina and Moffitt 1995).

To reduce the complexity and the number of EFH identifications required for individual species and life stages, the Council has designated EFH for crustacean species assemblages (Table 4.3.c). The species complex designations are spiny and slipper lobsters and Kona crab. The designation of these complexes is based upon the ecological relationships among species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual CMUS see Appendix 3.

Spiny and Slipper Lobster Complex	Hawaiian spiny lobster (*Panulirus marginatus*), Spiny lobster (*P. penicillatus*, *P.* sp.), Ridgeback slipper lobster (*Scyllarides haanii*), Chinese slipper lobster (*Parribacus antarticus*)
Kona Crab	Kona crab (*Ranina ranina*)

Table 4.3.c: Species complexes for crustacean management unit species

At present, there is not enough data on the relative productivity of different habitats of CMUS to develop EFH designations based on Level 3 or Level 4 data. There is little data concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages. The relationship between egg production, larval settlement and stock recruitment is also poorly understood. Although there is a paucity of data on the preferred depth distribution of phyllosoma larvae in Hawaii, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Later stages of panulirid phyllosoma larvae have been found at depths between 80–120 m. For these reason the Council designated EFH for spiny lobster larvae as the water column from the shoreline to the outer limit of the EEZ down to a depth of 150 m. The EFH for juvenile and adult spiny lobster is designated as the bottom habitat from the shoreline to a depth of 100 m.

Habitat Areas of Particular Concern

Research indicates banks with summits less than 30 m support successful recruitment of juvenile spiny lobster while those with summit deeper than 30 m do not. For this reason, the Council has designated all banks in the NWHI with summits less than 30 m as HAPC. The basis for designating this areas as HAPC is the ecological function provided, the rarity of the habitat type and the susceptibility of these areas to human-induced environmental degradation. The complex relationships between recruitment sources and sinks of spiny lobsters is poorly understood. The Council feels that in the absence of a better understanding of these relationships the adoption of a precautionary approach to protect and conserve habitat is warranted.

The relatively long pelagic larval phase for palinurids results in very wide dispersal of spiny lobster larvae. Palinurid larvae are transported up to 2,000 nm by prevailing ocean currents. Because phyllosoma larvae are transported by the prevailing ocean currents outside of EEZ waters, the Council has identified habitat in these areas as “important habitat.”

<u>Precious Coral Habitat</u>

Identification of PCMUS EFH

In the Hawaiian Islands, precious coral beds have been found only in the deep inter-island channels and off promontories at depths between 300–1,500 m and 30–100 m. The six known beds of pink, gold and bamboo corals are Keahole Point, Makapuu, Kaena Point, Wespac, Brooks Bank and 180 Fathom Bank. Makapuu is the only bed that has been surveyed accurately enough to estimate MSY. The Wespac bed, located between Necker and Nihoa Islands in the NWHI, has been set aside for use in baseline studies and as a possible reproductive reserve. The harvesting of precious corals is prohibited in this area. Within the western Pacific region the only directed fishery for precious corals has occurred in the Hawaiian Islands. At present, there is no commercial harvesting of precious corals in the EEZ, but several firms have expressed interest.

Precious corals may be divided into deep-water and shallow-water species. Deep-water precious corals are generally found between 350–1,500 m and include pink coral (*Corallium secundum*), gold coral (*Gerardia sp*. and *Parazoanthus sp*.) and bamboo coral (*Lepidistis olapa*). Shallow-water species occur between 30 and 100 m and consist primarily of three species of black coral, *Antipathes dichotoma*, *Antipathes grandis* and *Antipathes ulex*. In Hawaii *Antipathes dichotoma* accounts for around 90% of the commercial harvest of black coral and virtually all of it is harvested in State waters.

Precious corals are non-reef building and inhabit depth zones below the euphotic zone. They are found on solid substrate in areas that are swept relatively clean by moderate to strong (>25 cm/sec) bottom currents. Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Precious coral yields tend to be higher in areas of shell sandstone, limestone and basaltic or metamorphic rock with a limestone veneer.

Black corals are most frequently found under vertical drop-offs. Such features are common off Kauai and Maui in the MHI, suggesting that their abundance is related to suitable habitat (Grigg 1976). Off Oahu many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments. In the MHI the lower depth range of *Antipathes dichotoma* and *A. grandis* coincides with the top of the thermocline (ca. 100 m) (Grigg 1984).

Pink, bamboo and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. The length of the larval stage of all species of precious corals is unknown.

The habitat sustaining precious corals is generally in pristine condition. There are no known areas that have sustained damage due to resource exploitation, notwithstanding the alleged illegal heavy foreign fishing for corals in the Hancock Seamounts area.

To reduce the complexity and the number of EFH identifications required for individual species and life stages the Council designated EFH for precious coral assemblages (Table 4.3.d). The species complex designations are deep-water and shallow-water complexes. The designation of these complexes is based upon the ecological relationships between the individual species and their preferred habitat. For a broader description of the life history and habitat utilization patterns of individual PCMUS see Appendix 3.

Deep-Water Precious Corals (300–1500 m)	Pink coral (*Corallium secundum*), Red coral (*C. regale*), Pink coral (*C. laauense*), Midway deepsea coral (*C.* sp nov.), Gold coral (*Gerardia* sp), Gold coral (*Callogorgia gilberti*), Gold coral (*Narella* spp.), Gold coral (*Calyptrophora* spp.), Bamboo coral (*Lepidisis olapa*), Bamboo coral (*Acanella* spp.)
Shallow-Water Precious Corals (20–100 m)	Black coral (*Antipathes dichotoma*), Black coral (*Antipathis grandis*), Black coral (*Antipathes ulex*)

Table 4.3.d: Species complexes for precious coral management unit species

The Council considered using the known depth range of individual PCMUS to designate EFH but rejected this alternative because of the rarity of the occurrence of suitable habitat conditions. Instead, the Council designated the six known beds of precious corals as EFH. The Council feels that the narrow EFH designation will facilitate the consultation process. In addition, the Council designated three black coral beds in the MHI—between Milolii and South Point on Hawaii, Auau Channel between Maui and Lanai and southern border of Kauai—as EFH.

Habitat Areas of Particular Concern

The Council designated three of the six precious coral beds—Makapuu, Wespac and Brooks Bank—as habitat areas of particular concern. Makapuu bed was designated as HAPC because of the ecological function it provides, the rarity of the habitat type and its sensitivity to human-induced environmental degradation. The potential commercial importance and the amount of scientific information that has been collected on Makapuu bed were also considered. Wespac bed was designated as HAPC because of the ecological function it provides and the rarity of the habitat type. Its refugia status was also considered. Brooks Bank was designated HAPC because of the ecological function it provides and the rarity of the habitat type. Its possible importance as foraging habitat for the Hawaiian monk seal was also considered. For black corals the Council designated the Auau Channel as a HAPC because of the ecological function it provides, the rarity of the habitat type and its sensitivity to human-induced environmental degradation. Its commercial importance was also considered.

4.3.2 Adverse fishing impacts and conservation measures

The Council is required to act to prevent, mitigate or minimize any adverse effects from fishing if there is evidence that a fishing practice is having an identifiable adverse effect on EFH. Adverse fishing impacts may include physical, chemical or biological alterations of the substrate and loss of, or injury to, benthic organisms, prey species and their habitat and other components of the ecosystem. FMPs must also contain an assessment of the potential adverse effects of all fishing equipment types used in waters described as EFH. This assessment should consider the relative impacts of all fishing equipment types used in EFH on different types of habitat found within EFH.

The predominant fishing gear types—hook-and-line, longline, troll, traps—used in the fisheries managed by the Council cause few fishing-related impacts to the benthic habitat of bottomfish, crustaceans and precious corals. The current management regime prohibits the use of bottom trawls, bottom-set nets, explosives and poisons. The use of non-selective gear to harvest precious corals in the MHI is prohibited. The Council has determined that current management measures to protect fishery habitat are adequate and no additional measures are necessary at this time. However, the Council has identified the following potential sources of fishery-related impacts to benthic habitat that may occur during normal fishing operations:

- Anchor damage from vessels attempting to maintain position over productive fishing habitat.
- Heavy weights and line entanglement occurring during normal hook-and-line fishing operations.
- Lost gear from lobster fishing operations.
- Illegal fishing for precious corals with tangle nets.
- Remotely operated vehicle (ROV) tether damage to precious coral during harvesting operations.

Trash is sometimes discarded by fishing vessels operating in the EEZ and fishing hardware, such as leaders, hooks and weights, are occasionally lost after becoming snagged on the bottom. The Council determined that the effects of this marine debris on habitat are not adverse. However, the Council is concerned that marine debris originating from fishing operations outside the Council's area may have impacts on habitat. The source of this debris and its impacts are being investigated by NMFS. International cooperation will be necessary to find solutions to this broader problem.

Because the habitat of pelagic species is the open-ocean water column and managed fisheries employ variants of hook and line gear, there are no direct impacts to EFH. Lost gear may be a hazard to some species due to entanglement but has no direct effect on habitat. A possible impact would be caused by fisheries that target and deplete key prey species, but currently there is no such fishery.

While the Council has determined that current management measures to protect fishery habitat are adequate, should future research demonstrate a need the Council will act accordingly to protect habitat necessary to maintain a sustainable and productive fishery in the western Pacific Region.

4.3.3 Non-fishing adverse impacts and conservation measures

The Council is required to identify non-fishing activities that have the potential to adversely affect EFH quantity or quality and, for each activity, describe its known and potential adverse impacts and the EFH most likely to be adversely affected. The descriptions should explain the mechanisms or processes that may cause the adverse effects and how these may affect habitat function. The Council considered a wide range of non-fishing activities that may threaten important properties of the habitat utilized by managed species and their prey, including dredging, dredge material disposal, mineral exploration, water diversion, aquaculture, wastewater discharge, oil and hazardous substance discharge, construction of fish enhancement structures, coastal development, introduction of exotic species and agricultural practices. For a full description of non-fishing impacts see Appendix 5.

4.3.4 Cumulative impacts

The designation of EFH in and of itself will not have any biological impact. However, the proposed NMFS consultation process should have an overall beneficial effect on habitats important to managed fisheries in the western Pacific region. A direct benefit of the amendment is the compilation of information (Appendix 3) on the habitats and life history characteristics of managed species. This baseline information should facilitate the efforts of the Council and NMFS to assess cumulative impacts to EFH and propose measures to mitigate or avoid adverse impacts. Additionally, the review and compilation of the best available scientific data will serve to guide future research necessary to further describe and protect EFH. Second, EFH designation establishes a framework for NMFS and the Council to cooperatively comment on state and Federal agency actions affecting EFH. The comments of these agencies will, in turn, provide more specific guidance on how adverse impacts to EFH can be avoided or mitigated.

4.3.5 Research needs

Each FMP should contain recommendations for research efforts that the Council and NMFS view as necessary for carrying out the EFH management mandate. The need for additional research is to make available sufficient information to support a higher level of description and identification of EFH. Additional research may also be necessary to identify and evaluate actual and potential adverse effects on EFH, including, but not limited to, direct physical alteration; impaired habitat quality/functions; cumulative impacts from fishing; or indirect adverse effects, such as sea level rise, global warming and climate shifts. The EFH research needs identified by the Council are contained in Appendix 6.

The NMFS guidelines suggest that the Councils and NMFS periodically review and update the EFH components of FMPs as new data becomes available. The Western Pacific Council recommended that new information be reviewed, as necessary, during preparation of the annual reports for the managed fisheries in the region. Designations of EFH may be changed under the FMP framework processes if information presented in an annual review indicates that modifications are justified.

4.4 Include Impacts on Fishing Communities

> *Include a fishery impact statement for the plan or amendment (in the case of a plan or amendment thereto submitted to or prepared by the Secretary after October 1, 1990) which shall assess, specify, and describe the likely effects, if any, of the conservation and management measures on—*

(A) participants in the fisheries and fishing communities affected by the plan or amendment; and
(B) participants in the fisheries conducted in adjacent areas under the authority of another Council, after consultation with such Council and representatives of those participants.

4.4.1 Identification of fishing communities

The total land area of the islands within the Council's jurisdiction is about 7,000 square miles. In contrast, the EEZ waters surrounding them encompass nearly 1.5 million square miles, an area nearly equal to all other US EEZ waters combined. Fishery resources have played a central role in shaping the social, cultural and economic fabric of the societies of Guam, American Samoa, Hawaii and the Northern Mariana Islands, which today comprise 1.4 million people. The aboriginal peoples indigenous to these islands relied on seafood as their principal source of protein and developed exceptional fishing skills. Later immigrants to the islands from East and Southeast Asia also possessed a strong fishing tradition. The importance of fisheries in the region is recognized in the Magnuson-Stevens Act, which states, "Pacific Island Areas contain unique historical, cultural, legal political and geographical circumstances which make fisheries resources important in sustaining their economic growth" (§2 (a) (10)).

In contrast to most US mainland residents, who have little contact with the marine environment, a large proportion of the people living in the western Pacific region observe and interact daily with the ocean for food, income and recreation. While most island residents today no longer depend on their catches for food, seafood continues to be an integral part of the local diet. For example, in Hawaii the per capita consumption of seafood is almost twice the national US average and is comparable to that of other Pacific islands.

Fishing also continues to contribute to the cultural integrity and social cohesion of island communities. In American Samoa, for instance, skipjack tuna, known locally as atu, is an especially important species both nutritionally and culturally. The methods and equipment for catching skipjack tuna have changed, but the fish brought to shore continue to be distributed within Samoan villages according to age-old ceremonial traditions. One can find similar traditions still practiced in Hawaii, the Northern Mariana Islands and Guam. These sociocultural attributes of fishing are at least as important as the contributions made to the nutritional or economic well-being of island residents.

The fish resources under Council jurisdiction also support an important private boat recreational fishery that targets both pelagic and bottom-dwelling species. It is estimated that in 1996, $130 million in fishing trip-related expenditures occurred in Hawaii (US Fish and Wildlife Service 1997). Of course, fishermen value fishing over and above what they spend on it. A study conducted several years ago asked fishermen what their sport fishing experience was actually worth to them in dollar terms; the study estimated the value of fishing trips to Hawaii recreational fishermen to be $347 million (adjusted to 1995 dollars) (Meyer Resources 1987).

In each island area within the region the residential distribution of individuals who are substantially dependent on or substantially engaged in the harvest or processing of fishery resources approximates the total population distribution. These individuals are not set apart—physically, socially or economically—from island populations as a whole. This dispersion is most evident on the island of Tutuila in American Samoa, where tuna processing has been the largest industrial activity for more than three decades. The canneries themselves are located in the village of Anua; the shipyard is in Satala; the wharf is in Fagatonga; the fuel facility is in Utulei; and the employees of these various fisheries-dependent facilities commute daily from villages all around the island.

Given the reference in the Magnuson-Stevens Act to the economic importance of fishery resources to the island areas within the western Pacific region and taking into account these islands' distinctive geographic, demographic and cultural attributes, the Council concluded that it is appropriate to characterize each of these island areas —Hawaii, Guam, American Samoa and the Northern Mariana Islands—as a fishing community. Defining the boundaries of the fishing communities broadly will help ensure that fishery impact statements analyze the economic and social impacts on all segments of island populations that are substantially dependent on or engaged in fishing-related activities.

4.4.2 Economic and social importance of fisheries

The Council has compiled extensive information on the economic and social importance of fisheries to each island area. Summaries of this material are presented in the Council's FMPs, FMP annual reports and annual "Value of the Fisheries" report. Detailed information appears in a wide range of research reports that examine the history, extent and type of participation of island populations in the fisheries of the region. For example, in-depth analyses of the historical and contemporary importance of fisheries to the indigenous peoples of Guam, the Northern Mariana Islands, Hawaii and American Samoa are provided by Amesbury and Hunter-Anderson (1989), Amesbury et al. (1989), Iverson, et al. (1990) and Severance and Franco (1989). The Hawaii Fleet Industry and Vessel Economics project has produced cost-earnings studies of the Hawaii-based longline fleet (Hamilton et al. 1996) and Hawaii small-boat commercial fleet (Hamilton and Huffman 1997). Hamnett and Pintz (1996) examine the contributions of tuna processing and transshipment to island economies. A sociocultural study of Hawaii's troll and handline fishery has been conducted by Miller (1996). Clarke and Pooley (1988) provide an economic analysis of the lobster fishery in the NWHI. McCoy (1997) describes the traditional and ceremonial use of the green sea turtle in the Northern Mariana Islands. Additional detailed descriptions of the fisheries in the western Pacific region are presented in volume 55, number 2, of *Marine Fisheries Review* (1993).

4.4.3 Fishery impact statements

The FMPs for bottomfish and seamount groundfish, pelagic fish, crustaceans and precious corals fisheries in the western Pacific are consistent with the broad conception of fishing communities outlined above. Drawing on the research material described in the preceding section, the Council has prepared fishery impact statements that have assessed the likely positive and negative economic and social impacts of alternative management measures on harvesters, processors, brokers/dealers, gear suppliers and seafood consumers dispersed throughout island populations.

4.4.4 Discussion and conclusions

The accompanying regulatory impact reviews for FMPs and amendments submitted to the Secretary after October 1, 1990, adequately address the effects of management measures on fishing communities in the western Pacific region. However, the Council is seeking additional information to improve the depth and scope of fishery impact statements for future proposed management measures. Current research projects supported by the Council that will assist in these efforts include an integration of cost-earnings information for fishery sectors and estimated expenditure patterns into the Hawaii state input-output model; a linear programming model for estimating the potential impact of management measures (e.g., area closures) on the commercial, recreational and charter sectors in Hawaii; sociocultural investigations of the small boat fisheries for pelagic species in Guam, American Samoa and the Northern Mariana Islands; an economic study of the Hawaii charter boat sector; and an updated estimate of the aggregate economic value of small boat fishing by recreational anglers in Hawaii. Many of these projects are being conducted through the Pelagic Fisheries Research Program administered by the University of Hawaii–NOAA Joint Institute for Marine and Atmospheric Research.

Areas where additional research is required include an estimation of the value of shark fin landings in the western Pacific region; identification of economic or other barriers that have prevented full participation by indigenous island residents in western Pacific fisheries; and cost-earnings analyses of small-scale fishing enterprises in the Pacific Island Areas.

4.5 Specify Overfishing Criteria and Include Preventive Measures

> *Specify objective and measurable criteria for identifying when the fishery to which the plan applies is overfished (with an analysis of how the criteria were determined and the relationship of the criteria to the reproductive potential of stocks of fish in that fishery) and, in the case of a fishery which the Council or the Secretary has determined is approaching an overfished condition or is overfished, contain conservation and management measures to prevent overfishing or end overfishing and rebuild the fishery.*

NMFS has provided a number of guidelines and requirements regarding the new treatment of overfishing in FMPs (amended Section 50 CFR part 600 [63FR24211-24237]). How the Western Pacific Council intends to address these requirements is discussed below for each FMP.

Several considerations should be kept in mind regarding the MSY approach to assessing overfishing. MSY changes over time due to environmental and other conditions and may not directly be related to the spawning potential ratio (SPR). SPR is not directly amenable to producing MSY estimates, which typically require surplus production models. The parameters of such models can be highly confounded and produce a wide-range of meaningless values in data poor situations. Environmental variation may have a strong influence on the productivity of a given stock, such that the estimation of MSY might occur during a particularly good or bad period for the population. The determination that overfishing has occurred if the threshold is exceeded in one year may be unrealistic, considering the normal wide annual variation in effort, targeting and biological productivity for many fisheries.

4.5.1 Bottomfish fishery

Discussion

Review of Overfishing

The current indicator of overfishing in the FMP is SPR, which is based on CPUE and size-frequency of the catch. This was defined in Amendment 3 to the FMP as "the relative SPR—an index of the ratio of the spawning stock biomass per recruit at the current level of fishing [$SSBR_f$] to the spawning stock biomass per recruit in the absence of fishing [$SSBR_u$]" (Goodyear 1989). Specifically, a BMUS is recruitment overfished when its SPR is equal or less than 20%.

A review by Rosenberg et al. (1994) raised questions about the method used to determine overfishing based on "dynamic SPR." They concluded that "dynamic SPR" is misleading and the overfishing definition should be changed to reflect what is actually being calculated (i.e., in terms of relative biomass rather than SPR). Kobayashi (1997a) identified discrepancies in the Rosenberg report with regard to overfishing definitions in the FMP. He noted that the report misinterpreted the Somerton and Kobayashi (1990) description of the use of SPR and the assumptions involved in calculating SPR, based on CPUEs, as a substitute for a relative biomass measure. Recruitment is assumed to be constant, since if it is changing, spawning per recruit could change independently of a relative spawning biomass index. The dynamic estimator also has the advantage of avoiding the critical assumption of population equilibrium. Kobayashi (1997a) concluded that there was no need to modify the definition of overfishing in the FMP.

MSY Determination Criteria

To obtain estimates of MSY for BMUS, production models need to be run using a time series of species-specific catch-rate data. Contrast in the time series (e.g., catch rates, effort) is needed to determine how the population responds to different impacts and to estimate MSY. However, existing data only allow estimates based on species aggregates. Production models also require an estimate of total catch, which is unavailable for areas like the MHI, where a substantial recreational take is not reported. For the NWHI fishery production models would be based on species aggregates unless assumptions (which are probably unrealistic) are accepted, such as r and q being the same for all species. Even SPR estimates for the NWHI are based on aggregate CPUE data, as there are no data for "species targeted trips." A recent estimate of bottomfish MSY for the Hawaiian archipelago is 1,103,000 lb, compared to current reported annual landings of 732,000 lb.

In July 1998, the Council determined that in Hawaii the overfishing threshold (e.g., SPR proxy) should be applied archipelago-wide, based on preliminary genetic results and related information, strongly supporting archipelago-wide bottomfish stocks. This is consistent with managing the stock throughout its range. When calculated archipelago-wide, the sub-threshold SPR values for certain MHI species are well above the 20% level indicative of overfishing.

Determination of SPR Proxy for Overfishing Threshold

Kobayashi and Moffitt (1998) conducted an analysis to estimate spawning potential ratio (SPR) thresholds for bottomfish, consistent with the new national standard guidelines for overfishing that mandate the use of MSY as the point defining overfishing. For Hawaii's deep-water bottomfish, SPR is calculated annually by NMFS as part of the Council's annual report for the bottomfish and seamount groundfish fishery. SPR is defined as the current amount of reproductive output expressed as a percentage of that amount present in a virgin unfished population (Goodyear 1993). Various proxies and assumptions are used to estimate SPR from commercial CPUE data from HDAR catch reports and commercial size frequency data from a cooperative NMFS/HDAR monitoring program at the United Fishing Agency auction in Honolulu.

To be compatible with the new guidelines, it was necessary to determine the level of SPR and fishing mortality rate coincident with the highest level of long-term sustainable yield. To accomplish this task, an age-structured computer simulation model was configured to mimic a bottomfish population, given estimates of growth, natural mortality and other life history characteristics like size/age at sexual maturity. The model was parameterized for three species of primary commercial and management interest: opakapaka (*Pristipomoides filamentosus*), onaga (*Etelis coruscans*) and ehu (*Etelis carbunculus*).

An empirically derived relationship was used to specify the natural mortality rate parameter (M) for each of the species. Ralston (1987) presented regression formulas for a proposed relationship between the von-Bertalanffy growth coefficient (k) and M. The linear regression formula was $M=0.0189+2.06k$ and the functional regression formula was $M=-0.0666+2.52k$. The two predicted natural mortality rates were averaged and summarized as follows:

Major Species	Growth parameter k	Natural mortality rate M
Opakapaka	0.25	0.55
Onaga	0.14	0.30
Ehu	0.16	0.35

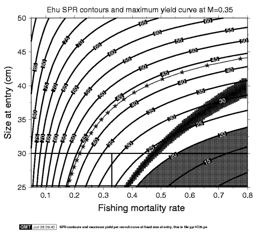
Sizes at entry for these species were estimated from a large sample of commercial fish size data over the past decade as converted to length-frequency distributions (Figure 4.5.a). Size at entry depends on the underlying population size frequency and the size-selective characteristics of the fishing gear, termed the gear selection curve. Size-at-entry estimates can be further confounded by size/age segregation by the fish into different depths or habitats, changes in fish behavior and size-dependent targeting/discarding/marketing by the fishermen. Probable sizes at entry are within the 30–40 cm fork-length (FL) range for opakapaka and onaga and within the 25–30 cm FL range for ehu.

The model used a constant level of recruitment and evaluated scenarios with size at entry ranging from 25 to 50 cm FL and fishing mortality rate ranging from 0.05 to 0.80. All possible combinations of these variables were used in the model to generate equilibrium condition output. Yield per recruit (YPR) and SPR were output for each combination, and these data were used to generate Figures 4.5.b–d, which show contours of SPR overlain by black/gray shaded linear regions representing the maximum YPR at a given size at entry (also termed F-max lines). SPR at or below 20% is shaded, and estimated ranges of size at entry are shown by horizontal dashed lines.

If recruitment is nonconstant and it is assumed that a spawner-recruit function applies at <20% SPR (i.e., population at recruitment overfished level), then all shaded regions are nonexistent, in the sense that at these combinations of size at entry and fishing mortality rate, diminishing recruitment will eventually crash the populations. Assuming that recruitment is constant at or above 20% SPR appears to be more consistent with a precautionary approach than assuming that recruitment will systematically increase with increases in population biomass. A constant-recruitment model would appear to be more conservative, particularly with regard to stock rebuilding.

The stars and lines on the plots represent an exploratory attempt to blend the characteristics of a production model with a more formal age-structured model. Since production modeling is used to estimate MSY directly, one of its characteristics was used to drive an age-structured model. That characteristic is that production models estimate MSY to be at a point where exactly half of the original carrying capacity biomass is remaining in the population. An age-structured model was configured and fishing mortality was applied until the population biomass was exactly half of its original unfished amount. SPR and the fishing mortality rate corresponding to this point were recorded, and this process was repeated for other values of size at entry. These age-structure derived values of SPR at MSY tend to be higher, thus more conservative or precautionary, than the corresponding SPR at maximum YPR. Therefore, age-structured reference points may be more useful than the YPR-based SPRs, since they may reflect some of the important density-dependent characteristics of population dynamics. Thus the more complex age-structured model allows a detailed “snapshot” of the population to be made at this point (e.g., SPR calculation), something not easily calculated with a simple biomass model.

Suggested species-specific threshold reference points consistent with the new overfishing guidelines are summarized in Table 4.5.a, using an average of the F-max and 50% biomass reference points. Depending on size at entry, SPR proxies for minimum stock size thresholds (MSST) at MSY would range from approximately 13% to 18% for opakapaka, 10% to 14% for onaga and 33% for ehu. These ranges were determined by averaging SPR values along the two yield curves for the range of size at entry. Using onaga, for example, the starred line (age-structured model) intersects the 40 cm size at entry line at 16% SPR and the MSY curve intersects



Common Species	Entry Size	Max. F_{MSY}	Min. Stock Size Threshold MSY Proxy (%SPR range)
Opakapaka	30-40 cm	0.44-0.69	SPR=20% (13-18)
Onaga	30-40 cm	0.17-0.20	SPR=20% (10-14)
Ehu	25-30 cm	0.26-0.33	SPR=33%

Table 4.5.a: Biological reference points relative to overfishing for common Hawaii bottomfish

this line at 3% SPR, which average to 10% SPR; at the 30 cm entry size limit, the starred line intersects at 23% and the MSY curve intersects at 5%, which average to 14% SPR; the SPR proxy for onaga MSST thus ranges from 10% to14% (Figure 4.5.b). For ehu the average of the two methods for the upper size limit and that for the lower size limit both approximate 33% SPR, thus no range is listed. These interspecific differences are consistent with what is known about their life histories. For example, onaga does not reach sexual maturity until 66 cm FL, while ehu matures at approximately 30 cm FL. Maximum fishing mortality thresholds (MFMT or F_{MSY}) are estimated from Figures 4.5.b–d, where SPR contours for MSST intersect the minimum-maximum entry size lines, to be 0.44–0.69 for opakapaka, 0.17–0.20 for onaga, and 0.26–0.33 for ehu. The F_{MSY} range for ehu are the F values corresponding to the average F-max and 50% biomass reference points; the range for opakapaka and onaga are the F values corresponding to an SPR threshold of 20%, since the average F-max and 50% biomass reference points fall below the recruitment overfishing threshold. Threshold SPR proxy values for opakapaka and onaga will essentially default back to the 20% SPR recruitment overfishing value. The ehu threshold value represents an average of the two approaches used in the analysis. A precautionary approach could allow a buffer for these threshold values by setting a target level slightly higher until the precision and accuracy of the proxy estimator are better understood. A better understanding of size at entry and the natural mortality rate is also needed to improve these results.

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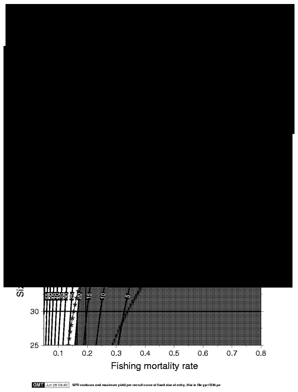

Measures to Prevent Overfishing

The FMP already includes a number of measures, or control rules, aimed at preventing overfishing. These include a moratorium on the harvest of NWHI seamount armorhead, the prohibition of destructive fishing methods, a limited entry system in the NWHI and a recruitment overfishing threshold of 20% SPR.

Measures to Rebuild Overfished Stocks

The Council was notified by NMFS in September 1997, as part of a national listing, that armorhead, MHI onaga and MHI ehu are overfished and that MHI hapuupuu is approaching an overfished condition. This determination was based on SPR values in the latest bottomfish annual report that were below or near the 20% threshold, under the current definition for recruitment overfishing. No other BMUS from any part of the western Pacific region was listed as overfished or threatened.

SPR values obtained at Colahan Seamount for armorhead stocks have been shown to correlate well with values from Hancock Seamount and can be used as a proxy value. Armorhead stocks outside the US EEZ experienced a short pulse in recruitment in 1992. However, this did not continue in 1993, indicating a collapsed fishery. The Council extended the moratorium prohibiting fishing for seamount groundfish (pelagic armorhead) for another six years (from August 1998). In January 1998, the NMFS SW Regional Administrator informed the Council that no further action is required to rebuild the stock.

Based on preliminary results of recent genetic analyses supporting archipelago-wide stock boundaries for onaga and ehu, the Council concluded that it is more appropriate biologically to assess overfishing only on a archipelago-wide basis in Hawaii. NMFS simulation modeling of larval drift also suggests considerable genetic exchange between the NWHI and MHI, further strengthening the single genetic stock hypothesis for bottomfish in the Hawaiian archipelago. This is a refinement of previous assessments based on geo-political sub-management areas—MHI, Mau Zone, Hoomalu Zone—that had no biological basis. Consistent with this determination, the 1997 *Bottomfish and Seamount Groundfish Fisheries Annual Report* of the western Pacific region concludes that none of the five BMUS for which SPR values can be calculated have SPR values below the 20% threshold that defines recruitment overfishing under the FMP. Consequently, the Council has requested that NMFS remove MHI onaga, ehu and hapuupuu from the national list of overfished or stressed species.

However, the Council also recognizes that onaga and ehu are locally depleted in the MHI, where about 80% of the fishery occurs in state waters. In June 1998, the State of Hawaii implemented rules under a new bottomfish management plan, mainly to close 20% of the fishing grounds in the MHI and also to restrict certain gear and impose non-commercial bag limits. NMFS Honolulu Laboratory staff modeled a recovery scenario for MHI onaga SPR based on reduced fishing mortality through closed areas. Recovery to 20% SPR in 10 years was found to be possible and reasonably feasible under the state's plan that closes 20% of the fishing grounds, under certain assumptions (Kobayashi 1997b). While acknowledging the value of the state's plan to restore these locally depleted species in the MHI, the Council continues to consider various options to further assist the state in this effort. Federal assistance with monitoring and enforcement could improve the effectiveness of the state's regulations. The Council is currently considering delegating authority to the state, under the reauthorized Magnuson-Stevens Act (Sec. 306[a][3][B]), to manage bottomfish in the Federal EEZ of the MHI, so the state can enforce its rules in all MHI waters.

If biological overfishing should actually be determined for any BMUS, then the Council will take appropriate action to rebuild any such stocks to healthy levels. A variety of catch and effort reduction measures may be considered.

<u>Conclusions</u>

Preferred Alternative

The main control rule in the NWHI bottomfish fishery is a limited entry system. Minimum stock size threshold was determined by SPR proxy to range from 20% to 33% for bottomfish, based on an analysis of common Hawaiian species. Maximum fishing mortality threshold for MSY was determined as F=0.17-0.69 for bottomfish. Information is insufficient to quantify a value for OY at this time, however, a precautionary approach could be to allow a buffer for these MSY threshold values by setting a target level slightly higher until the precision and accuracy of the proxy estimator, and information on social, economic and ecological factors are better known.

Other Alternatives

The "no action" alternative would not be responsive to the mandate of the Magnuson-Stevens Act. Some alternative control rules include constant catch, constant fraction of biomass and constant escapement. Other alternatives to specifying MSY, MFMT and MSST basically follow those described in Restrepo et al. (1998). Alternatives for determining MSY by MFMT include $F_{SPR=20\text{-}40\%}$, F_{MSY}=M and $F_{0.1.}$ Alternatives for MSST include $B_{MSY}=0.4\text{-}0.5B_{o.}$ However, the preferred alternative was selected because it best meets the various objectives of the Magnsuson-Stevens Act.

Rebuilding Plans

In contrast to the above mentioned determination, results from recent genetic analyses and related studies, supporting archipelagic stock ranges, indicate that no BMUS are overfished based on either a recruitment-based or MSY-based definition of overfishing. Concurrent with the required change in definition of overfishing from a SPR-based threshold to a MSY-based threshold, overfishing (based on MSY or its SPR proxy) is now calculated based on the stock as a unit throughout its range, as determined by the best available information. Existing measures in the FMP are also sufficient to prevent overfishing at this time. If any stock would in the future be determined to be overfished the Council would implement measures to rebuild the stock. The rebuilding plan would consider estimates of B_{MSY}, a maximum rebuilding time-frame, a rebuilding trajectory and transition to post-rebuilding management.

Data Needs

Additional scientific data needs for the bottomfish fishery include 1) CPUE data for species targeted trips in the NWHI fishery; 2) improved estimates of the size at entry and natural mortality rate to obtain a more reliable MSY proxy; 3) estimated MSY-based overfishing thresholds, or proxies, for BMUS in American Samoa, Guam and the Northern Mariana Islands; 4) monitoring and evaluation of the state’s management plan for closed areas to restore locally depleted bottomfish in the MHI; and 5) detailed information on economic, social and ecological factors to quantify OY.

4.5.2 Pelagics fishery

<u>Discussion</u>

Review of Overfishing

The FMP includes a discussion of consistency with the requirement to prevent overfishing of PMUS while achieving OY. To determine biological limitations and the health of the stocks the best estimates of MSY at that time (1987) were provided for stocks throughout their Pacific range. The FMP also notes that any level of fishing on migratory Pacific pelagic species likely to occur in the US EEZ cannot appreciably affect the overall condition of the stocks and will not significantly contribute to overfishing. It was concluded that a nonnumeric definition of OY should be used since 1) limiting catches in the EEZ will not affect stock conditions, 2) annual availability of fish in the EEZ is highly variable and unpredictable, 3) only a small but unknown fraction of the PMUS population occurs in the EEZ at a time, and 4) there are no known economic or social objectives that warrant a direct allocation. The FMP thus defines OY as the amount of each PMUS that will be caught by domestic and foreign vessels fishing in the EEZ in accordance with the measures contained in the plan. The FMP also states that management of a stock (or interrelated stocks) should be as a unit throughout its range. The domestic annual harvest (DAH) and total allowable level of foreign fishing (TALFF) are defined in nonnumeric terms.

In 1991, Amendment 1 to the FMP revised the definition of OY to be the amount of pelagic fish that can be harvested by domestic and foreign vessels in the EEZ of each island area without causing “local overfishing” or “economic overfishing” and without significantly contributing to “growth overfishing” or “recruitment overfishing” on a stock-wide basis. Local overfishing can occur when fish are removed from local waters at a faster rate than they can be replaced by new recruits entering from more distant areas. OY is MSY as modified by relevant socioeconomic factors, ecological considerations and fishery biological constraints to provide the greatest long-term benefits to the nation. Amendment 1 also established a measurable definition of recruitment overfishing as “a harvest rate that is not consistent with a program established to maintain the species or stock above the minimum level of SPR and incapable of achieving OY.” Billfish, mahimahi and wahoo are considered overfished when their SPR is less than or equal to 0.20. Oceanic sharks are considered overfished when their SPR is less than or equal to 0.35. The FMP defines overfishing of a PMUS as a harvest rate not consistent with a program to maintain the stock above the minimum SPR level and achieve OY. Amendment 6, which added tunas as PMUS to the FMP, defined overfishing for tunas and related stocks as SPR less than or equal to 0.20.

Amendment 7 notes that a meaningful definition of OY must recognize the impact of all vessels that fish anywhere throughout the range of PMUS stocks in the Pacific. It is unlikely that yield in the US EEZ would decline due to local fishing, as migration and recruitment from the high seas is considerable. However, local effort would eventually start to decline upon market saturation and price decreases. The amendment revised the definition of OY as follows: “OY is the amount of each management unit species or species complex that can be harvested by domestic and foreign fishing vessels in the EEZ and adjacent waters to the extent regulated by the FMP without causing ‘local overfishing’ or ‘economic overfishing’ within the EEZ of each island area, and without causing or significantly contributing to ‘growth overfishing’ or ‘recruitment overfishing’ on a stock-wide basis”.

The existing SPR-based overfishing definition assesses the status of the current spawning potential compared to that of an unfished population. Migratory Pacific pelagic species are subject to significant international fishing pressure outside the US domestic EEZ. Assessment and prevention of overfishing requires a concerted international effort. Rosenberg et al. (1994) concluded that the Council’s overfishing definition is ambiguous since it could be related to either a maximum harvest rate or a minimum biomass (current spawning biomass compared to unexploited spawning biomass). However, they concluded that a preferable alternative may not be available and suggested that it could be clarified by indicating which of the two alternatives is being used to measure each stock and that further research on the population dynamics of PMUS is needed.

MSY Determination Criteria

The definition of MSY as "an average over a reasonable length of time of the largest catch which can be taken continuously from a stock" is consistent with the initial FMP. The FMP further stated that, since little information is available on stock structure and condition for mahimahi, wahoo and oceanic sharks, estimates of MSY cannot be derived for these species. The lack of data on catch, effort and population dynamics precluded the use of fishery production models to estimate MSY. For migratory pelagic species MSYs need to be estimated on a Pacific-wide basis.

Referring to the initial MSY estimates, the FMP states: "Attempting to finagle meaningful estimates of MSY for each MUS which are specific to the 200- mile zone of each widely scattered American Pacific Island would serve no useful purpose. Doing so would be frustrating and frivolous because of several compelling reasons." Main reasons given are 1) they are indeed highly migratory and their abundance in the EEZ can vary greatly from year to year and season to season, and 2) annual catches in the EEZ are only about 1–10% of the total catches of these species in the Pacific. Therefore, such MSY estimates represent 1–10% of the Pacific-wide estimates of MSY for these species. MSY can also vary with annual variation of prey abundances in the EEZ, oscillations of water masses and El Niño events.

The NMFS guidelines state that status determination criteria must specify 1) a maximum fishing mortality threshold (or proxy) that does not exceed F_{MSY} and 2) a MSST (or proxy) in terms of spawning biomass or other productive capacity. Table 4.5.d. includes estimates of the maximum fishing mortality threshold (based on the assumption that F_{MSY}=M), MSST (by SPR proxy for spawning biomass), estimated Pacific-wide MSY (where known) and stock status for PMUS. F_{MSY} is dependent on a number of factors such as the assumed stock recruitment relationship, inter-annual and decadal-scale environmental variations, type of fishing gear and geographical location. As it may be difficult to accurately identify F_{MSY} for pelagic fisheries, proxies may be used (Mace 1998). Rosenberg et al. (1994) suggested that most highly migratory pelagic species have natural mortality rates of 0.2–0.4. This may be appropriate for Pacific bigeye, albacore and bluefin tunas; however, many Pacific pelagics have higher rates. Natural mortality rates of 0.4–1.0 or higher are more appropriate for skipjack, yellowfin, frigate, bullet, slender and dogtooth tunas, as well as for

Species (PMUS)	Max. F_{MSY}	Min. B_{MSY} (proxy)	Est. MSY(mt)	Stock Status
Blue marlin	0.2-1.0	SPR=20-30%	unknown	unknown
Striped marlin	0.2-1.0	SPR=20-30%	unknown	unknown
Swordfish	0.2-1.0	SPR=20-30%	unknown	unknown
SB spearfish/sailfish	0.2-1.0	SPR=20-30%	unknown	unknown
Oceanic sharks	0.2-1.0	SPR=35-45%	unknown	unknown
Thresher sharks	0.2-1.0	SPR=20-30%	unknown	unknown
Mackerel sharks	0.2-1.0	SPR=20-30%	unknown	unknown
Hammerhead sharks	0.2-1.0	SPR=20-30%	unknown	unknown
Mahi mahi	0.4-1.0	SPR=20-30%	unknown	unknown
Wahoo	0.4-1.0	SPR=20-30%	unknown	unknown
Yellowfin tuna	0.8-1.0	SPR=20-30%	700-900,000[1]	lightly utilized

Bigeye tuna	0.2-0.4	SPR=20-30%	150-180,000[2]	unknown
Skipjack tuna	1.0-1.5	SPR=20-30%	2,000,000+	lightly utilized
Albacore (NP)	0.2-0.4	SPR=20-30%	75-94,000[3]	lightly utilized
Albacore (SP)	0.2-0.4	SPR=20-30%	20,000-42,000[4]	lightly utilized
Bluefin tuna (NP)	0.2-0.4	SPR=20-30%	unknown	unknown
Frigate tuna	0.4-1.0	SPR=20-30%	unknown	unknown
Bullet tuna	0.4-1.0	SPR=20-30%	unknown	unknown
Slender tuna	0.4-1.0	SPR=20-30%	unknown	unknown
Dogtooth tuna	0.4-1.0	SPR=20-30%	unknown	unknown
Mackerel	0.4-1.0	SPR=20-30%	unknown	unknown
Moonfish	0.2-1.0	SPR=20-30%	unknown	unknown
Oilfish (family)	0.2-1.0	SPR=20-30%	unknown	unknown
Oceanic pomfrets	0.2-1.0	SPR=20-30%	unknown	unknown

Table 4.5.d: Estimates of maximum fishing mortality threshold (F_{MSY}), MSST (B_{MSY}), Pacific-wide MSY and stock status for Pacific PMUS [Sources: [1]J. Hampton (SPC, pers. comm.); [2]Miyabe (1991); [3]N. Bartoo (NMFS-SWFC, pers. comm.); [4]Yeh and Wang (1991)]

mahimahi, wahoo and mackerel. Maximum F_{MSY} for the other PMUS, where M is largely unknown, are listed as 0.2–1.0 in the table.

A reasonable proxy for MSST is 20–30% of the stocks virgin spawning biomass (Caddy 1998). This level has been assigned as a default to prevent overfishing, until more precise information is available by species. SPR for oceanic sharks are set at 35–45%, since they have a reproductive capacity that is lower than tuna-like species but higher than coastal sharks.

Pacific-wide estimates of MSY for some PMUS are also listed in Table 4.5.d. While estimates for a number of Pacific pelagic species have been proposed, most include a large degree of uncertainty. The estimate of MSY for most of the PMUS is listed as “unknown,” as the database is insufficient or it failed to fit the model. For a number of species total catch data may be lacking. Estimates of MSY for yellowfin and skipjack tunas are based on recent annual yields, with no indication of declining CPUEs. Early estimates for yellowfin and skipjack tunas have proven to be wrong, as recent production has reached levels well beyond these estimates following the expansion of surface fisheries. Tagging results have been used to estimate biomass and turnover rates of western Pacific yellowfin and skipjack tunas.. Estimates of MSY have not yet been derived from these studies, but suggest that yellowfin and skipjack tuna stocks are sill under-exploited. The MSY estimate for bigeye tuna may be an underestimate as it is based on longline data, which may not fully reflect the different age classes of the stock. North Pacific albacore catches may also be higher than that suggested by Bartoo, as catches have been sustained at 100–110,000 mt since 1994. At the time the FMP was implemented, several species of marlin were considered fully or over-exploited. However, a more recent analysis (Hinton and Nakano 1996) noted that Pacific-wide standardized blue marlin CPUE estimates showed an increasing trend in the late 1980s (the latest data available) and speculated that this was due to decreasing effective fishing effort for relatively shallow-dwelling blue marlin. However, because Korean and Taiwanese longline effort supplanted Japanese longline effort during the past decade, the increase in CPUE may not have continued (WPRFMC 1994). Thus, there is still concern regarding the status of blue marlin, even though there is no conclusive evidence that it is currently overfished.

Determination of MSY for an indicator species from a mixed pelagic stock should be based on the following characteristics: oldest average age, lowest fecundity and most vulnerable life history characteristics (e.g., for bigeye or bluefin tuna).

Recent annual landings for major tuna species average 650,000 mt for yellowfin tuna; 157,000 mt for bigeye tuna; 1,029,000 mt for skipjack tuna; and 95,000 mt for North Pacific albacore (SPC 1998). This suggests that full exploitation has not been reached for these species; however, stock status is uncertain for bigeye tuna. Annual landings of blue marlin caught by longline in the western and central Pacific are stable at 5,000–7,000 mt. Landings of striped marlin are about 12,000 mt, and catches of black marlin have been under 1,000 mt since 1980. Swordfish catches Pacific-wide have averaged 30,000–35,000 mt per year since 1990, with larger swordfish being more abundant at higher latitudes. Annual landings of swordfish caught by longline in the western and central Pacific have been 10,000–14,000 mt since 1980. Fisheries in Hawaii, Japan, Australia and Fiji are the primary sources of effort on Pacific swordfish (Lawson 1996).

Alternative measures of stock status and overfishing that are not necessarily related to MSY include less data intensive indicators, such as trends in CPUE, range of the fishery, percent mature fish in the catch and average size of the catch compared to the size at 50% maturity. A decline over time of these indices may suggest decreasing stock abundance. Limiting values that define overfishing in these ways need to be determined.

Based on time series trends in CPUE there are no signs of impacts from fishing for central and western Pacific stocks of skipjack tuna, yellowfin tuna, bigeye tuna (in the western Pacific), south Pacific albacore, striped marlin (both north and south Pacific), broadbill swordfish and black marlin. However, bigeye tuna in the eastern Pacific has shown decreases in CPUE in recent years, suggesting full exploitation in that area. Genetic evidence suggests that eastern and western Pacific stocks are actually one stock. Fishing impacts on stocks of spearfish and sailfish cannot be determined as catch statistics for these two species are combined. Full exploitation or overfishing of Pacific blue marlin was suspected in the past, but the current status is unknown.

Measures to Prevent Overfishing

Because US landings account for only a very small percent of total landings of Pacific-wide pelagic stocks, it is unlikely that domestic fishing effort alone could produce a measurable impact on a stock. The FMP includes provisions to adjust effort, if required, through restrictions on catch or the time or area in which effort could be deployed, to prevent any long-term adverse fishing impacts on stocks. Tropical tunas are also rather resilient to recruitment overfishing. The Council manages its pelagic fisheries to prevent overfishng and achieve OY, as defined in Amendments 1 and 7, to the extent practicable. Prevention of overfishing for PMUS requires full international cooperation in assessment and management by Pacific fishing nations. While a limited entry program is a primary management measure for the main pelagic fishery, Hawaii-based longline, it is not a control rule aimed to prevent overfishing, but rather was implemented based more on social (e.g., gear conflict) and economic (e.g., local market saturation) concerns.

Measures to Rebuild Stocks

No PMUS is listed as being overfished or approaching an overfished condition. The above mentioned measures of the FMP to prevent overfishing, through various restrictions on catch and effort, can be used to rebuild any stock that may be determined in the future to be overfished. Amendment 7 added to the FMP framework procedures to allow for the rapid adjustment of established management measures.

<u>Conclusions</u>

Preferred Alternative

The Council manages its pelagic fisheries to prevent overfishng and achieve OY, as defined in Amendments 1 and 7, to the extent practicable: "OY is the amount of each management unit species or species complex that can be harvested by domestic and foreign fishing vessels in the EEZ and adjacent waters to the extent regulated by the FMP without causing 'local overfishing' or 'economic overfishing' within the EEZ of each island area, and without causing or significantly contributing to 'growth overfishing' or 'recruitment overfishing' on a stock-wide basis". Any control rules to prevent overfishing for PMUS will require full international cooperation in assessment and management by Pacific fishing nations with the US. Methods to objectively measure MSY and assess overfishing for pelagics include non-equilibrium based dynamic production models (e.g., delay difference) or time trends in CPUE, but all must be applied on a Pacific-wide basis and be based on sufficient data. For only a few species are reasonable MSY estimates available. The threshold for F_{MSY} or MFMT, while unknown for most PMUS stocks, is estimated to be 0.2–1.5 per year, based on F_{MSY}=M. The threshold level for MSST, also not known for most pelagic stocks, is estimated by the proxy SPR=20–30% (35–45% for oceanic sharks). The Council maintains that MSY-related definitions of overfishing cannot be applied to the US Pacific island EEZs given the Pacific-wide distribution of most pelagic stocks and the current highly uncertain estimates of stock-wide MSYs. Information is also insufficient to quantify a value for OY at this time, until social, economic and ecological factors are better known. The Council asserts that the new overfishing provision can best be addressed through US participation in international management initiatives in the Pacific.

Other Alternatives

The "no action" alternative would not be responsive to the mandate of the Magnuson-Stevens Act. Other alternatives typically used to specifying MSY, MFMT and MSST are described in Restrepo et al. (1998). However, as SPR cannot be estimated for Pacific pelagic species, due to incomplete data or its inability to fit a model (e.g., total catch is lacking for many species), there are no alternatives available upon which to estimate MSY. The preferred alternative was selected because it is not possible or practicable to do otherwise.

Rebuilding Plans

Existing measures in the FMP are also sufficient to prevent overfishing and no pelagic stocks are known to be overfished at this time. If any stock is determined to be overfished the Council would implement measures through various restrictions on catch and effort to rebuild the stock, according to Magnuson-Stevens Act guidelines. Such a rebuilding plan would consider estimates of B_{MSY}, a maximum rebuilding time-frame, a rebuilding trajectory and transition to post-rebuilding managment.

Data Needs

Additional scientific data needs for pelagics fisheries include 1) international efforts to assess PMUS stocks Pacific-wide, improve estimates of parameters to determine MSY, or proxies thereof, and prevent overfishing; 2) more complete and accuracate population dynamics data on PMUS; 3) the determination of limiting or threshold values and the robustness of biological reference points that define overfishing through simulation models; 4) estimated MSY from results of tagging studies in the Pacific; 5) improved database of time-series information to estimate SPR for PMUS Pacific-wide; and 6) detailed information on economic, social and ecological factors to quantify OY. Obtaining complete information on these needs requires established and fully functional international organizations.

4.5.3 Crustaceans fishery

<u>Discussion</u>

Review of Overfishing

Amendment 6 to the FMP states: “Lobster stocks shall be deemed overfished with regard to recruitment when the spawning potential ratio (SPR, measured for a specific fishing area) is 20% or below.” FMP regulations are based on the principles of OY, i.e., MSY as modified by relevant ecological and socio-economic considerations. MSY is defined in the FMP as the largest average annual catch of fish that can be taken from an area on a continuing basis. Amendment 6 defines OY as a SPR of 50%. For a fishing level such that SPR is 50%, the increased egg production and survival of young lobsters at the fished density must be twice the level in the absence of fishing, if overfishing is to be avoided (Goodyear 1989). The lobster fishery annual report also addresses the status of the stocks relative to overfishing for both the NWHI as a whole and for specific banks. The fishery currently operates with a SPR level of about 70%.

Rosenberg et al. (1994) reviewed the overfishing definition for CMUS and concluded that a SPR of 20% was a reasonable threshold for the lobster fishery in the absence of stock recruitment information. However, the report stated that it may not be possible to accurately estimate the SPR for these stocks with available data. In the late 1980s and early 1990s, an environmental regime shift caused SPR to approach the 20% threshold level.

Amendment 9 incorporated a new constant harvest rate strategy (control rule) to minimize the risk of overfishing. The annual harvest guideline is determined by the product of *N* times *r*, where *N* is the number of exploitable lobsters in the population (derived from a population model with parameters for natural mortality, catch and recruitment) and *r* is a "constant harvest rate" (or portion of the population that can be exploited). The Council accepted a 10% (maximum) risk of overfishing, which corresponds to a *r* of 13% (i.e., only once every 10 years will this strategy result in a SPR less than 20%). A SPR less than 50% indicates a warning level.

MSY Determination Criteria

The FMP states that, in theory, a fishery can be managed to generate MSY by controlling the time, location and manner of fishing. Conventional stock assessment methods are typically used to derive MSY for established fisheries, using parameters such as catch, effort, size distribution, sex ratio of catch, natural mortality, fecundity and growth rates. Because information on many of these factors was not available when the FMP was prepared, MSY could not be reliably estimated. However, by accepting a number of assumptions and extrapolating across the NWHI chain, crude estimates were generated. It was concluded that MSY for the NWHI spiny lobster stock may be 200,000–435,000 lobsters per year. The most productive banks were thought to be Maro (MSY=68,000), Necker (MSY=53,000), Gardner (MSY=26,000) and Raita (MSY=8,000). For the 1998 season, bank specific harvest guidelines were determined to be 80,000 lobsters for Maro, 70,000 lobsters for Necker and 20,000 lobsters for Gardner.

As noted above, Amendment 9 incorporated a constant harvest rate strategy, where annual yield is 13% of estimated exploitable stock size. Harvest strategies were compared by varying the allowable catch target level and assessing the risk of overfishing and other performance statistics (e.g., average catch, CPUE, catch variability and SPR). The constant harvest rate strategy produced the highest average annual catches and SPRs (well above the threshold, even at the 10% level of risk). Other control rules considered were constant escapement (where all individuals above an "optimum" population size are harvested) and constant catch (where annual yield is constant). As new data become available the harvest strategy will be revised, as necessary.

Revised Model Analysis

DiNardo and Wetherall (1998) reevaluated a lobster population dynamics and harvest simulation model to identify biological reference points, including MSY, based on data from the NWHI fishery. The report describes the equilibrium relationships among the annual fishing mortality coefficient (F), relative spawning biomass (RSB), spawning potential ratio (SPR), harvest rate (HR), catch in numbers (C) and catch in weight (Y), assuming various degrees of dependence between recruitment and spawning biomass (R-SB function). In addition, assuming a 13% harvest rate (as stipulated in Amendment 9), estimates of the risk of exceeding the levels of F associated with the various reference points are provided. Risk is defined as the probability that SPR will fall below 20% due to fishing.

The structure and parameterization of the model are the same as those underpinning the 1995 analysis of Amendment 9 harvest guidelines, which is currently the best available data for

determining MSY. Maintaining consistency with the key harvest guideline decisions made in Amendment 9 is also necessary at this time. An analysis is planned for the near future that will modify the model structure, update model parameter estimates and rerun the model. In Amendment 9 the estimate of long-term yield considered recruitment as being constant and independent of stock size, as no relationship was known. In the current assessment parameters for varied recruitment are included.
The model used in Amendment 9 to simulate population dynamics and test harvest policy alternatives was expanded to incorporate biological reference points relative to overfishing. This age-based, sex-structured, auto-regressive model simulates population dynamics and mimics monthly stock dynamics and fishery dynamics, given a set of assumptions about growth, natural mortality, maturation, recruitment and fishing mortality. The model pools spiny and slipper lobster as one species-complex and implies no spatial structure in fishing. The model also assumes that population parameters and fishing characteristics are specific to spiny lobster (as time-series of data on slipper are lacking). Four biological reference points are defined for evaluating lobster harvest levels: 1) Amendment 9 target level (10% risk of a 20% SPR); 2) Amendment 9 warning level (50% SPR); 3) MSY (the maximum equilibrium yield) level; and 4) MSST—one-half of the equilibrium spawning biomass corresponding to MSY) level.

With several assumptions about the dependence of recruitment on spawning biomass, equilibrium values of RSB (the ratio of equilibrium spawning biomass for a given value of F to the equilibrium spawning biomass in the absence of fishing), SPR (the ratio of the equilibrium spawning biomass per recruit for a given value of F to the equilibrium spawning biomass per recruit in the absence of fishing), HR (the ratio of the annual catch of lobster (in numbers) to the July 1 exploitable lobster population size), C (the annual harvest of lobster in numbers) and Y (the annual catch of lobster in weight) were computed over a range of F values from 0 to 2.0. A retain-all fishery was assumed. With additional assumptions about systematic, process and measurement error, as well as auto-correlation in recruitment innovations, the model was used in a Monte Carlo harvest simulation to estimate risks of overfishing. In the Monte Carlo simulation, the model mimics the monthly dynamics of the lobster stock, the annual stock assessment process upon which harvest guidelines are based and the dynamics of the fishery. From these results equilibrium values of F, RSB, SPR, HR, C, Y and Y/MSY were identified, corresponding to the four biological reference points for lobster harvest levels.

Except for the stock-recruitment relationship, all model processes were density independent. Annual lobster recruitment was modeled using a power function: $R/R_{MAX} = (SB/SB_{MAX})^{\beta}$, where R is recruitment; R_{MAX} is maximum equilibrium recruitment in the absence of fishing; SB is spawning biomass;, SB_{MAX} is the spawning biomass corresponding to $R_{MAX;}$ and β is a parameter controlling the strength of the dependence between recruitment and spawning biomass. If $\beta = 0$, recruitment is independent of spawning biomass. As β increases, the dependence of recruitment on spawning biomass also increases. The R-SB relationships assumed in the analyses are depicted in Figure 4.5.e. The actual R-SB relationship for NWHI lobsters is unknown. Until it is better understood, a reasonable (and conservative) assumption might be that $\beta = 0.10$, approximately. As shown below, when $\beta = 0.10$ the SPR associated with harvesting at MSY is approximately 20%, which is consistent with the overfishing definition effected when the Council established the 13%

constant harvest rate control rule. In other words, under these conditions the MSY overfishing reference point is the same as the SPR overfishing reference point under Amendment 9.

The present analysis is consistent with the Council's preferred harvest rate of 13%. Accordingly, risks of overfishing with respect to the four reference points defined above, assuming a 13% harvest rate, were computed. Overfishing risk is defined as the probability that in a given year F will exceed the value of F consistent with the reference point.

The extracted values of F, RSB, SPR, HR, C, Y, and Y/MSY for the four reference points, corresponding to the various values of β, are given in Table 4.5.e. The equilibrium relationships between F, HR, SPR, and Y for a range of values of β are shown in Figures 4.5.f–l. Estimates of overfishing risk for each of the reference points at a 13% harvest rate are presented in Table 4.5.f. As β increases the overfishing risks associated with the MSY and MSST status determination criteria increase. However, β does not affect the risk with regard to the Amendment 9 target and warning level reference points.

If a β level of 0.10 is assumed for the R-SB relationship, then the maximum F_{MSY} would be 0.72 and the proxy for MSST would be SPR=11% (or conservatively default back to the current 20% SPR level for recruitment overfishing) (Table 4.5.e). A harvest rate of 58% of the exploitable population, which would produce a equilibrium catch of 461,260 lobsters, would be expected at these threshold levels. Under the 13% constant harvest rate control rule, under which the fishery currently operates, F_{MSY}=0.14 and SPR=65%, which are conservatively above the threshold values. Risk of overfishing by exceeding the maximum F_{MSY} or MSST thresholds is no greater than 10%, as it is under the current management strategy (Table 4.5.f). For β=0.10, the equilibrium relationship between F, HR, SPR and Y can be described as follows (Figure 4.5.h). A harvest rate of 0–13%, corresponds to a fishing mortality rate of 0–0.14, as yield increases to about 130,000 kg of lobster, and SPR declines from 100% to about 65%. As F further increases, SPR continues to decline exponentially, reaching 20% at about F=0.7, while yield increases exponentially and then exhibits a slight decline at F greater than 0.7. Equilibrium relationships for β less than 0.10 are similar but differ mainly in that slightly higher yields can be obtained as the strength of the R-SB relationship diminishes, for comparable levels of F (Figures 4.5.f–g). Conversely, for equilibrium relationships where β is greater than 0.10, the main difference can be seen as a diminishing yield curve, especially at higher levels of F, as recruitment becomes more dependent on spawning stock biomass (Figures 4.5.i–l).

The Magnuson-Stevens Act stipulates that the target of fishery management should be OY, a harvesting objective that takes into account not only biological criteria but social and economic factors as well. However, NMFS has not established standards for the incorporation of socioeconomic data, nor is such information presently available. The Council may choose to consider the average annual yield associated with a 13% harvest rate as a provisional estimate of OY, and the current harvest guidelines as an OY harvest policy, until a full analysis of economic and social factors is available. If a β value of 0.10 is assumed, the risk characteristics of the OY policy would be indicated by the third row in Table 4.5.f. The Council selected a 10% risk level of exceeding overfishing, with which the β level of 0.10 is most consistent. Under the current

	Biological Reference Point or Status Determination Criterion			
	------AMENDMENT 9------		-----------Magnuson-Stevens Act------------	
	Target 10% risk of 20% SPR	Warning 50% SPR	MSY	MSST
β	Fishing Mortality (F)			
0.00	0.14	0.24	1.25	1.97
0.05	0.14	0.24	0.91	1.49
0.10	**0.14**	**0.24**	**0.72**	**1.20**
0.15	0.14	0.24	0.60	1.03
0.20	0.14	0.24	0.51	0.87
0.25	0.14	0.24	0.44	0.75
0.50	0.14	0.24	0.21	0.37
β	Relative Spawning Biomass (RSB)			
0.00	0.65	0.50	0.11	0.05
0.05	0.64	0.48	0.15	0.07
0.10	**0.63**	**0.46**	**0.17**	**0.09**
0.15	0.61	0.44	0.19	0.10
0.20	0.59	0.42	0.21	0.11
0.25	0.57	0.40	0.23	0.12
0.50	0.43	0.25	0.29	0.15
β	Spawning Potential Ratio (SPR)			
0.00	0.65	0.50	0.11	0.05
0.05	0.65	0.50	0.16	0.08
0.10	**0.65**	**0.50**	**0.21**	**0.11**
0.15	0.65	0.50	0.25	0.14
0.20	0.65	0.50	0.29	0.17
0.25	0.65	0.50	0.33	0.20
0.50	0.65	0.50	0.54	0.38

control rule of a 13% harvest rate, the expected SPR is 65%, significantly more conservative than the MSY threshold.

Biological Reference Point or Status Determination Criterion

	------AMENDMENT 9------		-----------Magnuson-Stevens Act------------	
	Target 10% risk of 20% SPR	Warning 50% SPR	MSY	MSST
β		Harvest Rate (HR)		
0.00	0.13	0.22	0.89	1.22
0.05	0.13	0.22	0.70	1.01
0.10	**0.13**	**0.22**	**0.58**	**0.87**
0.15	0.13	0.22	0.50	0.77
0.20	0.13	0.22	0.43	0.68
0.25	0.13	0.22	0.38	0.60
0.50	0.13	0.22	0.20	0.33
β		Equilibrium Yield (kg)		
0.00	138,440	191,110	272,470	269,190
0.05	135,390	184,290	244,840	238,560
0.10	**132,080**	**177,000**	**221,550**	**213,560**
0.15	128,480	169,190	201,030	191,270
0.20	124,540	160,820	182,510	172,150
0.25	120,230	151,830	165,560	154,740
0.50	90,687	95,834	96,432	86,360
β	Equilibrium Catch (Number of lobsters)			
0.00	205,320	308,400	663,250	743,180
0.05	200,800	297,400	543,820	610,470
0.10	**195,900**	**285,630**	**461,260**	**514,400**
0.15	190,550	273,040	398,630	439,990
0.20	184,720	259,520	346,030	377,770
0.25	178,320	245,020	302,120	325,560
0.50	134,500	154,650	152,140	151,540
β		Equilibrium Yield/MSY		
0.00	0.51	0.70	1.00	0.99
0.05	0.55	0.75	1.00	0.97
0.10	**0.60**	**0.80**	**1.00**	**0.96**
0.15	0.64	0.84	1.00	0.95
0.20	0.68	0.88	1.00	0.94
0.25	0.73	0.92	1.00	0.93
0.50	0.94	0.99	1.00	0.90

Table 4.5e: (continued)

Biological Reference Point or Status Determination Criterion

	------AMENDMENT 9------		-----------Magnuson-Stevens Act------------	
	Target 10% risk of	Warning		
β	20% SPR	50% SPR	MSY	MSST
0.00	10	39	7	4
0.05	10	39	8	4
0.10	**10**	**39**	**10**	**6**
0.15	10	39	13	7
0.20	10	39	17	8
0.25	10	39	20	10
0.50	10	39	45	25

is a more conservative strategy than basing overfishing on MSY or MSST, since it maintains sustainable yield well away from the threshold limits. Minimum stock size threshold was determined by SPR proxy to be 20%. Maximum fishing mortality threshold for MSY was determined as F=0.21-1.25. Under the current control rule the expected SPR is 65%, significantly more conservative than the MSY thresholds. Therefore the status determination criteria analysis concludes that a good SPR proxy for the MSY overfishing reference point is the same overfishing reference point developed under amendment 9 (SPR=20%). Until studies can be conducted on economic, social and ecological factors of the lobster fishery, a provisional estimate of OY may be the average annual yield associated with the 13% constant harvest rate.

Other Alternatives

The "no action" alternative would not be responsive to the mandate of the Magnuson-Stevens Act. Some alternative control rules are constant catch and constant escapement. Other alternatives to specifying MSY, MFMT and MSST basically follow those described in Restrepo et al. (1998). Alternatives for determining MSY by MFMT include $F_{SPR=20\text{-}40\%}$, $F_{MSY}=M$ and $F_{MSY}=F_{0.1.}$ Other alternatives include varying the level for β for MFMT and MSST (estimated by $B_{MSY}=0.5B_o$). These alternative ways to determine overfishing thresholds and OY are considered sub-optimal, as the present method is supported by the above detailed analyses and results in an even more conservative strategy. The preferred alternative was also selected because it best meets the various objectives of the Magnuson-Stevens Act.

Rebuilding Plans

Existing measures in the FMP are also sufficient to prevent overfishing and no stock is listed as being overfished or approaching an overfished condition. If any stock would in the future be determined to be overfished the Council would implement measures to rebuild the stock. An established framework mechanism is available in the FMP to facilitate this process. The rebuilding plan would consider estimates of B_{MSY}, a maximum rebuilding time-frame, a rebuilding trajectory and transition to post-rebuilding management.

Data Needs

Additional scientific data needs for the crustaceans fishery may include 1) rerunning the population dynamics simulation model using updated parameter values and a revised model structure based on current NWHI lobster fishery information, 2) studies of the stock-recruitment relationship in the NWHI lobster fishery, 3) studies on the feasibility of species-specific and area-specific modeling and 4) studies on economic, social and ecological factors in the fishery to improve the estimate of OY.

4.5.4 Precious corals fishery

Discussion

Review of Overfishing

According to the FMP, OY is determined by estimating MSY and then downwardly adjusting the harvest level based on economic, social or ecological considerations. A strategy of 2-year pulse fishing, where continuous fishing pressure is applied until the target level is acquired then stopped, was determined to be the best compromise between minimizing biological risks and maximizing economic benefits. OYs for the Makapuu bed are set as 2-year quotas.

Pink, gold and bamboo corals occur in all six known beds, although only the "Established" Makapuu bed has been quantitatively surveyed. While it is believed that harvestable quantities of precious corals may exist in other areas of the western Pacific region, no information exists on their distribution, abundance or status.

The current (Amendment 2) definition of overfishing for all species of precious corals is when the total spawning biomass is less than or equal to 20% of its unfished condition (SPR$\leq$20%), based on cohort analysis of the pink coral, *Corallium secundum*. This definition takes into account the mean survivorship, yield, age at maturity, reproductive potential and MSY of the coral populations. It also protects 20% of the spawning stock biomass. For beds other than the "Established" Makapu'u bed more information is needed before the overfishing definition can be applied.

MSY Determination Criteria

According to the FMP, if recruitment is constant or independent of stock size, then MSY can be determined from controlling the fishing mortality rate (F) to maximize the yield per recruit (MYPR), i.e., MSY = MYPR(g/recruit) x R(recruits/yr)). MYPR is a function of area of the bed, average colony density and natural mortality. If a stock-recruitment relationship exists, recruitment is reduced as a function of reduced stock size, and MSY will also be reduced. The assumption of constant recruitment appears to be reasonable based on the robust recovery and verification of annual growth rings from a recent resurvey (Grigg 1977).

Alternatively, the Gulland (1969) method to estimate MSY is especially useful for gold and bamboo coral, where information on population dynamics is lacking. MSY is 40% of the natural mortality rate times virgin stock biomass (estimated from the product of area of the bed, average colony density and weighted average weight of a virgin colony; MSY = 0.4 x M x B). The mortality rate for pink coral (M=0.066) is used as a proxy for other species. Values for species with sufficient information to estimate MSY are summarized in Table 4.5.g.

Species (common name)	MSY (kg/yr)	MSY (rounded)	Method of Calculation
Corallium secundum (pink)	1,185	1,000	Cohort production model
Corallium secundum (pink)	1,148	1,000	Gulland model
Gerardia sp. (gold)	313	300	Gulland model
Lepidisis olapa (bamboo)	285	250	Gulland model

Table 4.5.g: Estimates of MSY of precious corals in the Makapuu Bed

The MSY for pink, gold and bamboo from the six beds in the Hawaii EEZ is about 3,000 kg/yr. The estimated MSY for the Makapuu bed is 1,000 kg/yr. A recent resurvey, which used a newer technology enabling deeper dives, found the Makapuu bed to be about 15% larger than previously estimated. However, no increase in the MSY or quota was suggested (Grigg 1997). MSY for conditional beds has been extrapolated, based on size, by comparison with that of the established beds. Amendment 2 set MSY at 1,000 kg/yr for each American Samoa and Guam (Exploratory Areas). No quotas or MSY estimates have been determined for species of black corals. MSY values have been estimated for a number of the permit areas. A summary of quotas, based on MSY estimates, occurs in the code of Federal regulations (Table 4.5.h).

MSY has also been estimated to correspond to a 30% SPR level to maintain 30% of the spawning stock biomass. The Council currently manages at the MSY level. From the mid-1960s to late 1970s, annual landings from the Makapuu bed averaged 685 kg (below the MSY of 1,000 kg). No known harvesting of precious corals has occurred in the U.S. EEZ for the past 20 years. The 1997 resurvey found that pink coral in the Makapuu bed has recovered to 74-90% of its pristine biomass, while recruitment of gold coral is low.

Name of Coral Bed	Type of Bed	Harvest Quota	Number of Years	Gear Restriction
Makapuu Bed, main Hawaiian Islands	Established	Pink 2,000 kg Gold 600 kg Bamboo 600 kg	2	Selective only
Ke-ahole Point, main Hawaiian Islands	Conditional	Pink 67 kg Gold 20 kg Bamboo 17 kg	1	Selective only
Kaena Point, main Hawaiian Islands	Conditional	Pink 67 kg Gold 20 kg Bamboo 17 kg	1	Selective only
Brooks Bank, Northwest Hawaiian Islands	Conditional	Pink 17 kg Gold 133 kg Bamboo 111 kg	1	Selective or Non-Selective (see Note 1 below)
180 Fathom Bank, Northwest Hawaiian Islands	Conditional	Pink 222 kg Gold 67 kg Bamboo 56 kg	1	Selective or Non-Selective (see Note 1 below)

Wespac Bed, Northwest Hawaiian Islands	Refugia	0 kg	N/A	N/A
Hawaii, American Samoa, Guam, other US Pacific Islands	Exploratory	1,000 kg per area, all species combined (except black corals)	1	Selective or Non-Selective (see Note 1 and 2 below)

Note 1: Only 1/5 of the indicated quota amount is allowed if non-selective gear is used; that is, the non-selective harvest will be multiplied by 5 and counted against the quota. If both selective and non-selective methods are used, the bed will be closed when $S + 5N = Q$, where S = selective harvest amount, N = non-selective harvest amount and Q = total harvest quota, for any single species on that bed.

Note 2: Only selective gear may be used to harvest coral from the EEZ seaward of the main Hawaiian Islands.

Table 4.5.h: Precious coral quotas based on MSY estimates

Measures to prevent overfishing

Provisions of the FMP, as amended, are already sufficient to prevent overfishing. Precious coral beds are classified as Established (with fairly accurate estimated harvest levels), Conditional (with extrapolated MSY estimates) and Refugia (reproductive reserves or baseline areas). Exploratory Areas are grounds available for exploratory harvesting with an Exploratory Permit.

Fishing in the EEZ of the MHI is limited to selective gear. If fishing is by non-selective methods, the allowable quota is reduced by 80% and the bed is closed when the quota for any one species is taken. Other provisions that help prevent overfishing are fishing seasons; annual quotas (based on MSY); restrictions on size, harvest area and gear, incidental catches and permit conditions; and an annual report that identifies possible overfishing and recommends rebuilding measures. Private interests can assess the production potential of newly discovered and unsurveyed beds prior to the determination of OY and allowable quotas.

Measures to rebuild overfished stocks

No stocks are overfished at this time. If a precious corals stock is overexploited, a long time period of zero or reduced fishing mortality will be required for recovery to the MSY level due to life-history characteristics of precious corals, such as slow growth and long generation time.

<u>Conclusions</u>

Preferred Alternative

The precious corals fishery is already managed based on OY quotas (i.e., control rule), calculated by downwardly adjusting MSY estimates. Values for OY quotas are listed in the Code of Federal Regulations for the main species of precious corals. The SPR proxy for minimum stock size threshold that corresponds to MSY is SPR=30%, and is already defined as such in the FMP. If one assumes $F_{MSY}=M$ then the maximum fishing mortality threshold for MSY is $F=0.066$.

Other Alternatives

The "no action" alternative would not be responsive to the mandate of the Magnuson-Stevens Act. Other alternatives to specifying MSY are suboptimal to the approach existing in the FMP. The preferred alternative was selected because it best meets the various objectives of the Magnsuson-Stevens Act.

Rebuilding Plans

As no harvesting has occurred for the past 20 years, nearly full recovery has been attained. The Council determined that the existing FMP has sufficient measures to prevent overfishing of precious corals and that no stocks are overfished, thus no further action is required at this time. If any stock would in the future be determined to be overfished the Council would implement measures to rebuild the stock. A rebuilding plan would consider estimates of B_{MSY}, a maximum rebuilding time-frame, a rebuilding trajectory and transition to post-rebuilding management.

Data Needs

Scientific data needs for precious corals include 1) research on the distribution, abundance and status of precious corals in the Pacific Island Areas; 2) MSY estimates for Conditional Beds and Exploratory Areas; 3) MSY estimates for black corals; 4) surveys of Makapuu bed to better define the bed's boundaries, monitor the recovery of corals (particularly gold coral) and determine the impacts of fishing activity should it occur; and 5) improved and updated information on economic, social and ecological factors to better quantify OY.

5.0 REGULATORY IMPACT REVIEW

In preparing this amendment the Council determined that no regulatory actions are necessary in order for its FMPs to be in compliance with the new provisions required by the Magnuson-Stevens Act. The information compiled for this amendment may be used as a basis for fishery management measures proposed in the future. While significant ecological, economic and social impacts could result from future management actions, this amendment itself has no such impacts.

6.0 OTHER APPLICABLE LAWS

6.1 National Environmental Policy Act

6.1.1 NEPA compliance

This amendment adds new Magnuson-Stevens Act definitions to the FMPs of the western Pacific region and addresses the requirement of the Act that any FMP contain provisions regarding bycatch (Section 4.1), fishing sectors (Section 4.2), essential fish habitat (Section 4.3), fishing communities (Section 4.4) and overfishing (Section 4.5). The amendment compiles the best available scientific information pertaining to each of these new provisions and incorporates it directly or by reference into the Western Pacific Council's management plans for bottomfish and seamount groundfish, pelagics, crustaceans and precious corals fisheries. In addition, the amendment identifies other scientific data which are needed to more effectively address the new provisions.

In preparing this amendment the Council determined that no regulatory actions are necessary for its FMPs to be in compliance with the new provisions required by the Magnuson-Stevens Act. However, the Council concluded that actions related to compliance with the provision concerning EFH could lead to future environmental impacts. Therefore, an environmental assessment was prepared for the EFH provision.

6.1.2 Environmental assessment

<u>Purpose and Need</u>

Fisheries are an important economic, social and natural resource, both nationally and regionally. Despite Federal action in many parts of the United States, fish stocks have declined due to a variety of factors including loss of habitat. Effective management to protect EFH is necessary to ensure the long term productivity of fish stocks. The Council regards the EFH mandate of the Magnuson-Stevens Act as a significant opportunity to make a difference in improving the success of sustainable fisheries and healthy ecosystems.

The Act directs the Council to include descriptions of EFH in its FMPs, outline feasible measures to minimize adverse impacts and identify measures to conserve and enhance to these areas. In addition, the Act establishes a consultation process for Federal agency actions that may adversely affect the habitat, including EFH, of a fishery resource under the Council's authority.

The Act also requires the Council to identify adverse impacts to EFH but does not mandate any regulatory action pursuant to the description of non-fishing and cumulative impacts. The Council addresses this requirement in Sections 4.3.3 and 4.3.4 of the amendment. Because no regulatory action is contemplated by the Council at this time, this aspect of EFH description is not separately considered in the environmental assessment.

Affected Environment

Detailed descriptions of the biological and physical environment in which the managed fisheries of the western Pacific region take place are presented in Section 1.1 (bottomfish), Section 2.1 (pelagics), Sections 3.1–3.3 (precious corals) and Section 4.1 (crustaceans) of Appendix 3.

Alternatives Considered to Describe and Designate EFH

With regard to the description and identification of EFH for FMP fisheries, four alternatives were considered: (1) designate EFH based on the best available scientific information (preferred alternative); (2) designate all waters EFH; (3) designate a minimal area as EFH; and (4) no action.

Preferred Alternative: Designate EFH based on observed habitat utilization patterns in localized areas

The unavailability of information on geographic variation in the density of managed species or relative productivity of different habitats, and to a lesser degree species' habitat preferences, precluded precise designations of EFH. However, as outlined in regulations (50CFR600.815(2)(c)), EFH can be inferred based on observed habitat utilization patterns in localized areas. This data represents the best scientific information available.

The preferred depth ranges of specific life stages were used to designate EFH for bottomfish (Section 4.3.1.1) and crustaceans (Section 4.3.1.3). In the case of crustaceans, the designation was further refined based on productivity data. Water temperature was a useful indicator for the distribution of pelagic species' EFH (Section 4.3.1.2). Temperature also expresses a depth range; many species are confined to mesopelagic waters above a permanent thermocline. However, it is recognized that certain species make extensive vertical migrations, in some cases below the thermocline, to forage. The precious corals designation combines depth and bottom type as indicators, but it is further refined based on the known distribution of the most productive areas for these organisms (Section 4.3.1.4). Species were grouped into complexes because available information suggests that many of them occur together and share similar habitat.

This alternative is preferred by the Council for three reasons. First, it adheres to the intent of the Magnuson-Stevens Act provisions and to the guidelines that have been set out through regulations and expanded on by NMFS. The best available scientific data were used to make carefully considered designations. Second, it results in more precise designations of EFH at the species complex level than would be the case if Alternative 2 (see below) was chosen. At the same time it does not run the risk of being arbitrary and capricious as would be the case if Alternative 3 was chosen. Finally, this alternative recognizes that EFH designation is an ongoing process and will set out a procedure for reviewing and refining EFH designations as more information on species' habitat requirements becomes available.

Alternative 2: Broad designation of EFH

The Council recognizes that for some managed species even information on distribution is incomplete. Consequently, the Council chose to add a fifth data level, Level 0, to the four outlined in the regulations (Section 4.3.). Given the paucity of data for certain species, a conservative approach would be to designate all EEZ waters and the benthos from the shoreline to the outer EEZ boundary as EFH.

This alternative was rejected because it does not use the best available scientific information, as required by the Magnuson-Stevens Act and regulations.

Alternative 3: Narrow designation of EFH

The regulations (50CFR600.815 (1) (C)) encourage Councils to obtain data at the highest level of detail. As already noted, data at this level are generally not available for fisheries in the western Pacific region. However, the inference process described above could be used to extend the limited highest level data that is available. The resulting EFH designation would be confined to those habitats or areas that have been shown to generate the highest known level of production.

This alternative was rejected because it exceeds a scientifically justifiable threshold for extending known results to unknown conditions. Furthermore, it may not identify sufficient habitat to sustain the long-term productivity of managed fisheries.

Alternative 4: No action

The Council's FMPs include substantial information on the habitat requirements of MUS. However, the Council rejected the alternative of taking no action because the original habitat descriptions did not adequately address the requirements of the Magnuson-Stevens Act provision regarding EFH. EFH is not described in detail nor is its geographic extent precisely delineated.

Impacts of the Preferred Alternative

Biological impacts

The designation of EFH in and of itself will not have any biological impact. However, the proposed NMFS consultation process should have an overall beneficial effect on habitats important to managed fisheries in the western Pacific region. A direct benefit of the amendment is the compilation of information (Appendix 3) on the habitats and life history characteristics of managed species. This baseline information should facilitate the efforts of the Council and NMFS to assess cumulative impacts to EFH and propose measures to mitigate or avoid adverse impacts. Additionally, the review and compilation of the best available scientific data will serve to guide future research necessary to further describe and protect EFH. Second, EFH designation establishes a framework for NMFS and the Council to cooperatively comment on state and Federal agency actions affecting EFH. The comments of these agencies will, in turn, provide more specific guidance on how adverse impacts to EFH can be avoided or mitigated.

Social and economic impacts

Designation of EFH will not directly result in significant social and economic impacts. To the degree that designation, in combination with the NMFS consultation process, enhances and conserves EFH by minimizing adverse impacts, fisheries may benefit from higher production. In addition, healthier marine habitats may benefit other economic sectors, such as marine recreation and tourism.

Relationship between Short-Term Uses and Long-Term Productivity

The overall purpose of the amendment is to conserve, protect and restore fisheries and coastal environments and thus to enhance the long-term health of all living marine resources. The amendment will not include any short-term uses of the environment that may reduce long-term productivity.

Irreversible and Irretrievable Commitment of Resources

The amendment will not cause any irreversible or irretrievable commitment of resources as a result of its implementation. The amendment required the compilation of information on and preparation of maps of the general distribution and geographic limits of EFH for each life stage for specific managed species. This requirement may result in the conservation of natural resources.

Summary of Environmental Consequences

The amendment implemented the requirements of the Magnuson-Stevens Act to describe, identify, conserve and enhance EFH for the western Pacific region's FMPs. The establishment of a regional information base for making decisions about the management of fish habitat should improve coordination and consultation among Federal and State agencies and the Council in the management of EFHs. Implementation of the amendment should result in an improvement in the conservation and restoration of fish habitat and fish stocks, which should result in improved stability for the fishing industry.

Finding of No Significant Impact

Based on the information contained in the environmental assessment and other sections of this document, I have determined that the proposed alternative would not significantly affect the quality of the human environment, and, therefore, preparation of an environmental impact statement is not required under the National Environmental Policy Act or its implementing regulations. Therefore, a finding of no significant impact is appropriate.

______________________ ______________________

Rolland Schmitten Date

6.2 Paperwork Reduction Act

The Paperwork Reduction Act requires Federal agencies to minimize paperwork and reporting burdens whenever collecting information form the public. This amendment will not create any additional record-keeping and reporting requirements.

6.3 Coastal Zone Management Act

Section 307(c)(1) of the Coastal Zone Management Act of 1972 requires all Federal activities which directly affect the coastal zone be consistent with approved state coastal zone management programs to the maximum extent practicable.

6.4 Endangered Species Act

This amendment will not have any effect on any listed endangered or threatened species or their habitats.

6.5 Marine Mammal Protection Act (MMPA)

All fisheries in the western Pacific region are designated as Category 3, meaning that fishermen must report interactions with marine mammals, but they are not required to obtain exemption certificates in order to fish. This amendment does not require a MMPA category redesignation.

6.6 Regulatory Flexibility Act

In preparing this amendment the Council determined that no regulatory actions are necessary in order for its FMPs to be in compliance with the new provisions required by the Magnuson-Stevens Act. The information compiled for this amendment may be used as a basis for fishery management measures proposed in the future. While significant impacts on small businesses could result from future management actions, this amendment itself has no such effect. Therefore, a regulatory flexibility analysis was not prepared.

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Appendix 1
Fisheries Data Collection Systems in the Western Pacific Region

Hawaii

Any person who for commercial purposes takes marine life, whether caught or taken within or outside of the state, must first obtain a commercial marine license. Every holder of a commercial marine license must furnish to the Hawaii Division of Aquatic Resources (HDAR) a monthly catch report commonly referred to as the “C3” form.

Every commercial marine dealer must furnish to HDAR a monthly report detailing the weight, number and value of each species of marine life purchased, transferred, exchanged or sold and the name and current license number of the commercial marine licensee from whom the marine life was obtained.

Catches of bottomfish in the Northwestern Hawaiian Islands (NWHI) are reported separately to HDAR on the NWHI Bottomfish Trip Daily Log. Fishermen complete the Trip Sales Report after the fish are sold. HDAR staff monitor the Honolulu Harbor and Kewalo Basin docks on a daily basis to collect Daily Logs and Trip Sales Reports. The pole-and-line fleet submits the HDAR Aku Catch Report. Albacore troll vessels landing their catch in Honolulu are required to complete a HDAR Albacore Trolling Trip Report.

The National Marine Fisheries Service (NMFS) collects catch data from the Hawaii-based longline vessels through the Western Pacific Daily Longline Fishing Logbook. These vessels are also required to complete a HDAR Longline Trip Report. Data are also collected by NMFS observers deployed on longline vessels principally to record interactions with marine turtles.

Catch data from the NWHI lobster fishery is collected both by NMFS using the Daily Lobster Catch Report and by HDAR using the Crustaceans Trip Report Form.

Harvesters on the NMFS Daily Precious Coral Harvest Logbook record harvests of precious corals in Hawaii. Harvesters are also required by HDAR to complete a C3 catch report form.

Finally, NMFS administers a market-monitoring program. In a cooperative effort with HDAR, staff from both agencies visits the fish auctions administered by the United Fishing Agency (UFA) and obtain size frequency and economic data on pelagic fish and bottomfish being auctioned. NMFS staff collects data on one selected day each week, while HDAR staff collects data on every Monday.

American Samoa

Daily catches from longline fishing are recorded on the Western Pacific Daily Longline Fishing Logbook. Other fish catch data are collected through creel surveys administered by the Department of Marine and Wildlife Resources (DMWR). During the early 1980s interview data were only collected in the bottomfish fishery from commercial vessels. Since 1985, the Offshore Creel Survey on Tutuila has examined both commercial and recreational boat trip catches at five designated sites. For two weekdays and one weekend day per week, DMWR data collectors sample offshore fishermen between 0500 and 2100 hours. Two DMWR data collectors based on Tau and Ofu collect fishing data from the Manua Islands fleet.

Data on fish sold to outlets on non-sampling days or caught during trips missed by data collectors on sampling days are accounted for in a separate dealer invoice data collection system. A vessel inventory conducted twice a year provides data on vessel numbers and fishing effort.

Guam

An offshore creel survey program administered by the Division of Aquatic and Wildlife (DAWR) provides comprehensive estimates of island-wide catch and effort for all the major fishing methods used in commercial and recreational fishing. In 1982, the Western Pacific Fisheries Information Network (WPacFIN) began working with the Guam Fishermen's Cooperative Association to improve their invoicing system and obtain data on all fish purchases on a voluntary basis. Data from two other fish wholesalers were collected beginning in 1983 and continued until their closing in 1987. Another major fish wholesaler and several retailers who make purchases directly from fishermen have begun operating since then and are voluntarily providing data to WPacFIN using invoices ("trip tickets") provided by DAWR.

Northern Mariana Islands

Since the mid-1970s, the Northern Mariana Islands Division of Fish and Wildlife (DFW) has monitored the commercial fishery by summarizing sales ticket receipts from commercial establishments. DWF staff routinely distributes and collect invoice books from 80 participating local fish purchasers on Saipan, including fish markets, stores, restaurants, government agencies and roadside vendors.

In 1988, the DFW implemented a creel survey program to monitor the boat-based (offshore) fishery to provide comprehensive estimates of island-wide catch and effort for all the major fishing methods (trolling, spearfishing, handlining, bottomfishing and net-fishing) used in commercial and recreational fishing. The creel survey program was discontinued in 1996 due to logistical reasons.

Uninhabited Pacific Area Islands

Fish caught in the EEZ around Baker Island, Howland Island, Jarvis Island, Johnson Atoll, Kingman Reef, Palmyra Atoll and Wake Island by holders of Hawaii commercial marine licenses and landed in Hawaii are required to be reported on the C3 form. US longline vessels fishing in the US EEZ around these islands must complete the Western Pacific Daily Longline Fishing Logbook. Charter vessels based at Midway Island complete catch reports administered by the US Fish and Wildlife Service.

US purse seine vessels occasionally fish within the EEZ around the above islands. The purse seiners generally complete a South Pacific Regional Purse Seine Logsheet, although they are not required to. The logsheet program is designed and administered by the Secretariat of the Pacific Community (SPC) and the Forum Fisheries Agency (FFA). Catch and effort data collected from the logsheets are stored at the NMFS SW Regional Science Center and the SPC in New Caledonia. Observers are deployed on the purse-seine vessels to monitor compliance and to collect ancillary information such as bycatch.

Appendix 2
Fisheries Data Forms Used in the Western Pacific Region

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Appendix 3
Essential Fish Habitat Species Descriptions

1. BOTTOMFISH SPECIES

1.1 Bottomfish Habitat

Unlike the US mainland with its continental shelf ecosystems, the Pacific islands are primarily volcanic peaks with steep drop-offs and limited shelf ecosystems (Ralston 1979). Bottomfish are found concentrated on the steep slopes of deep-water banks of these islands. In the Hawaiian deep-sea handline fishery, 13 species of snappers and jacks and one species of grouper are commonly caught at depths of 60 to 350 m (Ralston and Polovina 1982). As noted in Amendment 2 of the Fishery Management Plan (FMP) for Bottomfish and Seamount Groundfish Fisheries, these depths have insufficient sunlight to support an abundance of coral or algae (calcareous or otherwise); however, some corals, particularly black coral (*Antipathes* spp.), have been observed at depths of 15 to 50 fathoms, which correspond to shallow bottomfish habitat.

The habitat of six of the most important Northwestern Hawaiian islands (NWHI) bottomfish tend to overlap, as indicated by the depth range at which they can be hooked. Even with this overlap, certain species are still more common at specific depths. As noted in Amendment 2 of the bottomfish FMP, adult bottomfish in the NWHI are found at depths of from 40 to 145 fathoms (Table 1).

Species	Hooking Depth Range (Fa)	Average
Opakapaka	30-110	70
Onaga	100-150	125
Hapu'upu'u	50-150	100
Butaguchi	40-100	70
Ehu	110-180	145
Uku	20-60	40

Table 1: Habitat depth range for dominant Northwestern Hawaiian Islands Bottomfish. Source: (Amendment 2 of bottomfish FMP).

In a five-year study of the bottomfish fishery resource of the Northern Mariana Islands and Guam, Polovina et al. (1985) found bottomfish species to be stratified by depth with three broad distributions located throughout the archipelago. Between 164 and 183 m, black trevally (*Caranx lugubris*), yelloweye opakapaka (*Pristipomoides flavipinnis*), pink opakapaka (*P. filamentosus*) and lehi (*Aphareus rutilans*) are common; between 183 to 201 m, yellowtail kalekale *(P. auricilla*), kahala (*Seriola dumerili*) and gindai (*P. zonatus*) are most abundant; and at depths of greater than 201 m, *Pristipomoides sieboldii* (pink kalekale), onaga (*Etelis coruscans*), ehu *(E. carbunculus*) and *Epinephelus sp* were the most abundant (Table 2).

Scientific Name	Mean Depth		
From 164 to 183 m	M	Fathoms	N
Caranx lugubris (black lugubris)	166	91	270
Pristipomoides flavipinnis (yelloweye opakapaka)	170	93	499
Pristipomoides filamentosus (pink opakapaka)	170	93	191
*Aphareus rutilans (*lehi*)*	174	95	81
From 183 to 201 m			
Pristipomoides auricilla (yellowtail kalekale)	188	102	1,166
Seriola dumerili (kahala)	196	107	47
Pristipomoides zonatus (gindai)	199	109	3,890
>201 m			
Epinephelus sp	214	117	38
Pristipomoides sieboldii (pink kalekale)	214	117	200
Etelis coruscans (onaga)	218	119	200
Etelis carbunculus (ehu)	225	123	950

However, depth alone does not assure satisfactory habitat. As noted in Amendment 2 of the bottomfish FMP, variations in catch rates along the same depth contour indicate that the quantity and quality of benthic habitat are also both important. The underwater habitat of bottomfish consists of a mosaic of sandy and rocky areas. In the NWHI the benthic topography varies dramatically from abrupt drop-offs associated with pinnacles and banks to gently sloping atolls.

Within their natural habitat, bottomfish populations are not evenly distributed but are found dispersed in a non-random, patchy fashion. As noted in the bottomfish FMP, adult bottomfish in the NWHI are found in habitats characterized by a hard substrate of high structural complexity. Areas of increased bottom complexity—such as pinnacles, drop-offs and other high relief, rocky substrate—are prime fishing grounds (Ralston 1979). In his study of the Penguin Bank in the Hawaiian Islands, Haight (1989) observed aggregations of up to 100 opakapaka *(Pristipomoides filamentosus)* and lehi (*Aphareus rutilans)* 2–10 m above high-relief coral bench substrate and in the vicinity of underwater headlands and promontories. Areas of high relief form localized zones of turbulent vertical water movement, which may increase the availability of prey (Haight et al. 1993).

The distribution of some species of deep-water snappers also appears to be closely related to current flow. Ralston et al (1986) found that the up-current side vs. the down-current side of Johnston Atoll supported higher densities of opakapaka. It is hypothesized that water flow may enhance food supplies in certain areas (Haight 1989; Parrish et al. 1997).

While bottomfish species are attracted to similar habitat, there appears to be negligible multi-species interaction (Ralston and Polovina 1982). Polovina (1987) found a weak predator-prey relationship among the species of the NWHI bottomfish complex. As noted in Amendment 2, the establishment of territorial strongholds by individual species may account for the low multi-species interaction. Amendment 2 also notes that variations are known to occur in the way different bottomfish utilize habitat.e.g., opakapaka are believed to migrate into shallower depths during the night hours; onaga are caught in considerably deeper water than other species of snappers and in association with abrupt relief zones, such as outcroppings, pinnacles and drop-offs; and groupers generally are much more sedentary than snappers and are more dependent on hard substrates. Haight (1989) found that niche overlap between species of deep-slope snappers on Penguin Bank, in terms of forage habitat and forage period, was reduced by the individual species' different depth and dietary preferences.

1.2 Bottomfish Yield

Bottomfish production off western Pacific islands is inherently limited because only a narrow portion of the ocean bottom satisfies the depth requirements of most bottomfish species. Since bottomfish are typically found concentrated in the steep drop-off zones around the 100-fathom isobath, the length of the 100-fathom isobath is commonly used as an index of bottomfish habitat (Polovina, 1985).

Bottomfish yield estimates in the western Pacific bottomfish fishery are usually estimated on the basis of yield per nautical mile of the 100-fathom contour that surrounds an island or bank (Polovina, 1985). Beginning in 1980, the National Marine Fisheries Service (NMFS) conducted a five-year resource assessment of the fishery resources of the Mariana archipelago. This resource assessment was designed to quantify the sustainable yield and distribution of the fishery resources, including bottomfish, of Guam and the Northern Mariana Islands. A systematic fishing survey of the bottomfish resources at depths of 125–275 m of 22 islands and banks in the Mariana archipelago was conducted (Polovina et al. 1985). In this study Eteline snappers, particularly *Pristipomoides zonatus*, *P. auricilla*, and *Etelis carbunculus*, dominated the catch (Dalzell and Preston 1992). In addition, bathymetric surveys were conducted at 11 banks and islands where the bathymetric data were insufficient to conduct fishery resource assessment work (Polovina et al. 1985). As part of this resource assessment, a depletion experiment was carried out at Pathfinder Reef, a seamount west of the main islands. The results of this experiment were used to estimate the unexploited biomass at 288 tons for the archipelago. The estimated yield of 403 lb. of bottomfish per year per nautical mile of 100-fathom isobath appears to be representative of the maximum sustainable yield (MSY) that can be expected from bottomfish resources of tropical islands in the Pacific, as noted in Amendment 1 of the bottomfish FMP. Applying this figure to the estimated length of the bottomfish habitat in American Samoa and Guam, an estimate of MSY of bottomfish can be derived for each area. As noted in Amendment 1 of the bottomfish FMP, American Samoa, with approximately 196 nautical miles of 100-fathom isobath, can expect a MSY of

79,000 lb per year, and Guam, with approximately 138 nautical miles of 100-fathom isobath, can expect an MSY of 56,000 lbs per year (Tables 3 and 4).

Island Area	Approximate Length of 100-fathom Isobath, nm (km)
American Samoa	196 (313)
Guam	138 (255)
Main Hawaiian Islands	997 (1,846)
Northwestern Hawaiian Islands	1,231 (2,280)

Table 3: Index of bottomfish habitat. (Source: Amendment 1 of bottomfish FMP).

Island Area	Approximate Length of 100-fathom Isobath (nm)	Approximate Maximum Sustainable Yield (MSY) of Bottomfish (lbs)
American Samoa and Offshore Banks	196	78,988
Guam and Offshore Banks	138	55,614

Table 4: Extent of Approximate Bottomfish Habitat and Yield for American Samoa and Guam. (Source: Amendment 1 to Bottomfish FMP)

Based on remote operational vehicle (ROV) and manned submersible observations, maximum densities of deep-water snappers on Penguin Bank were calculated to be 1.06 fish/m^2 to 1.37 fish/m^2 (Haight 1989).

1.3 Biological Information

As noted in Amendment 3 of the bottomfish FMP, bottomfish resources of the western Pacific region can be divided into three broad classes relative to their vertical distribution on the islands' shelves and slopes: the reef fish complex, occupying shallow reefs, bays and lagoons; the bottomfish complex, inhabiting the outer shelf and deep slopes; and the groundfish complex, associated with seamount summits. The bottomfish complex includes at least 65 species of four families: snapper (Lutjanidae), groupers (Serranidae), jacks (Carangidae) and emperor fish (Lethrinidae). These species are primarily caught by hook-and-line fishing gear. About 20 of these species are landed in substantial quantities.

Species composition and relative abundance of bottomfish management unit species (BMUS) in the western Pacific have regional variations. For example, Uchiyama and Tagami (1984) observed considerable variation throughout the NWHI; the most notable trend was predominance of opakapaka at French Frigate Shoals, Brooks Banks and Necker Island and of ehu (*Etelis carbunculus*) west of Lisianski Island. The principal species of NWHI bottomfish and seamount groundfish are shown in Table 5.

As noted in Amendment 2 of the FMP, although 15 bottomfish species are included in the management unit, four species account for 95% of the 1986 landings of NWHI bottomfish (Table 6).

In a five-year study of the bottomfish fishery resource of the Northern Mariana Islands and Guam, Polovina et al. (1985) found gindai (*Pristipomoides zonatus*) accounted for 51.2 percent of the total catch, while gindai, ehu and yellowtail kalekale (*P. auricilla*) accounted for 79.1 percent of the total bottomfish catch.

Scientific Name	Common Name	American Samoa	Guam/ NMI	Hawaii
Bottomfish				
Aphareus rutilans	red snapper/silvermouth	palu-gutusiliva	maraap tatoong	lehi
Aprion virescens	gray snapper/jobfish	asoama	tosan	uku
Caranx ignobilis	giant trevally/jack	sapoanae	tarakito	white ulua/pauu
C. lugubris	black trevally/jack	tafauli	trankiton attilong	black ulua
Epinephelus fasciatus	blacktip gouper	fausi	gadao matai	
E. quernus	sea bass			hapuupuu
Etelis carbunculus	red snapper	palu-malau	guihan boninas	ehu
E. coruscans	red snapper	palu-loa	onaga	onaga
Lethrinus amboinensis	ambon emperor		mafuti/lililok	
L. rubrioperculatus	redgill emperor	filoa-paoomumu	mafuti tatdong	
Lutjanus kasmira	blueline snapper	savane	sas/funai	taape
Pristipomoides auricilla	yellowtail snapper	palu-iusama	guihan boninas	yellowtail kalekale
P. filamentosus	pink snapper	palu-enaena	guihan boninas	opakapaka
P. flavipinnis	yelloweye snapper	palu-sina	guihan boninas	yelloweye opakapaka
P. seiboldi	pink snapper		guihan boninas	kalekale
P. zonatus	snapper	palu-sega	guihan boninas/gindai	gindai
Pseudocaranx dentex	thicklip trevally		terakito	butaguchi/pig ulua
Seriola dumerili	amberjack		guihan tatdong	kahala
Variola louti	lunartail grouper	papa	bueli	
Seamount Groundfish:				
Beryx splendens	alfonsin			kinmedai (Japanese)
Hyperoglyphe japonica	ratfish/butterfish			medai (Japapanese)
Pseudopentaceros richardsoni	armorhead			kusakari tsubodai (Japapanese)

Table 5: Bottomfish Management Unit Species (BMUS)

Local Name	Common English Name	Percent of 1986 Landings of NWHI Bottomfish
Opakapaka	pink snapper	36.9
Onaga	longtail snapper	13.3
Hapuupuu	seabass	25.9
Butaguchi	thick-lipped trevally	19.6
Ehu	squirrelfish snapper	3.7
Uku	gray snapper	1.0

Table 6: Principal species of NWHI bottomfish and their percentages of the 1986 NWHI bottomfish lands (Source: FMP for Bottomfish and Seamount Groundfish Fisheries)

1.4 Life History

Despite the importance of bottomfish and seamount groundfish species in the western Pacific, the life histories of most of the species are not well known.

1.4.1 Eggs and larval stages

There have been very few taxonomic studies of the eggs and larval stages of snappers (lutjanids) and groupers (epinepheline serranids), and, currently, very few larvae can be identified to species. Leis (1987) provide a detailed review of the early life history of tropical groupers (Serranidae) and snappers (Lutjanidae), which includes the following information: Grouper and snapper larvae tend to be more abundant over the continental shelf than in oceanic waters. Exceptions are the larvae of the subfamily eteline lutjanid, which are generally more abundant in slope and oceanic waters than over the continental shelf. During the day, grouper and snapper larvae tend to avoid surface waters. At night they are more evenly distributed vertically in the surface water column. During the winter month’s larvae of most species are much less abundant. Very little is known about the food habits of serranid and lutjanid larvae. What is known is based on limited laboratory data. More research is needed on all aspects of the early life history of snappers and groupers, including feeding, growth and survival; ecology of early life history stages around oceanic islands; year-to-year variation in spatial and temporal patterns; and return of young stages to adult habitat from the pelagic larval habitat.

1.4.2 Juvenile

During 1988, the NOAA Fisheries’ Honolulu Laboratory initiated an investigation to identify the habitat requirements of juvenile snappers in the Hawaiian Islands. The preliminary investigations have demonstrated the presence of juveniles of both recreational and commercially important snappers (*Pristipomoides filamentosus*, *Aprion virescens*, *Aphareus rutilans*) in a habitat relatively close to the fishing grounds for adults but not where the adults congregate. Although the boundaries of the habitat and the characteristics that make it attractive to juveniles remain to be defined, initial results indicate juveniles occupy a flat, open bottom of primarily soft substrate in depths ranging from 40 to 73 m. There is strong evidence that juvenile snappers utilize habitat that is quite different then the adults (Parrish, 1989; Haight, 1989; Moffitt and Parrish, 1996; Parrish et al., 1997). Parrish (1989) identified an aggregation of juvenile *A. virescens* and *P. filamentosus* "in 30 to 80 m of water over soft, flat bottom substrate." The occurrence of juvenile snappers in relatively shallow water and featureless bottom habitat indicates the need to reconsider the importance of an area of ocean bottom previously thought to be of minimal importance as fishery habitat.

1.4.3 Adults

The habitat utilization patterns of adult bottomfish are described in detail in section 1.1 and the following species profiles.

1.4.4 Forage and prey (feeding habits and principal prey)

There have been very few food habit studies of groupers and snappers that have documented the depth at which feeding occurs. Without data on feeding depths it is difficult to identify the specific depth range that constitutes a species-feeding habitat. Food habit studies of deep-water snappers are especially difficult because gut contents are frequently lost due to regurgitation when specimens are bought to the surface from great depths. Parrish (1987) provides a detailed review of the trophic biology of snappers and groupers, which includes the following information:

The reported depth range of many species of snappers and groupers is very great and often changes with age. A small number of snapper species and a considerably larger list of groupers appear to be restricted to feeding almost entirely in waters a few tens of m deep. By contrast, a good many snappers and a very few groupers appear to feed almost entirely in deep water down to depths of 400–500 m. Of the remaining fishes for which some information is available, many species of both families seem to cover a range of intermediate depths. Several occur very shallow as well as fairly deep, while others appear limited to an intermediate range. In both families there are a few species that occur shallow enough, commonly enough, to distinguish them from the deep-water group, but they are also commonly caught considerably deeper than the intermediate group (150–200m) (Table 8).

Shallow (To a few tens of m)	**Intermediate** (Shallow to over 100m)	**Mixed** (Intermediate to deep)	**Deep** (Mostly over 100 m to 500 m).
[1]*Aprion virescens* (uku)	*Lutjanus kasmira* (blueline snapper)		*Etelis carbunculus* (ehu)
			Etelis coruscans (onaga) *Pristipomoides auricilla* (yellowtail kalekale) *Pristipomoides filamentosus* (opakapaka) *Pristipomoides flavipinnis* (yelloweye opakapaka) *Pristipomoides sieboldii* (kalekale)

Shallow (To a few tens of m)	**Intermediate** (Shallow to over 100m)	**Mixed** (Intermediate to deep)	**Deep** (Mostly over 100 m to 500 m).
			Pristipomoides zonatus (gindai) *Epinephelus quernus* (hapuupuu)

Table 8: Likely depth ranges for major feeding of snapper and grouper management unit species. Source: (Parrish 1987).

Based on the review of the available literature, Parrish (1987) concluded that snappers engage in widespread, nocturnal foraging; groupers feed at all times of day, but particularly near dusk and dawn; and most species of groupers take most of their prey at or very close to the bottom. The food habits of very young juvenile snapper and grouper are often different from those of adults.

Both groupers and snappers are omnivorous, opportunistic carnivores. Their diets include a wide range of food items dominated by fish, crabs, shrimp and other benthic crustaceans, especially stomatopods and lobsters. Cephalopods are another common diet component, especially for snappers, which also eat large plankton, including particularly pelagic urochordates and gastropods. Planktonic forms of prey are surprisingly important for snappers, both in bulk consumed and frequency of occurrence, especially for many deep-water species. Major planktonic food items include pelagic urochordates (Pyrosomida, Salpidae, and Dolioda) and pelagic gastropods (pteropods and heteropods) In most, but not all cases, these planktonic food items occur in species believed to forage somewhat above the bottom. While surprisingly common in the diets of snappers, planktonic animals have not been reported in the diets of groupers. As a whole, the diet of snappers is considerably broader than that of groupers and includes a wider range of non-crustacean benthic organisms.

1.4.5 Reproductive biology

Grimes (1987) provide a detailed review of the reproductive biology of the Lutjanidae. In the lutjanids, spawning take place at night, and is apparently timed to coincide with spring tides at new and full moons. "Courtship behavior culminates in an upward spiral swim, with gametes released at the apex," Grimes observers. "Many features of the reproductive biology of lutjanids (e.g., spawning site preference, spawning seasonality, lunar periodicity and spawning behavior) appear to be a strategy to introduce gametes into an environment where predation is relatively less intense, "Grimes adds. However, the strategy must also assure that young juveniles are returned to suitable, but patchy habitat for settlement. *Aprion virescens* feeds high in the water column, i.e., in shallow water, as well as at greater depths near the bottom.

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1.5 Life Histories and Habitat Descriptions for Bottomfish Species

1.5.1 Habitat description for *Aphareus rutilans* (red snapper, silvermouth)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Aphareus rutilans is a member of the family Lutjanidae and the subfamily Etelinae and is one of two species of snappers found in the genus *Aphareus*. The English common name of this species is red snapper or silvermouth. In American Samoa it is known as palu-gutusiliva; in Hawaii, lehi; in Guam and Northern Mariana Islands, maraap tatoong.

Allen (1985) describes the geographical distribution of *A. rutilans* as widespread throughout the tropical Indo-Pacific Ocean. It is found from East Africa in the west to the Hawaiian Islands in the east and from southern Japan southward to Australia. It inhabits hard rocky bottoms and coral reefs at depths of 6 m to at least 100 m and is typically found singularly or in small groups, well above the bottom.

According to Allen, the medium-sized snapper is reported to reach a maximum length of about 80 cm. The reported life span of snappers ranges between 4 and 21 years, with larger species generally tending to have longer life spans of between 15 to 20 years. Lutjanids reach sexual maturity when they've reached between approximately 43% and 51% of their maximum total length.

The lutjanids are dioecious (separate sexes) and display little or no sexual dimorphism in color patterns or physical structure (Allen 1985). At Vanuatu, spawning reportedly occurs during spring and summer but with a peak activity occurring during November and December. Lutjanids are batch spawners, with females spawning several times over the course of spawning season.

A. rutilans is an important commercial species in the island areas of the Indo-Pacific region and is one of the principal target species in the Hawaiian deep-slope handline fishery, Allen notes. It is caught primarily by handlines or bottom longlines, he adds.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987), lutjanids eggs typically are less than 0.85mm in size and hatch in 17–36 h depending on water temperature.

Little is known about this species larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. The duration of the pelagic phase of lutjanids has been estimated to range from 25 to 47 days (Leis 1987). Snapper larvae are subject to advection by ocean currents (Munro 1987). It is thought that the pelagic phase of eteline lutjanids, such as *A. rutilans*, is longer than that of *Lutjanus* spp., and size may be a more important factor than age in determining when larval settlement occurs in lutjanids (Leis 1987).

Juvenile

There is virtually no information available concerning the life history and habitat requirements of the juveniles of this species. Parrish (1989) found that the diet of juvenile *Pristipomoides filamentosus* (red snapper or opakapaka), an eteline snapper, consists primarily of small crustaceans. Other prey items include juvenile fish, cephalopods, gelatinous plankton and fish scales.

Adult

Deep-water snappers, such as *A. rutilans*, are found on the steep slopes and deep-water banks of Pacific islands. Adults aggregate near areas of high bottom relief (Parrish 1987). Mixed groups of 50–100 individual snappers are known to aggregate above high relief structures.

The diets of deep-water snappers, such as *A. rutilans* are poorly understood. Parrish (1987) list of prey items include pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs. He reports that snappers feed mostly at night and forage over a wide area, but notes that the depths at which snappers feed are not well documented. Most of the fishing effort for deep-water snappers, such as *A. rutilans* occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago (Ralston and Polovina 1982).

Essential Fish Habitat: Deep-water bottomfish complex (100-400 m)

Habitat description for *Aphareus rutilans* (red snapper, silvermouth)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17–36 h depending on water temperature.	25 to 47 days (Leis 1987).	UK	4 and 21 years
Diet	N/A	Unknown (UK)	UK	Pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs.
Distribution: General and Seasonal	UK	UK		Widespread throughout the tropical Indo-Pacific Ocean.
Water Column	Pelagic	Pelagic	Demersal	Found on the steep slopes and deepwater banks of Pacific islands.
Bottom Type	N/A	N/A	UK	Inhabits hard rocky bottoms Adults aggregate near areas of high bottom relief
Oceanic Features	Subject to advection by ocean currents	Subject to advection by ocean currents	N/A	N/A

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1.5.2 *Aprions virescens* (Gray snapper, jobfish, uku)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands..

Aprion virescens is an eteline snapper in the family Lutjanidae. English common names for this species include jobfish and gray snapper. The Hawaiian name for the species is uku.

A. virescens is widely distributed throughout the Indo-Pacific region from Hawaii to East Africa (Druzhinin 1970, Tinker,1978).

It comprises a major portion of the total bottomfish caught in Hawaii, second only to the *Pristipomoide filamentosus* (red snapper, or opakapaka) in total landings. According to the *1996 Annual Report Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*, reported landings in 1996 for *A. virescens* was approximately 49,000 lb from the MHI and an additional estimated 28,000 lb from the NWHI, or roughly 11% of the total reported BMUS landings in the Hawaiian Islands that year (WPRFMC 1997). Kramer (1986) reports that *A. virescens* is caught only at Nihoa Island, Brooks Banks, St. Rogatien Bank and Midway Islands in the NWHI. However, in a survey of the nearshore fishery resources of the NWHI, uku were also observed at Necker Island, French Frigate Shoals and Pearl and Hermes Atolls (Okamoto and Kanenaka 1983).

In American Samoa *A. virescens* is the fourth most important species in terms of total weight landed (11%) based on estimated total 1996 bottomfish landings published in the *1996 Annual Report Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*. In Guam, it was the third most abundant species caught in a 1995 creel survey of the bottomfish resources of Guam. According to the 1996 annual report, *A. virescens* made up approximately 10% of the total reported BMUS landings in Guam in 1996. The species is much less abundant in the Northern Mariana Islands. In a fishery assessment of the deep-water bottomfish in the Mariana archipelago, it comprised less than one tenth of 1 percent of the total catch (Polovina 1987).

Ralston and Polovina (1982) report that most of the fishing effort for dee-pwater bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago. They also state that a rough estimate of the total amount of bottomfish habitat can be calculated by measuring the 100-fathom isobath that surrounds an island or bank. They estimate that 1,025 nmi of 100-fathom isobath surrounds the MHI. Dalzell and Preston (1992) estimate that American Samoa has 143.3 nm of 100-fm isobath, and the Northern Mariana Islands and Guam collectively have 485 nmi of 100-fathom isobath.

It has been shown that the distribution of deep-water snappers is non-random, with large aggregations form near areas of prominent relief features such as headlands and promontories (Ralston et al. 1986). Haight (1989) reports that if high relief, hard substrate is used as the criterion of habitat suitability for deepwater snappers only a 14% of the total area of Penguin Bank would be potential habitat. Based on the results of a depletion experiment carried out at pathfinder reef in the Northern Mariana Islands, an estimation for exploited biomass of 2.0 ton/nautical of 100-fathom isobath was calculated (Polovina et al. 1985, Polovina and Ralston 1986).

Eggs and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987) lutjanids spawn small, pelagic, spherical, eggs that are typically less than 0.85 mm in size and that hatch in 17–36 hours depending on species and water temperature.

Very little is known about this species's larval life history stage. The relatively low abundance of lutjanid larvae in plankton samples makes ecological studies of them difficult. Hoss et al. (1986, in Sale 1991) found that lutjanid larvae were most abundant above 40 m in Caribbean Sea. Leis (1987) describes newly hatched lutjanid eggs as typical of other pelagic larvae; they have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. The duration of the pelagic phase of lutjanid has been estimated to range from 25 to 47 days, Leis states. He also notes that the pelagic phase of eteline lutjanid, such as, is longer than that of *Lutjanus* spp and that size may be more important than age in determining when larval settlement occurs.

Juvenile

There is very little information available concerning the distribution and habitat requirements of the juvenile stage of this species. Parrish (1989) observed a dense aggregation of juvenile *A. virescens*, *Pristipomoides filamentosus* (pink snapper, or opakapaka) and *Aphareus rutilans* (red snapper, sivermouth, or lehi) offshore of Kaneohe Bay on the island of Oahu in an area of very low relief, at depths of 65–100 m. The predominant species collected at this site was *P. filamentosus*, of which the greatest abundance was located in an area comprised of soft, fine clay-silt sediments. In contrast, five juvenile uku were caught at depths of 40 m where the bottom substrate was comprised of hard, flat coarse sand, covered with *Halimeda* algae.

The flat, featureless habitat apparently favored by juvenile snappers is very different from the high relief areas preferred by adults of the family. It is thought that the habitat preferred by the juvenile may provide the advantage of reduced predation pressure and lessened interspecific competition. It is believed that areas of uniform sediment type are an important substrate feature for juvenile snapper (Parrish et al. 1997).

<u>Adult</u>

In Guam, *A. virescens* are found along the outer reef slopes, in deep channels and in shallow lagoons at depths of 3–180 m (Amesbury and Myers 1982). Druzhinin (1970) reported *A. virescens* at depths as great as 150 fathoms. Talbot (1960) reported that *A. virescens* was more abundant in shallow water over coral reefs along the coast of East Africa.

Haight (1989) found the diet of *A. virescens* on Penguin Bank in the MHI to include fish (89%), larval fish (6%), planktonic crustaceans (1%), shrimp (3%) and crab (1%). Talbot (1960) reported the diet of *A. virescens* on the coast of East Africa to consist of fish (49%), plankton (17%), cephalopods (14%), nonplanktonic crustaceans (12%) and others (8%). Unlike most other deepwater species of lutjanids, *A. virescens* has feeding habits that do not seem to be constrained by substrate association (Parrish 1987). The species forages throughout the water column, feeding high in the water column as well at greater depths (Ralston 1979, Parrish 1987). *A. virescens* is the only lutjanid that is regularly caught at or near the surface with a lure (Kramer 1986). Haight (1989) found the greatest CPUE (fish/line-h) at depths of 50–100 m on Penguin Bank in the MHI. Haight (1989) reports that *A. virescens* feed during daytime hours. The landings for this species are seasonal. In Hawaii, the majority of the landings are made June–December (Ralston 1979, Haight 1989).

A. virescens reach sexual maturity at approximately 438 cm (SL) (Grimes 1987). Lutjanid species associated with islands obtain sexual maturity at a relatively larger size than continental species. Likewise, deepwater species mature at a relatively larger size than shallow water species (Grimes 1987). There is a consistent difference between percentage of maximum length and when sexual maturity is obtained between continental and insular species. Amesbury and Myers (1982) report that uku in Palau form large spawning aggregations January–May on the outer reef slope on or just after a new moon. In Hawaii, *A. virescens* spawn during the summer months (Ralston 1979).

<u>Essential Fish Habitat</u>: Shallow-water species complex (0-100 m)

Species: *Aprions virescens* (Gray snapper, jobfish, uku)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17–36 h incubation time depending on the species and the water temperature (Leis 1987)		No information available	
Diet	N/A	No information available	(No information available for this species)	Fish (89%), larval fish (6%), Planktonic crustaceans (1%), shrimp (3%) and crab (1%), (Haight 1989).
Distribution: General and Seasonal	*Aprion virescens* form large spawning aggregations in Palau* Spawning in lutjanids typically occurs at night during spring tides (new moon and full moon) (Grimes 1987).			
Location			40 m, hard, flat, course sand bottoms (Parrish 1989)	
Water Column	Pelagic	Pelagic, lutjanid larvae were found to be most abundant above 40 m in the Caribbean Sea (Hoss et al. 1986).		Demersal
Bottom Type	N/A	N/A	Hard, flat, course sand bottom	
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents (Munro 1987	Lutjanid larvae are subject to advection by ocean currents (Munro 1987)	It is thought that distribution of juvenile snapper within its preferred habitat type may be closely related to water flow	

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and seamount groundfish fisheries of the western Pacific region, 1995 annual report. Honolulu: WPRFMC.

1.5.3 Habitat description for large jacks: *Caranx ignobilis* (giant trevally/jack); *Pseudocaranx dentex* (thick-lipped trevally, or butaguchi); *Seriola dumerili* (greater amberjack, or kahala); *Caranx lugubris* (black trevally/jack)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Because of the great similarity in habitat utilization patterns, a single, general habitat profile has been prepared for the following closely related BMUS: *Caranx ignobilis* (giant trevally); *Pseudocaranx dentex* (thick-lipped trevally, or butaguchi); *Seriola dumerili* (greater amberjack, or kahala); *Caranx lugubris* (black trevally/jack). Where available information has been provided on a species-specific level.

Large carangids, or jacks, form an important component of shallow water reef and lagoon fish catches throughout the Pacific Islands The species are found distributed throughout tropical and subtropical waters of the Indo-Pacific region in shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts, notes Sudekum et al. (1991). Despite their importance to fisheries, little is known about the basic biology and habitat requirements of the large jacks, the authors add.

Caranx ignoblis is one of the most abundant species of jacks found in Hawaii, (Sudekum et al. 1991). Seki (1986) notes that *Pseudocaranx dentex* is rarely caught in the MHI, but is abundant in the NWHI where it is found at depths of 18–183 m. In addition to living on deeper reef slopes and banks, *P. dentex* can also be found in near-shore areas in large schools of 200–300 fish, Seki observes. *Seriola dumerili* is commonly found inhabiting the inner reefs and outer slopes of island shelves to depths of 250 m (Humphreys 1986). It has been observed at depths of up to 335 m (Myers 1991, Ralston et al. 1986). *Caranx lugubris* occurs singularly or in small groups on offshore banks and along the steep outer reef slopes at depths of 12 to 354 m (Myers, 1991). This circumtropical species appears to be confined to clear, offshore waters at depths of 25 to 65 m (Smith and Heemstra, 1986). *C. lugubris* is the most common carangid taken from offshore banks in the Marianas.

Jacks are highly mobile, wide-ranging predators that travel throughout the water column from the surface to depths of 250 m, although they are closely more affiliated with demersal habitats and feeding on benthos (Uchida and Uchiyama 1986, Sudekum et al. 1991).

Sudekum et al (1991) found that *C. ignoblis* reached sexual maturity at about 3.5 years (60 cm). *C. ignoblis* is the largest of the jacks found in the Indo-Pacific region and may obtain a total weight of over 50 kg with a lifespan in excess of 15 years (Lewis et al. 1983). *S. dumerili* reaches sexual maturity at about 54 cm, when it is between 1 and 2 years old (Kikkawa and Everson 1986, Uchida and Uchiyama 1986). *C. lugubris* reach sizes of up to 85 cm (Randall et al., 1990).

The sex ratio of females to males for *C. ignoblis* in Hawaii was slightly skewed in favor of females—1:1.39 (Sudekum et al. 1991). In contrast, Lewis et al. (1983) report a sex ratio in favor of male *C. ignoblis* of nearly 2:1 in Fiji.

In Hawaii, peak spawning for *C. ignoblis* occurs between May and August. Gravid fish of are found between April and November in the NWHI (Sudekum et al. 1991). In Fiji, Lewis et al. (1983) found that a fairly brief spawning period occurs from October to December, with peak activity in late October to early November. Johannes (1981) reports that *C. ignoblis* spawns in pairs within larger aggregations during new and full moon events. Myers (1991) reports that *C. ignoblis* gather to spawn on offshore banks and shallow seaward reefs. Humphreys (1986) reports that in the NWHI, *S. dumerili* spawn throughout the year with peak activity occurring in April.

Jacks are taken principally by deep-sea handline gear as well as traps (Seki 1986). As commercial landing data for carangids are often combined, accurate catch data for individual species are usually not available. In American Samoa, Guam and the Northern Mariana Islands jacks as a group account for between 3% and 8% of the reported bottomfish landings. Landings of jacks in Guam comprise mainly a mix of *C. ignoblis* and *C. malampygus* (WPRFMC 1997). *C. lugubris* is an important food fish in the Marianas despite concerns about ciquatera (Myers, 1991).

S. dumerili is nowadays landed in insignificant amounts in Hawaii but used to be an important component of bottomfish landings in Hawaii. The decline in landings is due principally to its association with ciguatera intoxications and a ban on commercial sales of this species (Uchida and Uchiyama 1986). *P. dentex* accounts for approximately 15% of the total catch in the NWHI bottomfish fishery (WPRFMC 1997).

<u>Egg and Larval Distribution</u>

The available literature describing the egg and larval stages of tropical marine fish is exceedingly sparse. According to Miller et al. (1979), the available information demonstrates that carangid larvae are common in the near-shore waters of Hawaii. Caragnid eggs are planktonic, spherical and 0.70-1.3 mm in diameter (Laroche et al., 1984; Miller et al. 1979). One to several oil globules are usually present (Laroche et al., 1984). Caragnid eggs hatch in 24 to 48 hours after spawning at water temperatures of 18 to 30 C° (Laroche et al., 1984). The identification of carrangid eggs to even the family level is frequently impossible because their similarity in size and appearance to many other marine fishes (Laroche et al., 1984).

Carangid larvae are relatively small, 1.0 to 2.0 mm, at hatching (Laroche et al., 1984). Larvae have a relatively large yplk sac and possess an oil globule at the anterior end of the sac (Laroche et al., 1984). The lack of diagnostic morphological features makes it difficult to identify newly hatched carangid larvae to even the family level (Laroche et al., 1984).

Miller et al. describe *Seriola* sp. larvae as moderately deep-bodied and large-headed and possessing well-developed preopecular spines. In a survey of larval distribution in near-shore waters of Hawaii, *Seriola* sp. were found to be relatively uncommon, the authors add.. The researchers also found that more *Seriola* sp. larvae were taken in summer than in winter, although not significantly. They also found that *Seriola* sp. larvae were more common in offshore than in near-shore tows. The early life history of *C. lugubris* is poorly known.

<u>Juvenile</u>

Juvenile *C. ignoblis* are often found in near-shore and estuarine waters (Lewis et al. 1983) and in small schools over sandy inshore reef flats (Myers 1991).

There a few food habit studies available for the genus *Seriolla*. The feeding habits of a *S. quinqueradiata*, a related species, indicates that juveniles prey on the larvae and juveniles of Mullidae, Engraulidae, Scomberesocidae and planktonic crustaceans.

<u>Adult</u>

C. ignoblis is predominantly piscivorus in itsr diet, fish comprising >90% of its diets(Sudeum et al. 1991, Parrish et al. 1980). This fish also preys on crustaceans, gastropods and cephalopods. Sudekum et al. (1991) found that the diet of *C. ignoblis* included abundant (13.6%) parrotfish (Scaridae), as well as roundscads or opelu, wrasses (Labridae), bigeyes (Priacanthidae) eels (Muraenidae, Congridae), cephalopods and crustaceans (crabs, shrimp and lobsters).

The predominance of reef fishes in the diet of *C. ignoblis* strongly suggests that shallow-water reef habitats are of prime importance as foraging habitat for large jacks. However, the occurrence of small pelagic fish such as roundscads and squid in the diets of these species diets indicates that time is also spent foraging in the water column (Sudekum et al. 1991). *C. ignoblis* appears to be primarily a nocturnal feeder (Sudekum et al. 1991, Okamoto and Kawamoto 1980) It has been estimated that *C. ignoblis* along with *C. melampygus*, another large jack may annually consume as much as 30,000 mt of prey at French Frigate Shoals in the NWHI (Sudekum et al. 1991).

S. dumerili is an opportunistic bottom feeder, with primary prey items comprising fishes, eels, groupers (Serranidae), bigeyes, crustaceans (crabs and shrimps) and octopus (Seki 1986, Humphreys 1980). Humphreys (1986) observes that *S. dumerili* diet in the NWHI is includes bottom-associated prey and octopus while in the MHI the primary prey items are pelagic species, such as roundscads. There is a significant shift in the diet of *S. dumerili* from cephalopods to fish as it increases in weight (Humphreys 1980).

All species of jacks may range throughout the water column, but they are associated primarily with demersal habitat.

<u>Essential Fish Habitat</u>: Shallow-water species complex (0-100 m)

Habitat description for large jacks

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 to 48 hours after spawning at water temperatures of 18 to 30 C◦	In Hawaii, *Seriola* sp. larvae are more common in offshore than in near-shore tows. The early life history of *C. lugubris* is poorly known.	*C. ignoblis* reached sexual maturity at about 3.5 years (60 cm). *S. dumerili* reaches sexual maturity at about 54 cm, when it is between 1 and 2 years old	*C. ignoblis* lifespan in excess of 15 years
Diet	N/A	No information available	There is a significant shift in the diet of some species of jacks from cephalopods to fish they increase in age	Predominantly piscivorus, fish comprising >90% of its diets. Also preys on crustaceans, gastropods and cephalopods, eels. Shallow-water reef habitats are of prime importance as foraging habitat for large jacks. Time is also spent foraging in the water column.
Distribution: General and Seasonal		In Hawaii, *Seriola* sp. larvae were taken in summer than in winter, although not significantly.	Often found in near-shore and estuarine waters and in small schools over sandy inshore reef flats	Found distributed throughout tropical and subtropical waters of the Indo-Pacific region in shallow coastal areas and in estuaries and on reefs, the deep reef slope, banks and seamounts
Water Column	Pelagic	Pelagic	bentho-pelagic	bentho-pelagic, All species of jacks range throughout the water column, but they are associated primarily with demersal habitat.
Bottom Type	N/A	N/A	Jacks are found over a wide variety of bottom type, shallow-water reef habitats are prime foraging habitat	Jacks are found over a wide variety of bottom type, shallow-water reef habitats are prime foraging habitat
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Bottomfish and seamount groundfish fisheries of the western Pacific region, 1996 annual report. Honolulu: WPRFMC.

1.5.4 Habitat description for *Epinephelus fasciatus* (blacktip grouper)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Epinephelus faciatus is a member of the Serranidae family, the groupers. The English common name of species is blacktip grouper. In American Samoa it is known as fausi; in Guam and Northern Mariana Islands it is gadao matai.

According to Heemstra and Randall (1993) *E. fasciatus* is a common worldwide with distinguishable populations in six areas: 1) Western Pacific, 2) Pacific Plate islands, 3) Marquesas Islands, 4) Japan, 5) Western Australia, and 6) Indian Ocean and Red Sea. In the Pacific, it is found from the Pitcairn Islands in the east to Australia in the west and as far north as Japan and Korea. In the Indian Ocean, this species ranges from the Red Sea to Western Australia. It is not found in the Hawaiian Islands.

Heemstra and Randall state that *E. fasciatus* inhabit coral reefs and rocky bottom substrate from the shore to a depth of 160 m. In Madagascar, where i t is one of the most abundant serranids found, it inhabits depths of 20 to 45 m.

The authors go on to say that, except for occasional spawning aggregations, most species of groupers are solitary fishes with a limited home range. Based on the results of tagging studies, it has been found that serranids are resident to specific sites, often residing on a particular reef for years.

Based on the available data, groupers appear to be protogynous hermphrodites. Heemstra and Randall note that, after spawning for one or more years, the female undergoes sexual transformation, becoming male.

According to the authors, some species of serranids spawn in large aggregations, others in pairs. Individual males may spawn several times during the breeding season. Some species of groupers are known to undergo small, localized migrations, of several km to spawn.

Because of its distribution and abundance in shallow waters, *E. faciatus* is an important food fish throughout its geographic range. According to Heemstra and Randall, the primary fishing gear types used to take this species includes hook-and-line, gill nets, spears, and traps.

Egg and Larval Distribution

According to Heemstra and Randall, serranid larvae are distinguishable by their “kite-shaped” bodies and highly developed head spination. The pelagic, fertilized eggs of *E. faciatus* are spherical and transparent and range in size from 0.70 to 1.20 mm in diameter with a single oil globule 0.13 to 0.22 mm in diameter. Based on the available data, the length of the pelagic larval stage of groupers is 25–60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors note.

Juvenile

Very little is known about the distribution and habitat utilization patterns of this species. Research has found that transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL (Heemstra and Randall, 1993). The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *E. fasciatus*.

Adult

E. fasciatus is a common species throughout its range. It inhabits coral reefs and rocky bottom from shallows to 160 m (Smith and Heemstra 1986).

Serranids typically are long-lived and have relatively slow growth rates; *E. fasciatus* reported to reach a maximum length of about 40 cm (Heemstra and Randall 1993).

Groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey (Heemstra and Randall 1993). Adults reportedly feed during both the day and night. Harmelin-Vivien and Bouchon (1976) report the diet of *E. fasciatus* includes brachyuran crabs, fishes, shrimps and galathied crabs (Heemstra and Randall, 1993). Other food habit studies identify octopus, crabs, stomatopods, fishes and ophiurids in the diet of *E. fasciatus* (Morgan 1982, Randall and Ben-Tuvia 1983).

Essential Fish Habitat: Shallow-water species complex (0-100 m)

Habitat description for *Epinephelus fasciatus* (blacktip grouper)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	25–60 days	Transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL	Serranids are long-lived , slow growing species.
Diet	N/A	No information available	No information available	The diet of *E. fasciatus* includes brachyuran crabs, fishes, shrimps and galathied crabs, octopus, stomatopods, and ophiurids
Distribution: General and Seasonal	Serranid eggs have a relatively long pelagic phase that results in wide geographic distribution	Serranid larvae have a long pelagic phase that results in wide geographic distribution		Common worldwide including western Pacific region
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *E. fasciatus*.	Inhabits coral reefs and rocky bottom substrate from the shore to a depth of 160 m.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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1.5.5 Habitat description for *Epinephelus quernus* (sea bass, hapuupuu)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Epinephelus quernus is a member of the family Serranidae. The English common name of this species is sea bass. In Hawaii adults of this species are known as hapu. Juveniles are referred to as hapuupuu.

According to Heemstra and Randall (1993) *E. quernus* is endemic to the Hawaiian Islands and Johnston Atoll. It is the only grouper species native to the Hawaiian Islands, although a closely related species, *E. niphobles,* is found in the Eastern Pacific. *E. quernus* is found at a depth range of 20–380 m, the authors add.

Hook and line is the primary gear type used to take this species. Between the years of 1984–1995, *E. quernus* accounted for approximately 14% of the total deep-slope bottomfish landed in Hawaii (WPRFMC 1997).

Egg and larval distribution

Heemstra and Randall describe the small pelagic, fertilized eggs as spherical, transparent and 0.70–1.20 mm in diameter with a single oil globule 0.13–0.22 mm in diameter.

Serranid larvae are characterized by their "kite-shaped" bodies and highly developed head spination, Heemstra and Randall note. Based on the best available data the length of the pelagic larval stage of groupers 25–60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors continue. Transformation of pelagic serranid into benthic larvae takes place between 25 mm and 31 mm TL.

Juvenile

Juvenile *E. quernus* are commonly taken in lobster traps in the NWHI. Besides this limited information there is no specific information available for the distribution, habitat requirements or habitat utilization patterns of juveniles of this species. However, the juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools (Heemstra and Randall 1993).

Adult

Adults of this species typically attain at least 80 cm total length and reach a weight of 10 kg (Heemstra and Randall 1993).

Heemstra and Randall note that groupers are typically ambush predators, hiding in crevices and among coral and rocks in wait for prey. Adults feed during both day and night, the authors add. Seki (1984) reports that the diet of *E. quernus* consists primarily of fish with crustaceans, particularly shrimp, being the next most abundant prey item.

Essential Fish Habitat: Deep-water species complex (100-400 m)

Habitat description for *Epinephelus quernus* (sea bass, hapuupuu)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	25–60 days	Transformation of pelagic serranid into benthic larvae takes place between 25 mm to 31 mm TL	Serranids are long-lived, slow growing species.
Diet	N/A	No information available	No information available	*E. quernus* consists primarily of fish with crustaceans, particularly shrimp, being the next most abundant prey item.
Distribution: General and Seasonal	Serranid eggs have a relatively long pelagic phase that results in wide geographic distribution	Serranid larvae have a long pelagic phase that results in wide geographic distribution		*E. quernus* is endemic to the Hawaiian Islands and Johnston Atoll. It is the only grouper species native to the Hawaiian Islands.
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	Juvenile *E. quernus* are commonly taken in lobster traps in the NWHI. Besides this limited information there is no specific information available for the distribution, habitat requirements or habitat utilization patterns of juveniles of this species. However, the juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools	*E. quernus* is found at depths of 20–380 m. It inhabits rocky bottom substrate.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	N/A	N/A

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1.5.6 Habitat description for *Etelis carbunculus* (red snapper, ehu)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Etelis carbunculus is a red snapper that is known in Hawaii as ehu. It is widely distributed throughout the Indo-Pacific region from East Africa to the Hawaiian Islands and from southern Japan to Australia (Allen 1985; Everson 1984). Like most bottomfish species, *E. carbunculus* is important in western Pacific fisheries but its life history is not well known (Ralston 1979).

E. carbunculus are found concentrated on the steep slopes of deep-water banks of Pacific Islands in habitats characterized by a hard substrate of high structural complexity. They are found solitarily or in small groups in depths of 90 to 350 m (Allen 1985, Everson 1984, Ralston and Polovina 1982).

E. carbunculus reportedly obtain sexual maturity at about 29.8 cm FL (Everson 1986). Everson (1984) reports that the sex ratio is skewed 2:1 in favor of females over males. They reportedly reach a maximum length of 80 cm.

Everson (1984) reports that *E. carbunculus* are serial spawners, spawning multiple times during the spawning season, and that they have a shorter, more well-defined spawning period than do most other species of snappers, spawning from July to September in the NWHI. In Vanuatu spawning reportedly occurs throughout most of the year (Allen 1985).

E. carbunculus is an important commercial species throughout its range and is taken primarily with deep-sea handlines. It is one of the principal species in the deep-water bottomfish fishery in Hawaii, accounting for approximately 7% of the total reported bottomfish landings in 1996 (WPRFMC 1997). NMFS data show that it is the predominant species of deep-water bottomfish in the NWHI west of Lisianski, accounting for 22.7% to 86.5% of the total bottomfish landed in these areas (Everson 1986; Uchiyama and Tagami 1984).

In American Samoa, *E. carbunculus* is one of the most valuable species landed and comprised almost 9% of the total reported bottomfish landings in 1996 (WPRFMC 1997).

In a five-year study of the bottomfish fishery resources of the Northern Mariana Islands and Guam, Polovina et al. (1985) collected more than 30 species of fish. *E. carbunculus* was one of the three most abundant species collected, accounting for 12.5% of the total fish collected.
In Guam, it comprised 4% of the total reported bottomfish landed in 1996 (WPRFMC 1997). Catch data for the Northern Mariana Islands are not available for this species.

Egg and Larval Distribution

In a detailed review of the early life history of tropical snappers, Leis (1987) points out that there have been very few taxonomic studies of the eggs and larval stages of lutjanids and that very few larvae can be identified to species. However, it is possible to distinguish *E. carbunculus* larvae from *E. coruscans* in specimens larger than 13.7 mm (Leis and Lee 1994).

Eteline snapper larvae are generally more abundant in slope and oceanic waters than over the continental shelf (Leis and Lee 1994, Leis 1987). During the day, snapper larvae tend to avoid surface waters, but at night they are more evenly distributed vertically in the surface water column, Leis notes (1987). During the winter month's larvae of most species are much less abundant, he adds.

Juvenile

There is very little information available concerning the preferred habitat of juveniles of this species. Juvenile ehu are found dispersed in their natural habitat (Kelly 1998, Researcher Hawaii Institute of Marine Biology (HIMB), personal communication). Parrish (1989) demonstrated that the habitat requirements of the juveniles of several species of deep-water snappers are markedly different than those of adults.

Adult

The distribution and preferred habitat of adults of this species are described above.

In a detailed review of the trophic biology of snappers, Parrish (1987) states that, like most species of fully deep-water snappers, very little is known about the food habits of the *E. carbunculus*. Food habit studies of these species are difficult because gut contents are frequently lost due to regurgitation when specimens are brought to the surface from great depths, he explains. However, he notes, in the Mariana Islands important prey items in the diet of *E. carbunculus* include fish, benthic crustaceans and pelagic urochordates. Planktonic forms of prey are surprisingly important for snappers, both in bulk consumed and frequency of occurrence, especially for many deep-water species, Parrish adds. Major planktonic food items include pelagic urochordates (Pyrosomida, Salpidae, and Dolioda) and pelagic gastropods (pteropods and heteropods).

According to Parrish, the depths at which *E. carbunculus* feed are not well documented, but it is believed that most deep-water snappers, including this species, feed primarily at or near the bottom. There is also very little information available about the type of substrate where feeding occurs, he says. But, he notes, these species are usually caught in areas of rather high relief, particularly on the steep slopes of islands.

Haight (1989) found that the catch rate for *E. carbunculus* was highest between 200–250 m on Penguin Bank in the MHI. He also found that *E. carbunculus* fed primarily 1800–2000, with fish comprising almost 98% of the prey items in the species's diet. Other prey items included copepods, shrimp, crabs and octopus. This species is known to be an aggressive feeder (Haight 1989, Ralston 1979).

Essential Fish Habitat: Deepwater bottomfish complex (100–400 m).

E. carbunculus is found concentrated on the steep slopes of deepwater banks of Pacific

Islands in habitats characterized by a hard substrate of high structural complexity (Ralston 1979, Ralston and Polovina 1982, Everson 1984, Polovina 1985, Haight 1989, Moffitt and Parrish 1996). Ehu is found concentrated between the depths of 90 to 350 m (Allen 1985, Everson 1984, Ralston and Polovina 1982).

Habitat description for *Etelis carbunculus* (red snapper, ehu)

	Egg	Larvae	Juvenile	Adult
Duration	17–36 h incubation time depending on the species and the water temperature	The pelagic larval phase of lutjanids life history last for 25–-47 days and that size may be a more important factor than age in determining when settlement occurs. Size at settlement varies widely among species and ranges from 10-50 mm	No information available	No information available
Diet	N/A	No information available	No information available	The diet of *E. carbunculus* include fish, benthic crustaceans and pelagic urochordates
Distribution: General and Seasonal	Not well documented, widely distributed.	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf	No specific information available, the habitat requirements of the juveniles of several species of deepwater snappers are markedly different than those of adults.	It is widely distributed throughout the Indo-Pacific region from East Africa to the Hawaiian Islands and from southern Japan to Australia
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day (Leis 1987). At night, snapper larvae are found more evenly distributed throughout the surface waters (Leis 1987).	Demersal: No specific information is available for the distribution and habitat preferences of juvenile onaga	Demersal, *E. carbunculus* is found concentrated on the steep slopes of deepwater banks of Pacific Islands in habitats characterized by a hard substrate of high structural complexity. Found concentrated between the depths of 90 to 350 m
Bottom Type	N/A	N/A	No information available	Areas of high relief, (e.g., steep slopes, pinnacles, headlands, rocky outcrops)
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	Areas of high relief form localized zones of turbulent vertical water movement. Higher densities of some eteline snapper species have been found on the up-current side islands, banks and atolls.

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1.5.7 Habitat description for *Etelis coruscans* (red snapper, onaga)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Etelis coruscans has the common English name of red snapper and is known in Hawaii as onaga. Ralston (1979), while noting that the life history of the *E. coruscans* is poorly understood, says the species is widely distributed throughout the Pacific region and extends into the Indian Ocean, with known occurrences in Hawaii, Samoa, the Mariana Islands, the Cook Islands, Tuvalu and Vanuatu.

An eteline snapper in the Lutjanidae family, *E. coruscans* is found in considerably deeper waters then other species of deep-slope snappers (Everson 1986, Moffitt 1993). It is caught at depth ranging from 100–160 fathoms (Ralston 1979). *E. coruscans* is found in association with areas of abrupt relief, such as steep drop-offs, ledges, outcrops and pinnacles (Everson 1986). Ralston (1979) determined that 92% of the total *E. coruscans* landed in Hawaii were taken in deep, offshore waters beyond the 3-mile limit of state jurisdiction.

According to the *1996 Annual Report for Bottomfish and Seamount Groundfish in the Western Pacific*, *E. coruscans* accounted for approximately 10% of the total reported bottomfish landings for the NWHI (311,000 lb.) and almost 16% of the reported total landings of BMUS (421,000 lb.) in the MHI and commanded the highest price per pound of any bottomfish species landed in Hawaii. It also accounted for 11% of the total reported BMUS landings (32,245 lb.) in American Samoa and commanded the second highest price per lb. of any species landed in the territory. In the Northern Mariana Islands, *E. coruscans* was the single most abundant bottomfish species landed in 1996, accounting for almost 29% of the total catch (52,967 lb.), and commanded the highest price per pound of any bottomfish species landed in the commonwealth, the annual report continues. In Guam, the species comprised only about 3% of the total reported bottomfish landings (54,122 lb.), the report adds. While relatively uncommon in Guam, the *E. coruscans* is a highly prized species.

Haight (1989) studied the trophic relationships, density and habitat associations of deep-water snappers on Penguin Bank, Hawaii. Of the six species of lutjanid snappers collected in his study, *E. coruscans* made up 7% of the total catch. The size of the *E. coruscans* taken in this same study ranged from 26.5–74.4 cm FL.

Ralston (1979) says *E. coruscans* is known to reach sizes of up to 80 lb, but most commercially landed *E. coruscans* weigh between 1–15 lb. In the MHI most of the *E. coruscans* landed are taken from the Pengiun Bank–North Molokai region, Ralston adds. Landings of *E. coruscans* are seasonal in Hawaii, with CPUE increasing during the fall and early winter months, peak landings occurring in or around the month of December and minimum of *E. coruscans* landings occurring during the early summer months, Ralston observes.

A cluster analysis of bank catch composition in the Mariana archipelago determined that the banks could be grouped into three catch profiles, southern, northern and seamount clusters. The seamount cluster was characterized throughout the resource assessment by its higher proportion of *Etelis* species (*Etelis coruscans and E. carbunculus*), almost twice the amount of the other clusters (Polovina, 1985).

Lutjanids, such as *E. coruscans*, are hooked near or several m above the bottom (Moffitt 1993).

<u>Eggs and Larval Distribution</u>

There have been very few ecological or taxonomic studies of the eggs and larvae of *E. coruscans*. As discussed, most of the available data pertaining to the early life stages of lutjanids are broad, non-species specific in nature. Leis (1987) says lutjanids spawn small, pelagic, spherical, eggs that are typically less than 0.85 mm in size and that hatch in 17–36 hours depending on species and water temperature.

Little is known about this species' larval life. Leis (1987) notes that newly hatched lutjanid larvae have unpigmented eyes, no mouth, a large yolk sac, spination of the head and fins, and limited swimming capabilities, he says. Lutjanid larvae are known to avoid the surface layer during the day, but at night, they are found evenly distributed throughout the surface waters, he observes. The duration of their pelagic phase has been estimated to range 25 –47 days, and larvae of eteline snapper, including those of *E. coruscans*, are found in greater abundance over oceanic and slope waters than over the waters of the continental shelf, he notes. It is thought that the pelagic phase of eteline lutjanids is longer than that of *Lutjanus* spp., and size may be a more important factor than age in determining when larval settlement occur, Leis says. Snapper larvae are subject to advection by ocean currents (Munro 1987).

<u>Juvenile</u>

Virtually nothing is known about juvenile *E. coruscans* life history and habitat requirements. Current research has shown that shallow, flat featureless areas may be essential habitat for growth and survival of juvenile *Pritipomoides filamentosus, Aprion virescens* and *Aphareus rutilans*. Research has identified two areas that support dense, persistent aggregations of juvenile snapper in relatively shallow water (65–100 m). Both are in the MHI—the first is off Kaneohe Bay on the island of Oahu, and the second, off the southwest coast of Molokai. The flat featureless substrate of these two sites is quite different than the high relief, hard bottom that adult snappers are known to inhabit.

At the Kaneohe Bay site, an internal, semi-diurnal tide provides an influx of cold water to the area at high tide (Moffitt and Parrish 1996). It has been hypothesized that such a water flow may enhance food supplies in an area (Parrish et al. 1997). Parrish et al (1997) also found a significant correlation between juvenile snapper abundance and sources of coastal drainage at the site off of Molokai. Research to identify additional juvenile bottomfish nursery areas in the Hawaiian Islands is ongoing. Research to identify, describe and map nursery habitat areas for juvenile *E. coruscans* throughout the region is needed.

Adult

Adult *E. coruscans* are found in considerably deeper waters than other species of snappers (Everson 1986, Moffitt 1993). They are caught at depths ranging from 100 to 160 fathoms (Ralston 1979). They are found in areas of abrupt relief, such as steep drop-offs, outcrops, ledges and pinnacles. They grow to a much larger size (81 cm FL) than other species of *Etelis* and *Pristipomoides* and weigh up to 20 kg (Amesbury and Myers 1982). Everson (1986) reports the mean weights of males and females of the species to be 4.28 kg and 5.45 kg respectively in the NWHI.

Analyzing the CPUE distribution by depth intervals for all species landed, Haight (1989) found that *E. coruscans* are caught at the highest rate between depths of 250 and 300 m, the deepest region occupied by any of the snappers common to the Hawaiian Islands that have been collected. This compares with an average hooking depth of 125 fathoms in the NWHI noted in Amendment 2 of the bottomfish FMP and 119 fathoms in the Northern Mariana Islands observed by Polovina et al.(1985).

Peak feeding times for adult *E. coruscans* occur during daylight hours, with the highest catch rates between 0600–0800 hours (Haight 1989). *E. coruscans* feed at or near the bottom (Moffitt 1993), and their diet includes fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), chepalopods (2%), urocordates (1.5%) and crabs (.2%) (Haight 1989).

While little is known about the reproductive cycle of *E. coruscans* it is probably similar to ehu (Everson 1986). Polovina and Ralston (1986) estimate sexual maturity at two years of age. In the NWHI, ripe ovaries were collected from *E. coruscans* in August and September during a study that took place during the summer months only (Everson 1986). Grimes (1987) report that deep-water snappers reach sexually maturity at approximately 50% of their total length.

Essential Fish Habitat: Deep-water complex (100-400)

Species: *Etelis coruscans* (red snapper, onaga)

	Egg	Larvae	Juvenile	Adult
Duration	17–36 h incubation time depending on the species and the water temperature (Leis 1987)	Leis (1987) reports that the pelagic larval phase of lutjanids life history last for 25–-47 days and that size may be a more important factor than age in determining when settlement occurs. Size at settlement varies widely among species and ranges from 10-50 mm	No specific information available	*Etelis coruscans* is a long-lived, slow growing species
Diet	N/A	No information available	Not known	fish (76.4%), shrimp (16.4%), planktonic crustaceans (3.4%), chepalopods (2%), urocordates (1.5%), crabs (.2%) (Haight 1989).
Distribution: General and Seasonal		Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf (Leis 1987)	The species is widely distributed throughout the Pacific region	The species is widely distributed throughout the Pacific region and extends into the Indian Ocean, with known occurrences in Hawaii, Samoa, the Mariana Islands, the Cook Islands, Tuvalu and Vanuatu.
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day (Leis 1987). At night, snapper larvae are found more evenly distributed throughout the surface waters (Leis 1987).	Demersal:	Demersal, 100-160 fathoms
Bottom Type	N/A	N/A	No specific information is available for the distribution and habitat preferences of juvenile onaga	Areas of high relief, (e.g., steep slopes, pinnacles, headlands, rocky outcrops)
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	Higher densities of some eteline snapper species have been found on the up-current side islands, banks and atolls.

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1.5.8 Habitat description for *Lethrinus amboinensis* (ambon emperor)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Lethrinus amboinensis is a member of the Lethrinidae family and the subfamily Lethrininae. It has the English common name of ambon emperor, while in American Samoa, it is commonly known as filoa-gutumumu and in Guam and the Northern Mariana Islands, as mafuti or lililok. It is absent from the Hawaiian Islands.

Carpenter and Allen (1985) present a major review of the known habitat requirements and life history of *L. amboinensis*. The species is found from southern Japan to northwestern Australia and from Indonesia eastward through the Marshall Islands, Solomons, Samoa and the Marquesas. It is commonly confused with *L. microdon* and *L. olivaceus*, the authors note.

Very little is known about the biology of this species or its habitat utilization patterns. It is known to inhabit deeper waters of coral reefs and adjacent sandy bottom areas. According to Carpenter and Allen, lethrinids are found inhabiting coastal waters, including coral and rocky reefs, sandy bottoms, sea-grass beds and mangrove swamps.

The spawning behavior of lethrinids is poorly documented. Based on the limited data available, Carpenter and Allen describe a generalized pattern: Spawning is generally prolonged, occuring throughout the year. It is preceded by small, localized migrations at or near dusk. Peak spawning events occur on or near the new moon. Large aggregations of lethrinids have been observed spawning near the surface as well as at the bottom of reef slopes, the authors state.

Lethrinids are relatively long-lived, with an average age range of 7 to 27 years, Carpenter and Allen report. The average age of growth cessation for lethrinids is 11 years with a reported maximum size of approximately 70 cm total length. The males tend to be of a larger size than females. The ambon emperor is commonly taken at sizes ranging from 30 to 50 cm in total length, the authors add.

Lethrinids are of moderate to significant importance in commercial, recreational and artisanal fisheries throughout the tropical Pacific, Carpenter and Allen report. In American Samoa, *L. amboinensis* accounted for approximately 2% of the total landed bottomfish reported in the *1996 Annual Report of Bottomfish and Seamount Groundfish in the Western Pacific*. In contrast, *L. amboinensis* and *L. rubrioperculatus* accounted for approximately 18% and 20% of the total landed bottomfish in Guam and the Northern Mariana Islands, respectively, according to the 1996 annual report. In the case of the Northern Mariana Islands, there was a preponderance of *L. rubrioperculatus* in the total lethrinids landed. Emperors are taken primarily with handlines, droplines longlines and traps, the annual report notes. Carpenter and Allen (1989) say that lethrinids are important recreational target species in some countries, and some species of lethrinids are reported to be ciguatoxic.

Egg and Larval Distribution

Carpenter and Allen describe lethrinid eggs as pelagic, spherical and colorless, possessing an oil globule and ranging in size from 0.68 to 0.83 mm in diameter. The eggs typically hatch within 21 to 40 hours after fertilization occurs, they add.

Newly hatched lethrinid larvae range in size from 1.3 to 1.7 mm. The general physical characteristics include an unopened mouth, a large yolk sac, unpigmented eyes, variable body pigmentation and, most notably, extensively developed head spination and cheek scales, Carpenter and Allen report.

Juvenile and Adult

As discussed above, very little is known about the biology of *L. amboinensis* or its habitat utilization patterns. It is known to inhabit deeper waters of coral reefs and adjacent sandy bottom areas. Carpenter and Allen say lethrinids are found inhabiting coastal waters—including coral and rocky reefs, sandy bottoms, sea-grass beds and mangrove swamps—and adult *L. amboinensis* prey primarily on fishes and crustaceans.

Essential Fish Habitat: Shallow-water species complex (0-100 m)

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1.5.9 Habitat description for *Lethrinus rubriopeculatus* (redgill emperor)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Lethrinus rubrioperculatus is a member of the family Lethrinidae, the subfamily Lethrininae and the genus *Lethrinus*. The English common name of this species is redgill emperor. In American Samoa it is known as filoa-pa’o’omumu; in Guam and the Northern Mariana Islands it is called mafuti tatdong. *L. rubrioperculatus* is not found in the Hawaiian Islands. Carpenter and Allen (1989) describe the geographical distribution of this species as being widespread in the Indo-Pacific region, from East Africa to the Marquesas, from southern Japan to Australia. Adults of this species are found inhabiting sand and rubble areas on outer reef slopes to depths of 160 m, the researchers note. Individuals of the species are commonly found at lengths of approximately 30 cm and that the maximum reported total length for this species is 50 cm, they add.

The common mode of sexuality in Lethrinids is sequential protogynous hermaphroditism. When lethrinids first obtain sexual maturity they are initially female, later they change. Carpenter and Allen say that this reproductive mode explains several aspects of lethrinid population structure: the sex ration is usually slightly in favor of females, and on average males tend to be larger then females. Research indicates that the sexual transformation occurs over a wide size range, the authors note.

L. rubrioperculatus is commonly taken with handlines, trawls and traps and is one of the most important commercial species of bottomfish in the Northern Mariana Islands, Carpenter and Allen continue.

Egg and Larval Distribution

Lethrinid eggs are pelagic. They are described by Carpenter and Allen as spherical, possessing an oil globule and between 0.68 and 0.83 mm in size. They hatch between 21 and 40 hours after fertilization. Newly hatched lethrinid larvae are 1.3–1.7 mm in length, with unpigmented eyes, unopened mouth, variable body pigmentation and a large yolk sac. Extensive spination of the head is a notable feature of lethrinid larvae's physical appearance, Carpenter and Allen note.

Juvenile

There is virtually no information available concerning the distribution or habitat utilization patterns of this species.

Adult

Adults of this species feed primarily on crustaceans, fish, echinoderms and molluscs (Allen 1985).

Essential Fish Habitat: Shallow-water species complex (0-100 m)

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1.5.10 Habitat description for *Lutjanus kasmira* (blue-lined snapper, taape)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Lutjanus kasmira is in the family Lutjanidae, subfamily Lutjaninae. *L. kasmira* is distributed throughout the Indo-Pacific region; from East Africa to the Line and Marquesas Islands, from Australia to Japan (Allen 1985, Druzhinin 1970). It also occurs in waters around Hawaii where it was introduced in 1955 and 1961 by the Hawaii Department of Land and Natural Resources (Uchida 1986). There are concerns among fishermen that *L. kasmira* may compete with native species of commercially important bottomfish, but available data does not support this claim (Oda and Parrish 1981).

L. kasmira is found on outer reef slopes at depths of up to 265 m and in shallow inshore waters and lagoons (Myers 1991; Amesbury and Myers 1982). Myers (1991) observes that, during the day, the species commonly forms large aggregations near high relief bottom features such as prominent coral heads, ledges, caves, wrecks and patch reefs, and at night, disperses to forage on benthic organisms, primarily crustaceans and fish.

Lutjanids are dioecious (Allen 1985). *L. kasmira* reaches maturity at 12 –25 cm. Suzuki and Hioka (1979) note that group spawning has been observed in *L. kasmira* in the evening and at night. Males initiate courtship by rubbing and pecking against the body of the female. As other males congregate, they begin an upward spiral ascent, culminating with the release of the gametes near the surface, the authors state. Mizenko (1984) found that spawning events occur with a lunar periodicity coinciding with full and new moon events over an extended spawning period. In Western Samoa, peak spawning occurs during the autumn and winter months, the author adds.

<u>Egg and Larval Distribution</u>

Very little is known about this species's early life history. Suzuki and Hioka describe the eggs as 0.78–0.85 mm, noting that fertilized eggs are buoyant and spherical and contain, a single oil globule. They hatch in approximately 18 hours at 22 to 25° C under controled conditions, the authors add.

Newly hatched lutjanid eggs are typical of other pelagic larvae. They are subject to advection by ocean currents (Munro 1987). Suzuki and Hioka say newly hatched *L. kasmira* larvae measure 1.83 mm in total length and possess a large ellipsoid yolk. Leis (1987) estimates the pelagic larval phase of lutjanids at 25–47 days. It is thought that the pelagic phase of *Lutjanus* spp. is shorter than that of the eteline lutjanids, and size may be a more important factor than age in determining when larval settlement occurs, Leis notes.

<u>Juvenile</u>

Juveniles of this species are known to utilize shallow water habitats such as seaward reefs and sea-grass beds as nursery habitat (Myers 1991; Amesbury and Myers 1982).

<u>Adult</u>

L. kasmira is found widely distributed in the Indo-Pacific region, occurring in a variety of habitat types and depths. Mizenko (1984) found that except during spawning events the *L. kasmira* was segregated by sex, with males dominating the deeper waters of the outer reef slope.

L. kasmira is a nocturnal predator that preys primarily on fish and crustaceans (Parrish 1987, Oda and Parrish 1981, Van der Elst 1981). Rangarajan (1972) reports that the chief prey items of *L. kasmira*, in order of abundance, include teleost fish, crabs, megalopa and prawns. Rangarajan concludes that there is no significant difference in the diets of young and adult fish of this species.

L. kasmira is frequently sold in local markets. In American Samoa it accounts for approximately 11% of the total reported bottomfish landings (WPRFMC 1997). In Hawaii, it is one of the principal species taken in the deep slope handline fishery (Allen 1985). The bulk of the taape landed are taken in state waters (Ralston 1979). In Guam, taape accounted for a little over 3% of the total reported bottomfish landed (WPRFMC 1997). Catch data are not available for this species for in the Northern Mariana Islands. *L. kasmira* is taken primarily by means of handlines, gill nets and traps (Allen 1985).

Essential Fish Habitat: Shallow water bottomfish complex (0–100 m).

L. kasmira is found in a wide range of habitats. It is often found in shallow, near-shore habitats and is commonly found in association with coral reef habitats.

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1.5.11 Habitat description for *Pristipomoides auricilla* (yellowtail snapper, yellowtail kalekale), *P. flavipinnis* (yelloweye snapper, yelloweye opakapaka) and *P. zonatus*

(snapper, gindai)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

These three *Pristipomoides,* or snappers, are part of the fish assemblage associated with the rocky deeper reef slopes in the Indo-Pacific region beyond the areas of hermatypic corals. All three species are found in depths ranging from 80 to 300 m, although *P. auricilla* and *P. flavipinnis* are most abundant in the depth range 180–270 m, and *P. zonatus*, between 100 and 200 m. *P. auricilla* and *P. zonatus* are found throughout the western Pacific region, while *P. flavipinnis* is absent from Hawaii.

These three species do not comprise major fractions of bottomfish catches in Hawaii, but *P. zonatus* and *P. auricilla* form about 6% and 20% respectively of commercial bottomfish catches in Guam.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. Lutjanids eggs typically are less than 0.85mm in size (Leis 1987). They hatch in 17–36 h depending on water temperature.

Clarke (1991), in a larval fish survey conducted off Oahu in the MHI, found eteline snapper larvae were rarely collected, comprising less than 0.5% of the 5,200 fish larvae identified. In this study, eteline snapper larvae were collected exclusively during the late summer and fall.

Very little is known about this species larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. Snapper larvae are subject to advection by ocean currents (Munro 1987). Leis (1987) estimated the duration of the pelagic phase of lutjanids at 25– 47 days. It is thought that the pelagic phase of eteline lutjanids, such as *P. seiboldii*, is longer than that of *Lutjanus* spp, and size may be a more important factor than age in determining when larval settlement occurs in Lutjanids, Leis notes.

Juvenile

Very little is known about the distribution and habitat requirements of this species.

Adult

See “Life History and General Description” above.

Essential Fish Habitat: Deep-water species complex (100-400)

Habitat description for *Pristipomoides auricilla*, *P. flavipinnis* and *P. zonatus*

	Egg	Larvae	Juvenile	Adult
Duration	17–36 h 18 hours	The pelagic larval phase of lutjanids life history last for 25––47 days and that size may be a more important factor than age in determining when settlement occurs.	No information available	No information available
Diet	N/A	No information available	No information available	Cconsists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods
Distribution: General and Seasonal	Not well documented, widely distributed.	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf	Very little is known about the distribution and habitat utilization patterns of this species.	All three species are found in depths ranging from 80 to 300 m, although *P. auricilla* and *P. flavipinnis* are most abundant in the depth range 180–270 m, and *P. zonatus*, between 100 and 200 m. *P. auricilla* and *P. zonatus* are found throughout the western Pacific region, while *P. flavipinnis* is absent from Hawaii.
Water Column	Pelagic	Lutjanid larvae are known to avoid the surface layer during the day. At night, snapper larvae are found more evenly distributed throughout the surface waters.	Demersal	Demersal
Bottom Type	N/A	N/A	No information available	Found over rocky bottoms at depths of 80-300 m
Oceanic Features	Lutjanid eggs are subject to advection by ocean currents	Lutjanid larvae are subject to advection by ocean currents	No information available	No information available

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1.5.12 *Pristipomoides filamentosus* (pink snapper, opakapaka)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Pristipomoides filamentosus is an eteline snapper in the family Lutjanidae. It known by the English common name of pink snapper; in Hawaii, it is known as opakapaka. *P. filamentosus*, is widely distributed throughout the Indo-west Pacific region (Mees 1993, Druzhinin 1970). It is a deepwater species of snapper with a depth distribution of 30–360 m (Kami 1973, Moffitt 1993). It is a long-lived, slow-growing species, capable of reaching a length of 31.5 inches and an age of 18 years (Moffitt 1993, Waas 1994).

P. filamentosus is one of the most important demersal species of fish managed by the Western Pacific Regional Fishery Management Council (the Council). The Council's *1996 Annual Report for the Bottomfish and Seamount Groundfish Fisheries* reports landings for the species were 137,755 lb from the MHI and an additional 76,860 lb from the NWHI— approximately 32% of the total reported BMUS landings in the Hawaiian Islands. The species also commanded the second highest price per pound of any BMUS in Hawaii, the report adds.

While less prevalent, *P. filamentosus* is still an important species in the American Samoa, Guam and the Northern Mariana Islands bottomfish fishery. In Guam, it comprises roughly 3% of the total bottomfish landed, and in terms of price per pound, it is one of the most valuable bottomfish species landed, the 1996 annual report notes. In the Northern Mariana Islands, it comprises an estimated 10% of the total reported bottomfish landings, while in American Samoa, it accounts for less than 1% of the total BMUS species landed.

According to Ralston and Polovina (1982), most of the fishing effort for deep-water bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago; these researchers use the 100-fathom isobath that surrounds an island or bank to estimate the total amount of bottomfish habitat. Uchiyama and Tagami

(1983) found that *P. filamentosus* dominated the catch at Necker Island, French Frigate Shoals and Brooks Banks.

Egg and Larval Distribution

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. According to Leis (1987), lutjanids eggs typically are less than 0.85mm in size. They hatch in 17–36 h depending on water temperature. Pink snapper eggs are small, spherical and pelagic.

Little is known about the larval life of *P. filamentosus*. But the eggs of newly hatched lutjanid, such as *P. filamentosus*, are typical of other pelagic larvae. They have a large yolk-sac, no mouth, unpigmented eyes and limited swimming capabilities. Leis (1987) estimates that the duration of the pelagic phase of lutjanids to range from 25 to 47 days. The pelagic phase of eteline lutjanids is longer than that of *Lutjanus* spp., he notes. Size may be a more important factor than age in determining when larval settlement occurs in lutjanids, Leis adds. Snapper larvae are subject to advection by ocean currents (Munro 1987).

Juvenile

Little is known about the life history and habitat requirements of juvenile *P. filamentosus*. A dense aggregation of juvenile of this species has been found offshore of Kaneohe Bay on the island of Oahu in an area of very low relief, at depths of 65–100 m. This flat, featureless habitat is very different from the high relief areas preferred by adults of the species. While sampling for juvenile snapper was extended beyond the 60–100 target depth, no juveniles were taken outside of this depth range (Moffitt and Parrish 1996). These data demonstrate, that at this specific location, juvenile *P. filamentosus* has a strong affinity for a relatively narrow depth range. It is thought that this habitat may provide them the advantage of reduced predation pressure and lessen interspecific competition.

Parrish et al. (1997) suggest that areas of uniform sediment type are an important substrate feature for juvenile *P. filamentosus*. They found a significant correlation between their abundance and clay-silt substrate; they also found significantly lower abundance of these juvenille in areas surrounded by escarpment-type relief than in areas of uniform sediment bottom. The same research found a similar pattern of significantly lower abundance of juveniles in areas of exposed hard substrate.

Juvenile *P. filamentosus* first appear at Kaneohe Bay at a size of about 7–10 cm FL (Moffitt and Parrish 1996). They stay in this habitat for less than a year before moving into deeper waters (150–190 m) as they mature (Parrish et al. 1996). When the juveniles move into deeper water, they are 18–20 cm FL (Moffitt and Parrish 1996). Age-length studies for species indicate a body length of 18 cm length would be obtained by age 1 (DeMartini et al. 1994).

A fishing survey of the MHI has identified only one other area with an aggregation of juvenile *P. filamentosus* similar to the Kaneohe Bay site. Parrish et al. (1997) identified the second site in 1993 off the southwest coast of Molokai. Snapper abundance at this site was found not to be correlated with substrate type. However, there was a significant correlation between juvenile snapper abundance and sources of coastal drainage. At the Kaneohe site, an internal, semi-diurnal tide provides an influx of cold water to the juvenile snapper nursery grounds during high tide (Moffitt and Parrish 1996). Parrish et al. postulate that distribution of juvenile snapper within their preferred habitat type may be more closely related to water flow than sediment particle size. They hypothesize that water flow may enhance the food supplies in these areas. Parrish (1989) reports the diet of juvenile *P. filamentosus* comprises primarily small crustaceans. Other prey items include juvenile fish, cephalopods, gelatinous plankton and fish scale.

The results of a tagging study found that juvenile *P. filamentosus* migrate between deeper daytime locations and shallow nighttime positions (Moffitt and Parrish 1996). This movement, which displayed a crepuscular periodicity, was unrelated to water temperature. The results of this study demonstrated that these juvenile pink snapper were more active during the day than night.

Based on video abundance data, Parrish et al. (1997) calculated a mean estimated density of 6.6 km^2 for "non-premium" habitat. They applied this number to the entire available habitat at the 60–90 m depth range in the MHI (2,600 km^2) and came up with an estimate of 17,200 individuals. This estimate is only 15% of the 115,600–189,200 juvenile snappers, back-calculated from commercial catch data, needed to sustain the current level of landings in the MHI for this species of pink snapper, the authors note.

It is not known how widespread the preferred habitat of juvenile *P. filamentosus* is in the waters of Hawaii. Surveys suggest that it represents only a small fraction of the total habitat at the appropriate depths (Parrish et al. 1997). Areas of flat featureless bottom have typically been thought of as providing low value fishery habitat. The discovery of dense juvenile snapper aggregations in areas of very low relief provides substantial evidence to the contrary. This fact has important management implications for the conservation and protection of this critical and limited habitat type. More research is needed to help identify, map and study nursery habitat for juvenile *P. filamentosus*.

Adult

Adult *P. filamentosus* are found on the steep slopes and deep-water banks of Pacific islands. They aggregate near areas of high bottom relief (Parrish 1987). Large mixed groups of snappers (50–100), including *P. filamentosus*, have been observed aggregating 2–10 m above high relief structures on Penguin Bank (Haight 1989). Moffitt (1993) reports that some species of deep-water snappers, such as *P. filamentosus*, are not be restricted to high relief, deep-slope habitat. During the day, individuals of this species are found in areas of high relief at depths of 100–200 m; during the night, these individuals migrate into shallower flat, shelf areas, where they are found at depths of 30–80 m, Moffitt observes. Areas of high relief form localized zones of turbulent vertical water movement that increase the availability of prey items (Haight et al. 1993). Ralston et al. (1986) found higher densities of *P. filamentosus* on the up-current side vs. the down-current side of Johnston Atoll.

Haight (1989) studied the trophic relationships, density and habitat associations of deep-water snappers (Lutjanidae) on Penguin Bank. Based on the observations of the manned submersible and ROV surveys, a maximum density of 1.37 fish/m^2 and 1.24 fish/m^2 for snapper were calculated (Haight 1989). During the manned submersible dives, a mean encounter rate of 0.035 fish/m^2 was observed .*P. filamentosus* occur in progressively shallower waters (103 m) in the more northern reaches of the NWHI (Humphreys 1986).

The diets of deep-water snappers, such as *P. filamentosus,* are poorly understood. Parrish (1987) includes pelagic tunicates, fish, shrimp, cephalopods, gastropods, planktonic urochordates and crabs as prey items and reports that snappers feed mostly at night and forage over a wide area. Haight (198(9) characterizes *P. filamentosus* as a crepuscular feeder, displaying two peak foraging periods, shortly before dawn and shortly after sunset; he also found the species to display a seasonal variation in its diet.

The depths at which snappers feed are not well documented. According to Parrish (1987), *P. filamentosus* feed primarily at depths of greater than 100 m and stay within several m of the bottom, but little is known about the type of substrate where they feed. Haight (1989) found the greatest catch per unit effort (CPUE) for *P. filamentosus* on Penguin Bank at depths of between 100 and 150 m. Moffitt (1993) observed a diurnal migration from areas of high relief at depths of 100–200 m during the day to shallow flat shelf areas at depths of 30–80 m at night.

Female of this species reach maturity at a length of 42.7 cm and have a protracted spawning period of seven months (June–December) that peaks in August (Kikkawa 1983).

Essential Fish Habitat: Deep-water species complex (100-400)

Habitat Description for *Pristipomoides filamentosus* (pink snapper, opakapaka)

	Egg	Larvae	Juvenile	Adult
Duration	17-36 h. incubation time depending on species and water temperature (Leis, 1987)	Leis (1987) reports pelagic phase of lutjanids life history last for 25-47 days. Size may be a more important factor than age in determining when settlement occurs (Leis 1987). Size at settlement varies widely among species and ranges from 10–50 mm	10 months of age (7–10 cm FL) -- 17 month (18–25 cm FL) (Haight et al. 1997).	17 months–18 years (need to confirm) Haight et al. (1993) reports the age of entry into the fishery as 2 to 3 years after settlement
Diet	N/A	No information available	Small crustaceans, juvenile fish, cephalopods gelantinous plankton, fish scale	Prey items include: pelagic tunicates, fish, shrimp, cephalopods gastropods, planktonic urochordates, crabs
Distribution General and Seasonal	***P. filamentosus*** spawn from June to December.	In Hawaii Pristipimoides larvae were found in August–October. Most species of lutjanid larvae are less abundant in winter	Juvenile opakapaka appear during fall and early winter months (Haight et al. 1993).	*P. filamentosus* migrate diurnally from areas of high relief during the day at depths of 100–200 m, to shallow (30–-80 m) flat shelf areas at night (Moffitt 1993)
Location	Lutjanids are generally more abundant over the continental shelf waters	Eteline snapper larvae are more abundant in slope and oceanic waters than over the continental shelf (Leis 1987)	Bottom; 65–100 m	Bottom; 30–343 m.
Water Column	N/A	Pelagic: lutjanids larvae display diurnal vertical migrations in water column (Leis 1987); lutjanids larvae's abundance has been shown to increase with depth during the day (Leis 1987).	Demersal	
Bottom Type		N/A	Low relief , current flow, clay silt	Areas of high relief, (e.g., steep slope and pinnacles)
Oceanic Features		Snapper larvae are subject to advection by ocean currents (Munro 1987)	It is thought that distribution of juvenile snapper within its preferred habitat type may be closely related to water flow.	Areas of high relief form localized zones of turbulent vertical water movement. Higher densities of *P. filamentosus* have been found on the up-current side of Johnston Atoll

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Fishery Management Council.

1.5.13 Habitat description for *Pristipomoides sieboldii* (pink snapper, kalekale)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Pristipomoides sieboldii is a member of the family Lutjanidae. Within the family Lutjanidae there are four subfamilies including the Etelinae, in the which the genus *Pristipomoides* is found. The English common name of this species is pink snapper. In Hawaii it is known as kalekale while in Guam and the Northern Mariana Islands it is called guihan boninas.

There are 15 known species in the genus *Pristipomoides* in the Indo-Pacific region. According to Allen (1985), individuals of this genus are typically found singularly or in small groups, and members of *P. seiboldii* are found over rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region from East Africa to Hawaii and as far north as southern Japan.

P. sieboldii is taken primarily with handlines and bottom longlines (Allen 1985). According to the *1996 Annual Report of Bottomfish andSeamount Groundfish in the Western Pacific,* the species is commonly taken in the MHI offshore handline fishery. Most of the fishing effort for deepwater bottomfish species occurs in the steep drop-off zone that surrounds the islands and banks of the Hawaiian archipelago (Ralston and Polovina 1982). However, as noted in the bottomfish FMP, *P. sieboldii* is infrequently taken in American Samoa, Guam and the Northern Mariana Islands, based on the available landing data.

<u>Egg and Larval Distribution</u>

There are relatively few taxonomic studies of the eggs and larvae of species of lutjanids. Lutjanids eggs typically are less than 0.85mm in size (Leis 1987). They hatch in 17–36 h depending on water temperature.

In a larval fish survey conducted off Oahu in the MHI, Clarke (1991) found eteline snapper larvae were rarely collected, comprising less than 0.5% of the 5,200 fish larvae identified. In this study, eteline snapper larvae were collected exclusively during the late summer and fall.

Very little is known about this species' larval life history stage. Newly hatched lutjanid eggs are typical of other pelagic larvae. They have a large yolk sac, no mouth, unpigmented eyes and limited swimming capabilities. Leis (1987) estimate the duration of the pelagic phase of lutjanids at 25–47 days and believes that the pelagic phase of eteline lutjanids, such as *P. sieboldii*, is longer than that of *Lutjanus* spp. However, he notes that size may be a more important factor than age in determining when larval settlement occurs in lutjanids. Munro (1987) says snapper larvae are subject to advection by ocean currents.

Juvenile

Very little is known about the distribution and habitat requirements of this species. In the Hawaiian Islands, schools of several hundred juvenile *P. sieboldii* have been observed along the Oahu's north shore (Kelley C. 1998. pers. comm).

No information concerning the diet of juvenile *P. sieboldii* is available. Parrish (1989) found the diet of juvenile *P. filamentosus,* another eteline snapper, to consist primarily of small crustaceans. Other prey items included juvenile fish, cephalopods, gelatinous plankton and fish scales.

Adult

P. sieboldii's maximum size is is commonly about 40 cm but can reach to approximately 60 cm (Allen 1985).

The diets of deepwater snappers, such as kalekale, are poorly understood (Parrish 1987). The diet of adult *P. sieboldii* consists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods (Allen 1985). The depths at which snappers feed are not well documented. Parrish (1987) reports that snappers feed mostly at night and forage over a wide area.

Essential Fish Habitat: Deep-water species complex (100-400 m)

Habitat description for *Pristipomoides sieboldii* (pink snapper, kalekale)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	17–36 h depending on water temperature	25–47 days, the pelagic phase of eteline lutjanids, such as *P. sieboldii*, is longer than that of *Lutjanus* spp. Size may be a more important factor than age in determining when larval settlement occurs in lutjanids.	No information available	No information available
Diet	N/A	No information available	No information concerning the diet of juvenile *P. sieboldii* is available	The diet of adult *P. sieboldii* consists primarily of fish, crab, shrimp, polychaetes, pelagic urochordates and cephalopods
Distribution: General and Seasonal	Widely distributed throughout range	Widely distributed throughout range	No information	*P. seiboldii* are found over rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region from East Africa to Hawaii and as far north as southern Japan.
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	No information available	Rocky bottoms at depths of 180 to 360 m throughout the tropical Indo-Pacific region
Oceanic Features	Eggs are subject to advection by ocean currents	Snapper larvae are subject to advection by ocean currents	No information available	No information available

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1.5.14 Habitat description for *Variola louti* (lunartail grouper)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Variola louti is a member of the family Serranidae, the groupers. *V. louti* is one of only two species of the genus *Variola.* It is the more common of the two genuses (Heemstra and Randall 1993). The English common name of this species is the lunartail grouper. In American Samoa it is known as papa. In Guam and the Northern Mariana Islands it is known as bueli.

Heemstra and Randall (1993) describes *V. louti*'s distribution as being throughout the tropical Indo-Pacific region from the Red Sea to South Africa to the Pitcairn Islands. In the western Pacific, it ranges southern Japan to New South Wales, Australia, and is found at most of the islands of the west central Pacific, the authors continue. *Variola louti* is absent from the Hawaiian Islands.

According to Heemstra and Randall, the lunartial grouper is commonly found on coral reefs at depths of 4 to 200 m. The species seems to prefer clear water areas typical of offshore reefs and islands and is normally found swimming up in the water column well above the reef, the authors note.

V. louti are reported to reach maturity between 81 cm and 100 cm in length (Van der Elst 1981, Heemstra and Randall 1993) and 12 kg in weight (Postel et al. 1963).

Very little is known about the spawning behavior of this species. One study found mature females at 33 cm standard length (Morgans 1982). Research has documented spawning activity between December and February (Heemstra and Randall 1993).

According to Heemstra and Randall, lunartail grouper is an important food fish in artisanal fisheries throughout the Indo-Pacific region, even though it is known to often be the cause of ciguatera poisoning.

Egg and Larval Distribution

Heemstra and Randall describe the fertilized eggs as pelagic, spherical and transparent and 0.70–1.20 mm in diameter with a single oil globule 0.13–0.22 mm in diameter. Based on the available data the length of the pelagic larval stage of groupers is 25–60 days. The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase, the authors note.

Heemstra and Randall calculate that the transformation of pelagic serranid into benthic larvae takes place between 25 mm and 31 mm TL. The serranid larvae are distinguishable by their "kite-shaped" bodies and highly developed head spination, the authors point out.

Juvenile

The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *V. louti*

Adult

Heemstra and Randall describe goupers as typically ambush predators, hiding in crevices and among coral and rocks in wait for prey. *V. louti* feeds primarily on fishes (particularly coral-reef species), crabs, shrimps and stomatopods, with adults reportedly feeding during both daylight and nighttime hours, the authors add.

Essential Fish Habitat: Shallow-water species complex (0-100)

Habitat description for *Variola louti* (lunartail grouper)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Serranid eggs incubate in 20-35 days	The pelagic larval stage of groupers is 25–60 days	*V. louti* are reported to reach maturity between 81 cm and 100 cm in length	No information available
Diet	N/A	N/A	No information available	*V. louti* feeds primarily on fishes (particularly coral-reef species), crabs, shrimps and stomatopods
Distribution: General and Seasonal		The wide geographic distribution of serranids is thought to be due to this relatively long pelagic larval phase	The juveniles of some species of serranids are known to inhabit sea-grass beds and tide pools. There is no specific information available for the habitat utilization patterns of juvenile *V. louti*	Distributed throughout the tropical Indo-Pacific region from the Red Sea to South Africa to the Pitcairn Islands. In the western Pacific, it ranges southern Japan to New South Wales, Australia, and is found at most of the islands of the west central Pacific. *Variola louti* is absent from the Hawaiian Islands.
Water Column	Pelagic	Pelagic	Demersal	Demersal
Bottom Type	N/A	N/A	No information available	Commonly found on coral reefs at depths of 4 to 200 m.
Oceanic Features	Subject to advection by prevailing currents	Subject to advection by prevailing currents	No information available	No information available

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1.5.15 Habitat description for *Beryx splendens* (alfonsin)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland

and Baker Islands and Wake Islands.

Life History and General Description

The alfonsins (Berycidae), typically bright red in coloration, are fairly large fish. The family consists of two genera, *Beryx and Centroberyx* (Mundy, 1990).

Alfonsin inhabit rocky bottom habitats at depths of several hundred meters (Seki and Tagami, 1986; Masuda et al., 1975). The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific, Indian and Atlantic oceans (Busakhin, 1982). In the Pacific northern hemisphere, alfonsin are found primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific. In the central Pacific, alfonsin are found over seamounts while in the western Pacific region they are also found over continental shelf areas (Humphreys et al., 1984). Over the SE-NHR seamounts their distribution overlaps with that of the pelagic armorhead (*Pseudopentaceros wheeleri*). Most of the available information about the biology and life history of alfonsin come from studies done in the South Pacific and a few Russian studies from the Atlantic. Alfonsin occupies a wide depth range from 10 to 1240 m (Lehodey and Grandperrin, 1995; Massey and Horn, 1990).

Based on examination of otoliths, Lehodey and Grandperrin (1996) calculated a maximum age of 16.8 years for a female of 56.7 cm (FL). The average size of alfonsin captured at the Hancock seamounts in the SE-NHR region ranges from 15.3 to 35.3 cm (FL) (Uchida, 1986).

In the South Pacific, females reportedly grow faster than males, the difference increasing with age (Lehodey and Grandperrin, 1994). At the Hancock seamounts, the sex ratio is nearly equal (Humphreys et al., 1983). In the South Pacific, Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males (Lehodey and Grandperrin, 1996; Mundy, 1990). In the western Pacific, alfonsin reportedly reach sexual maturity by age three (Ikenuye, 1969). Alfonsin spawns between August and October in the Hancock seamount region (Mundy, 1990). The pelagic eggs hatch approximately 1 day after spawning (Uchida, 1986)

Tagging studies conducted by Japanese researchers indicate that alfonsins migrate form coastal to offshore waters as they mature. Alfonsins become demersal at one year of age or less (Uchida, 1986)

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Alfonsin are taken primarily by means of bottom trawls. While it is the second most abundant species taken in the seamount groundfish fishery it comprises only a small portion of the total catch (Seki and Tagami, 1986). Much of the demersal habitat on the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts is too steep and rough for bottom trawling. In the past, the principal gear used in the harvest of alfonsin by the Japanese was bottom longlines and handlines (Seki and Tagami, 1986).

Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

Although alfonsin are commercially important species little is known about their early life history. As previously mentioned, the eggs of the alfonsin are pelagic and hatch in about 1 day after spawning. The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim (Uchida, 1986). The dispersal of eggs and larvae is determined by the prevailing currents (Humphreys et al., 1983).

Larvae

At the Hancock seamount *Beryx* larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m (Mundy, 1990).

Juvenile distribution

Juveniles undergo a pelagic development phase that lasts several; months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. (Lehodey and Grandperrin, 1994). Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature (Seki and Tagami, 1986).

Galaktionov (1984) studied the schooling behavior of juvenile alfonsin. He found that during midday juveniles were concentarted on the bottom. Between 1700 and 1800 hour’s school formation occurs relatively rapidly. The schooled juveniles move into shallower water at depths as shallow as 75 m around sunset.

Adult distribution

The alfonsin is a bentho-pelagic species, migrating to the surface at night to feed returning to the bottom during the day (Lehodey and Grandperrin, 1994). Galaktionov (1984) reports that adult alfonsin form dense schools from 1000 to 1100 hours and from 1600 to 1700 to hours. The fish school while at or near the bottom and slowly migrate upward through the water column.

Food habit studies indicate that small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids (Uchida, 1986). Alfonsin are believed to prey primarily on bathypelagic organisms with benthic prey contributing little to its diet (Lehodey and Grandperrin, 1994). In turn, large pelagic predators, including tuna, prey upon alfonsin.

In the western Pacific region, the abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio (Uchida, 1986). Size increases with depth and latitude (Uchida, 1986). Sekli and Tagami (1986) report an optimum temperature range for this species of 6◦ to 18◦ C.

Essential Fish Habitat: Seamount groundfish complex

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29°-35°N and longitude 171°E-179°W between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29°-35°N and Longitude 171°E-179°W.

Habitat description for *Beryx splendens* (alfonsin)

	Egg	Larvae	Juvenile	Adult
Duration	Eggs hatch approximately 1 day after spawning	The larvae are planktonic for the first 2 to 3 days of existence after which time they begin to swim.	Alfonsin reaches sexual maturity at 6 years of age for females and at 7 to 8 years for males; approximately 33 to 34 cm respectively for females and males	16.8 years for a female of 56.7 cm
Diet	N/A	No information available	No information available	Small fish dominate this species diet. Other prey items include small crustaceans including decapods, euphausiids, krill and mysids
Distribution: General and Seasonal	No information available	No information available	Alfonsins migrate form coastal to offshore waters as they mature	The distribution of the alfonsin is widespread in the tropical and subtropical waters of the Pacific. In the Pacific northern hemisphere, alfonsin are found primarily in two areas, over the southern Emperor and Northern Hawaiian Ridge (SE-NHR) seamounts in the central Pacific and from Japan to Palau in the western Pacific.
Water Column	Pelagic	Pelagic, At the Hancock seamount *Beryx* larvae have been found almost exclusively in the upper 50 m of the water column. Larvae are nearly twice as abundant in the upper 25 m than between the 25 to 50 m	Pelagic, Juveniles undergo a pelagic development phase that lasts several; months. Recruitment to benthic habitat takes place at approximately 1.5 years of age. Juveniles inhabit shallower water than do adults, moving into progressively deeper waters as they grow and mature	Demersal, Alfonsin occupies a wide depth range from 10 to 1240 m
Bottom Type	N/A	N/A	N/A	Alfonsin inhabit rocky bottom habitats at depths of several hundred meters. In the central Pacific, alfonsin are found over seamounts while in the western Pacific region they are also found over continental shelf areas
Oceanic Features	The dispersal of eggs is determined by the prevailing currents	The dispersal of larvae is determined by the prevailing currents	The abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio	The abundance and distribution of alfonsin is dependent on the prevailing currents, particularly the Kuroshio

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1.5.16 Habitat description for *Hyperoglyphe japonica* (ratfish, butterfish)

<u>Management Plan and Area</u>: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

There is no information available concerning the life history and basic biology of the ratfish. This species is infrequently taken as an incidental species in conjunction with the seamount groundfish fishery.

1.5.17 Habitat description for *Pseudopentaceros wheeleri* (armorhead)

<u>Management Plan and Area</u>: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

Boehlert and Sasaki (1988) and Humphreys et al. (1983) were the primary sources used in the preparation of this species profile.

The pelagic armorhead (*Pseudopentaceros wheeleri*) is widely distributed throughout the North Pacific Ocean (Boehlert and Sasaki, 1988). Electrophoretic and meristic work suggests that a single stock of pelagic armorhead exists (Humphreys et al., 1983). Oceanographic conditions seem to be the primary factor regulating the armorhead’s distribution. Zones of upwelling, produced by the prevailing currents, result in high biological productivity over the Southern Emperor-Northern Hawaiian Ridge (SE-NHR) seamounts (Pontekorvo, 1974 in Humphreys et al.,1983). The life histories and distributional patterns of the armorhead are poorly understood as is the effects of oceanographic variability on migration and recruitment of the armorhead.

The pelagic armorhead has two distinct life history phases that includes a pelagic juvenile phase and a demersal adult phase (Somerton and Kikkawa, 1992). Between 1.5 and 2.5 years of age, the pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy pre-recruit phase (Humphreys, 1995; Somerton and Kikkawa, 1992). During this time the fish remain nonreproductive. Subsequently, these fish recruit to demersal habitat on the SE-NHR seamounts. Humphreys et al. (1983) report that adults are found on the slopes of seamounts down to depths of 800 to 900 m. The commercial fishery for pelagic armorhead targets fish on the summits of seamounts at the 200 to 490 m depth range (Humphreys et al., 1983; Takahashi and Sasaki, 1977)

The smallest reported sizes for pelagic armorhead range from 5 to 20 mm and typically occurred south of 33 N◦ (Humphreys et al., 1984). Research indicates an age estimate of 3 years for 22 cm fork length (FL) and 6 years for 32 cm fork length (Humphreys et al., 1983). Based on length frequency data, it is believed that fish taken by the trawl fishery are typically 5 to 7 years of age (Chikuni, 1970 in Humphreys et al., 1983). Females are slightly larger than males.

Adult pelagic armorhead have three distinct morphological types: “lean type”, “intermediate type” and “fat type”. While all three types are found over the SE-NHR seamounts, the lean and intermediate types predominate. The epipelagic phase of the armorhead life history is characterized by the accumulation of fat reserves and continuous somatic growth (Humphreys et al., 1989). The bluish mottled coloration of the open ocean fat type is indicative of its epipelagic existence. The open ocean fat type is nonreproductive. After recruitment to the summits of the SE-NWR seamounts, newly settled adults rapidly lose their mottled bluish coloration, ultimately assuming a brownish coloration. This transformation is fairly rapid and explains the relatively low abundance of fat type on the seamounts. Somatic growth ceases and the fat reserves are depleted as the fish become reproductively active. These physiological changes result in the intermediate morphological type and ultimately the lean type as the fat reserves are further depleted (Humphreys et al., 1989). The existences of these distinct morphological types are absent in juveniles. (Humphreys et al., 1983).

The main reproductive population is found on SE-NHR seamounts between latitude 29° and 35° N. (Boehlert and Sasaki, 1988). Spawning activity is benthic and is restricted to December to February at the SE-NHR seamounts.(Humphreys, 1995). Peak spawning activity occurs between January and February (Humphreys et al., 1983). Research indicates that armorhead reach sexual maturity at 1.5 to 2.5 years in age, ranging in size from 23.0 to 28.5 standard length (Boehlert and Sasaki, 1988). Spawning occurs at depths ranging from 200 to 500 m (Boehlert and Sasaki, 1988). It is thought that *P. wheeleri* is semelparous, spawning only once before dying.

Eggs, larvae and juveniles are pelagic and are found widely distributed in the North Pacific Ocean (Boehlert and Sasaki, 1988). Initially the larvae are found in the epipealgic waters in the vicinity of the SE-NHR seamounts (Humprheys et al., 1993). The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean (Humphreys et al., 1993). Boehlert and Sasaki (1973) report a 1.5 to 2.5 year time period between spawning and recruitment to the seamounts. The process by which these fish return and recruit to the seamounts is poorly understood (Humphreys et al., 1993). It is thought that recruitment occurs only during the late spring to midsummer months. The long pelagic phase combined with the variability of oceanic conditions play an important role in determining the strength of year-classes in this species (Boehlert and Sasaki, 1988). The size of individuals at recruitment is generally uniform, ranging from 25 to 33 cm (Humphreys et al., 1989).

In the past, a large-scale foreign seamount groundfish fishery extended throughout the southeastern reaches of the northern Hawaiian Ridge. The seamount groundfish complex consists of three species (pelagic armorhead's, alfonsins, and ratfish). These species dwell at 200 to 600 m on the submarine slopes and summits of seamounts. A collapse of the seamount groundfish stocks has resulted in a greatly reduced yield in recent years. Although a moratorium on the harvest of the seamount groundfish within the EEZ has been in place since 1986, no substantial recovery of the stocks has been observed. Historically, there has been no domestic seamount groundfish fishery.

Egg and larval distribution

The egg, larval and juvenile stages of the pelagic armorhead all occur in the surface layers where they are subject to advection by the prevailing currents (Humphrey et al., 1984; Borets, 1979).

Larval and juvenile stages prey on zooplankton. Interannual variability in environment conditions affecting the abundance and availability of zooplankton may play an important role in the survival of these early life stages and thus year class strength (Boehlert and Sasaki, 1988).

Larvae of *P. wheeleri* are neustonic and are carried eastward by the prevailing wind driven surface flow in the SE-NHR seamount region (Boehlert and Sasaki, 1988). Through some unknown mechanism, fish move northeastward ultimately entering the subarctic waters of the Alaska gyre (Boehlert and Sasaki, 1988). The two available studies of larval distribution of armorhead conflict but suggest that the distribution of larvae varies from year to year (Boehlert and Sasaki, 1988).

Juvenile distribution

As stated, during the first 1.5 to 2.5 years of life, juveniles lead a pelagic existence., inhabiting the epipelagic zone of the subarctic-transitional waters of the North Pacific Ocean (Somerton and Kikkawa, 1992). Subsequently, a shift occurs from pelagic to demersal habitat. During the pelagic juvenile phase, armorhead acquire large reserves of fat before recruiting to SE-NHR seamounts. The largest influx of juvenile recruits to the Juveniles recruit to the SE-NHR seamounts occurs during spring between April and June (Humphreys, 1995). Recruits are characterized by their bluish to grey coloration and their fat reserves. After recruitment, the fish gradually assume a brownish coloration. The diet of juveniles is comprised primarily of small plankktonic prey items, particularly copepods (Borets, 1979).

Adult distribution

As stated, adults are found on the slopes of seamounts. *P. wheeleri* display crespuscular migrations through the water column. During daylight hours, they are found in the upper water column at depths between 80 to 100 m. As dusk approaches they descend to the summits of the seamounts. It is thought that these movements are related to foraging activity (Humphreys et al., 1983). At night, dense aggregations of armorhead are found on the summits of the seamounts (Somerton and Kikkawa, 1992).

The pelagic armorhead feeds during daylight hours, especially between the hours of 0800 and 1000. (Humphreys et al., 1983; Sakiura, 1972). Prey items include epipelagic crustaceans, copepods, amphipods, tunicates,eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish. Organisms of the deep scattering layer also comprise a portion of this species diet (Humphreys et al., 1983; Sakiura, 1972).

It is believed that the horizontal and vertical distribution of *P. wheeleri* is controlled by water temperature. The lower tolerance limit is approximately 5 C◦ while the upper limit is roughly 20 C◦. It is thought that the preferred temperature range of this species is 8 to 15 C◦ (Humphreys et al., 1983; Chikuni, 1971). Pelagic armorhead are found year-round on the southern Emperor-Northern Hawaiian Ridge seamounts.

The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years.

Essential Fish Habitat: Seamount groundfish complex

The EFH designation for the adult life stage of the seamount groundfish complex is all EEZ waters and bottom habitat bounded by latitude 29°-35°N and longitude 171°E-179°W between 80 to 600 m. EFH for eggs, larvae and juveniles is the epipelagic zone (~ 200 m) of all EEZ waters bounded by latitude 29°-35°N and Longitude 171°E-179°W.

Habitat description for *Pseudopentaceros wheeleri* (armorhead)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	No information available	No information available	Fish recruit to demersal habitat between 1.5 and 2.5 years of age	The life expectancy of the armorhead once it has recruited to demersal habitat ranges from 4 to 5 years
Diet	N/A	Larval stages prey on zooplankton	Juvenile stages prey on zooplankton	Prey items include epipelagic crustaceans, copepods, amphipods, tunicates,eupausiids, pteropods, sergestids, myctophids, macrura and mesopelagic fish.
Distribution: General and Seasonal	Eggs are found in the epipealgic waters in the vicinity of the SE-NHR seamounts	Initially the larvae are found in the epipealgic waters in the vicinity of the SE-NHR seamounts	The pelagic armorhead inhabits the epipelagic zone of the subarctic-transitional waters of the North Pacific during a lengthy pre-recruit phase	The pelagic armorhead (*Pseudopentaceros wheeleri*) is widely distributed throughout the North Pacific Ocean
Water Column	Pelagic	Pelagic	Pelagic	Demersal, During daylight hours, they are found in the upper water column at depths between 80 to 100 m. At night, dense aggregations of armorhead are found on the summits of the seamounts
Bottom Type	N/A	N/A	N/A	Adults are found on the slopes of seamounts down to depths of 800 to 900 m
Oceanic Features	The eggs are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	The larvae are transported by prevailing ocean currents to the subarctic waters of the North Pacific Ocean	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.	Oceanographic conditions seem to be the primary factor regulating the armorhead's distribution.

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2 PELAGICS SPECIES

The most important fish (economically, culturally and socially) in the Pacific are oceanic and pelagic, meaning they live in the near-surface waters of the ocean, often far from shore. Tuna, billfish and other large pelagic species are among the world's most popular fish sought for food and sport. These fish are noteworthy for their rapid growth and, for the tunas, high rates of reproduction, as well as their remarkable swimming speed and stamina. Unlike nearshore pelagic species or bottom-dwelling fish that spend most of their lives near islands, pelagic fish move freely in the oceanic environment. Variations in the distribution and abundance of these nomadic species are often related to differences between their life history profiles, migration patterns and habits that are affected by ever-changing environmental influences, such as water temperatures, current patterns and the availability of food.

2.1 Pelagics Habitat

Species of oceanic pelagic fish live in tropical and temperate waters throughout the world's oceans, including the Pacific. They are capable of long migrations that reflect complex relationships to oceanic environmental conditions. These relationships are different for larval, juvenile and adult stages of life. The larvae and juveniles of most species are more abundant in tropical waters, whereas the adults are more widely distributed. Geographic distribution varies with seasonal changes in ocean temperature. In both the northern and southern hemispheres, there is seasonal movement of tunas and related species toward the pole in the warmer seasons and a return toward the equator in the colder seasons. In the western Pacific, adults of pelagic fish range from as far north as Japan and as far south as New Zealand. Albacore, striped marlin and swordfish can be found in even cooler waters at latitudes as far north as 50°N and as far south as 50°S. As a result, fishing for these species is conducted year-round in tropical waters and seasonally in temperate waters.

Migration patterns of pelagic fish stocks in the Pacific Ocean are not easily understood or categorized, despite extensive tag-and-release projects for many of the species. This is particularly evident for the more tropical tuna species (yellowfin, skipjack, bigeye) that appear to roam extensively within a broad expanse of the Pacific centered on the equator. In other words, their migrations appear to be mainly restricted by water temperature and continental land masses and are often linked to large-scale water movements that physically transport fish from one area to another within a favorable temperature range. Although tagging and genetic studies have shown that some interchange does occur, it appears that short life spans and rapid growth rates restrict large-scale interchange and genetic mixing of eastern, central and far-western Pacific stocks of yellowfin and skipjack tuna. Morphometric studies of yellowfin tuna also support the hypothesis that populations from the eastern and western Pacific derive from relatively distinct sub-stocks in the Pacific. The stock structure of bigeye in the Pacific is poorly understood, but a single, Pacific-wide population is assumed.

The movement of the cooler-water tuna (bluefin, albacore) is more predictable and defined, with tagging studies documenting regular and well-defined seasonal movement patterns relating to specific feeding and spawning grounds. The oceanic migrations of billfish are poorly understood, but the results of limited tagging work conclude that most billfish species are capable of transoceanic movement, and some seasonal regularity has been noted.

Large pelagic fish are closely associated with their physical and chemical environment. Tuna tend to be most concentrated where food is abundant, commonly near islands and seamounts that create divergences and convergences, near upwelling zones along ocean current boundaries and along gradients in temperature, oxygen and salinity. Swordfish tend to concentrate along food-rich temperature fronts between cold, upwelled water and warmer oceanic water masses.

Gradients in temperature, oxygen or salinity determine whether or not the surrounding water mass is suitable for pelagic fish. Fishermen sometimes use satellite images to help locate these thermal fronts. Oceanic pelagic fish such as skipjack and yellowfin tuna and blue marlin prefer warm surface layers, where the water is well mixed by waves and is relatively uniform in temperature. Other fish such as albacore, bigeye tuna, striped marlin and swordfish, prefer cooler, more temperate waters, often meaning higher latitudes or greater depths. Preferred water temperature often varies with the size of the fish. Adult pelagic fish usually have a wide temperature tolerance, and during spawning they generally move to warmer waters that are preferred by larval and juvenile stages. Large-scale oceanographic events (such as the El Niño –Southern Oscillation) change the characteristics of water temperature and productivity across the Pacific, and these events have a significant effect on the habitat range and movements of pelagic species.

Tuna movements are related to oceanographic characteristics, particularly water temperature and oxygen concentration. In the ocean, light penetration and water temperature diminish rapidly with increasing depth and, once below the thermocline, the water temperature is only a few degrees above freezing. Many pelagic fish make vertical migrations through the water column. They tend to inhabit surface waters at night and deeper waters during the day, but several species make extensive vertical migrations between surface and deeper waters throughout the day. Certain species, such as swordfish and bigeye tuna, are more vulnerable to fishing when they are concentrated near the surface at night. Bigeye tuna may visit the surface during the night, but generally, longline catches of this fish are highest when hooks are set in deeper, cooler waters just above the thermocline (275–550 m or 150–300 fm). Surface concentrations of juvenile albacore are largely concentrated where the warm mixed layer of the ocean is shallow (above 90 m or 50 fm), but adults are caught mostly in deeper water (90–275 m or 50–150 fm). Swordfish are usually caught near the ocean surface but are known to venture into deeper waters.

2.2 Pelagics Yield

Tuna, billfish, dolphinfish and wahoo are caught collectively by a variety of fishing gear types. At the latitudes of the US Pacific islands, fishermen generally catch tuna and billfish during predictable seasons. Their actual abundance in any particular year, however, is difficult or impossible to predict and is subject to countless factors in the oceanic environment. This variability is probably related to annual fluctuations in standing stock size and oceanographic characteristics.

The rates at which pelagic fish grow vary greatly among species and to a large degree determine the level of fishing pressure a species can withstand. For instance, skipjack tuna that grow and mature quickly can be safely harvested at very high levels, while slower growing bluefin tuna are easily overfished.

Yellowfin Tuna—Semi-independent stocks may exist in the western and central Pacific, which are considered relatively distinct from eastern Pacific yellowfin, but the maximum sustainable yield (MSY) of these stocks is still not well known despite considerable scientific research. Estimates based on surface fisheries (purse seine) and sub-surface fisheries (longline) provide different perspectives The western and central Pacific regional catch has reached 375,000 mt. per year (of which, less than 1% comes from domestic landings in the US Pacific islands region). It appears that western Pacific yellowfin stocks are not yet fully utilized, but fishing effort and catch are expected to steadily increase in coming years.

Bigeye Tuna—A single ocean-wide stock of bigeye tuna is assumed. The Pacific-wide catch has reached 152,000 mt. per year (of which, about 1% comes from domestic landings in the US Pacific islands region). This is close to the estimated MSY, and the stock is considered fully utilized. Because juvenile bigeye are known to associate strongly with flotsam, increasing purse seine catches around flotsam and fish aggregating buoys raises concern about potential overfishing.

Skipjack Tuna—Tagging results indicate considerable movement of skipjack tuna in the Pacific. Even so, complete mixing of the population does not occur across the whole region within one generation of fish. Contradictory results of genetic studies suggest uncertainty about stock structure. The total annual catch from the central and western Pacific is approaching 800,000 mt. (of which, less than 1% is produced by domestic fisheries of the US Pacific islands). Although the current level of catch and fishing effort is at a record high, fishing mortality accounts for only a small fraction of stock attrition because of the skipjack tuna's high rates of reproduction, growth and mortality. Thus, while MSY has yet to be determined, the stocks appears to be underutilized and is expected to easily sustain expanded fishing pressure by expanding fisheries.

Albacore—Discrete spawning areas and larval distributions are apparent for North and South Pacific albacore stocks. Low catches of adults in equatorial waters suggest that the fish is limited between hemispheres. Domestic fisheries from the US Pacific islands produce less than 1% of the 59,000 mt annual Pacific-wide catch. MSY estimate for albacore in the North and South Pacific appeared to give reasonable stock assessments before the development of the high seas drift gillnet fishery. With the rapid development and cessation of the driftnet fishery, however, there are now uncertainties about the reliability of those earlier stock assessments. Adult fish in the South Pacific stock are considered fully or overexploited. Expansion of surface fisheries targeting juvenile fish could have a detrimental impact on the abundance of adult albacore in the South Pacific. In the North Pacific, some assessments conclude that the stock is overexploited, but other research concludes that the adult stock remains stable.

Striped Marlin—Separate North and South Pacific sub-stocks are hypothesized on the basis of a north-south separation of spawning grounds, except in the equatorial eastern and western Pacific. These fish spawn in the western Pacific, are recruited into the Mexican fishery of the eastern Pacific and move westward as they mature. In the North Pacific, semi-independent sub-populations are thought to blend over time. Domestic fisheries from the US Pacific islands contribute about 4% of the annual regional catch of 10,000 mt. MSY is unknown, but the stock is considered underutilized because there has been no decline in yield under increased levels of fishing pressure.

Blue Marlin—Pacific blue marlin are thought to belong to a single, ocean-wide stock due to an observed homogeneous distribution of larval and adult fish. The current stock status is unclear. The total annual Pacific catch in recent years is estimated to be around 20,000 mt (domestic landings from the US Pacific islands comprise less than 5% of the total). A recent MSY estimate of 20,000 mt/yr was 2,000 mt/yr less than previous estimates. During the 1970s the stock may have been over-utilized, but as longline fleets have changed fishing methods to target deeper-swimming bigeye tuna, the incidental catch of blue marlin has decreased. There may have been some recovery of the stock, evidenced by an increase in the average weight of blue marlin taken by the Japanese longline fishery since 1975.

Swordfish—The stock structure of swordfish in the western, central and South Pacific is unclear. Domestic landings from the US Pacific islands (mainly the Hawaii longline fishery) produce more than 20% of the 18,000 mt of swordfish caught in the northwest and eastern central Pacific, and about 15% of the Pacific-wide catch. The distribution of catches the possibility of, at least, North and South Pacific stocks. Changes in the longline fisheries have cast doubt on the way previous MSY estimates were calculated, and current catch levels have exceeded the two previous Pacific MSY estimates. To date, however, no indication of decreasing swordfish size has been found in the Hawaii fishery and stocks do not appear to have been exploited on a Pacific-wide basis to the extent that would cause a declining trend in catch rates.

Dolphinfish and Wahoo—North and South Pacific stocks of dolphin fish are apparently separate. Little is known of the stock structure of wahoo. No estimates of MSY are available for either species. The risk of overfishing dolphinfish is probably slight due to the apparent high natural turnover (with a maximum life span of four years). Too little is known about wahoo to estimate MSY.

2.3 Biological Information

Tuna and billfish have many physiological adaptations for life in the open ocean. Tuna and tuna-like species are the fastest fish in the world. Bursts of speed exceeding 12–20 kph (20–30 mph) are not unusual. Tuna have streamlined bodies that are specifically adapted for efficient swimming. They have large white muscle masses useful for swimming long distances and red muscle masses for short bursts of speed when chasing prey or escaping predators. Tuna also have circulatory heat exchangers that can raise or lower their body temperatures in response to heating up when vigorously feeding or swimming or cooling down when entering subsurface waters. Unlike most fishes, the circulatory system of tuna can maintain their body temperatures above that of the water in which they live, effectively making them a "warm blooded" animal. This adaptation may allow tuna to utilize their energy reserves quickly, which can translate to a rapid burst of speed and increased efficiency of the brain and eyes, so necessary to hunting prey in cold, deep water.

The tuna's circulatory and respiratory systems are unique in the fish world. Fish are cold-blooded, and, for most, the temperature difference between shallow and deep layers of the ocean is a physical barrier to vertical migrations. Tuna, however, have evolved the necessary physiological adaptations to accomplish this activity. The ability to make vertical migrations between cold, deep ocean waters and warm surface waters increases the tuna's available habitat for feeding and ability to maintain a relatively constant body temperature. Some tunas move into deeper water to dissipate excess heat produced by feeding in warmer surface waters. Other tuna exhibit the reverse behavior. The tuna's circulatory system is also designed to conserve heat when the fish is relatively inactive and to dissipate heat when activity increases.

Billfish have a large white muscle mass but a smaller mass of red muscle than tunas. Thus, billfish must rely on different defenses against the deleterious effects of changes in water temperature. For example, swordfish have heater organs that warm the brain and eyes to help to protect the central nervous system from rapid temperature changes. The bill of a billfish may also be a special adaptation to reduce drag and increase speed, as well as a weapon for killing prey and for defense.

To orient and guide themselves on their extensive migrations across the open ocean, tuna and billfish are thought to rely somehow on small particles of magnetite, a magnetic material found near nerve endings in the skulls of these fish. Combined with other environmental cues, the fish may use magnetite to navigate using a "biological compass" attuned to the earth's magnetic field.

For most species of tuna and billfish it is reasonable to assume a single, ocean-wide stock in the Pacific where a mingling of fish takes place gradually through the fish's whole life-span. The exchange of fish among areas is difficult to determine because these fish move seasonally between feeding and spawning areas, toward the poles and back. Sub-stocks may exist, with some studies supporting the idea of stock discrimination between the eastern and western Pacific. Results from genetic and tagging studies, however, indicate that some degree of mixing does occur. For albacore and striped marlin, there is evidence of distinct North and South Pacific sub-stocks.

Most of the oceanic pelagic fish form schools (wahoo less commonly so). Schools are most compact when the fish are spawning or attracted to a common food source near features such as a seamounts, flotsam or man-made fish aggregation buoys. Marlin are often seen in pairs or in groups of several males with a single female.

Direct interactions among tuna, billfish dolphinfish and wahoo species are not known, although they compete at the top of the food chain for the same prey. Tuna schools that are associated with dolphins are common in the eastern tropical Pacific, but are rare m the western and central Pacific. The distribution of surface skipjack and juvenile yellowfin tuna schools (as well as dolphinfish and wahoo) are frequently associated with logs, other flotsam and fish aggregation devices. Fishermen also search for flocks of seabirds, which help to reveal tuna schools feeding on baitfish at the surface. Although skipjack, small yellowfin and small bigeye tunas are sometimes caught together, they maintain discrete schools and their co-occurrence around flotsam is probably the result of mutual attraction to food. In the western Pacific, in addition to floating objects, yellowfin and skipjack tuna are sometimes associated with the presence of whales and whale sharks.

2.4 Life History

2.4.1 Eggs and larval stages

Pelagics eggs are tiny (about 1 mm diameter); they float with the help of an enclosed oil droplet. Billfish eggs are somewhat larger than those of tuna.

2.4.2 Juvenile

Although these pelagic fish begin life at only a few millimeters in length, they can reach large sizes. All species grow rapidly during the early years of life with a gradual slowing of growth thereafter. A young tuna may add 2–4 cm (0.8–1.6 in) per month to its body length during the first two years of life and 0.5–2 cm (0.2–0.8 in) per month thereafter. Growth rates vary considerably depending on ocean conditions and food availability. The relationship between age and size in billfish is not as well understood.

2.4.3 Adults

As subadults, male and female pelagic fish grow at approximately the same rate. After reaching sexual maturity, however, female tuna grow more slowly than male tuna, apparently in response to the higher energy requirements for egg maturation and spawning. In contrast, female marlin and swordfish grow faster than males after maturation and female marlin reach much larger sizes than the males. Dolphinfish males tend to be heavier than females of the same length after 68 cm (27 in) due to differences in body morphology, i.e., the large head of male dolphinfish.

2.4.4 Forage and prey

The energy demands of swimming are great, and tuna and other pelagic fish have voracious appetites. Some species consume as much as 25% of their own body weight every day. Most oceanic pelagic fish are opportunistic carnivores with variable diets. The major prey items can vary substantially during different stages of life, in different regions of the Pacific and in different seasons. Adults feed on a variety of small fish, shrimp and squid, while juveniles are more opportunistic, feeding on pelagic invertebrates such as crab larvae, isopods and copepods. Some species have very specific and well-known predator-prey relationships, such as dolphinfish preying on flying fish, swordfish on squid, and blue marlin on skipjack tuna. Larval and juvenile tuna are, in turn, prey for fish, seabirds, porpoises and other animals. Adult tuna are often cannibalistic, feeding on the young of their own species. The presence of tuna larvae in tuna stomach samples is common enough that this occurrence has been used to identify areas of recent tuna-spawning activity. Only humans, marine mammals and sharks are known to prey on adult tuna and billfish

2.4.5 Reproductive biology

Most oceanic pelagic fish spawn over vast areas of the Pacific in warm surface waters. Spawning generally occurs through out the year in the tropics, and more seasonally at higher latitudes when sea surface temperatures (SST) are over 24°C (75°F). Individual females may spawn many times during the season at short intervals. All tuna and tuna-like species have high reproductive rates, producing millions of eggs per year to compensate for the large percentage of eggs that do not survive to adults. A spawning female tuna or billfish may release about 100,000 eggs per kilogram of her body weight.

Species such as skipjack tuna and dolphinfish have short lives (4–5 years) and reach sexual maturity in their first year of life. Some billfish and larger tunas may live 10–20 years and do not reproduce until they are 3–5 years old. Swordfish may first reproduce at 5–6 years old.

2.2 Life Histories and Habitat Descriptions for Pelagic Species

2.2.1 Habitat description for *Coryphaena hippurus* and *C. equiselis* (dolphinfish, mahimahi)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reff, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Island.

Life History and General Description

There are two species of dolphinfish, or, as it is known in Hawaii, mahimahi: *Coryphaena hippurus*—by far the most common—and *C. equiselis* (the "pompano dolphin"), which is infrequent in inshore areas. Boggs and Ito (1993) describe the Hawaii fishery only in terms of *C. hippurus*. According to Kojima (1966), there are two sub-populations of *C. hippurus*—one in the Northern Hemisphere and one in the Southern—but this assertion is based on differing seasonal migration patterns.

The dolphinfish is a fast swimming primarily oceanic fish distributed throughout the tropics and sub-tropics of the world's oceans. According to Shcherbachev (1973) *C. hippurus* is widely distributed in the Pacific: longitudinally between 46ºN and 38ºS, in the central Pacific from the Hawaiian Islands in the north and the Tuamotu archipelago in the south and in the eastern part from Oregon to Peru. Although primarily an ocean fish, it may occasionally be caught in estuaries and harbors (Palko and Beardsley et al. 1982). *C. equisetis* is a more exclusively oceanic fish and is rarely caught in coastal waters. Schherbachev (1973) notes a more restricted range, 38ºN–28ºS in the western Pacific and in the east from California to around 17º20′S. Palko and Beardsley et al. (1982) state that *C. hippurus* is restricted by the 20ºC isotherm, although Shcherbachev (1967) notes that a specimen was caught in 12.4ºC in the Sea of Oshtok. Habitat conditions for *C. equisetis* are not well known but a minimum of 24ºC is suggested by Palko and Beardsly et al (1982). They also state that this species is common in Hawaiian waters. Insufficient information is available to describe the hypothetical habitat of dolphinfish beyond these temperature limits in the 20º–24º range with occasional intrusions into much cooler waters.

According to Palko and Beardsly et al. (1982) there is little information about migrations of either species. Kojima (1965) argued that dolphinfish in the Sea of Japan make a northward migration in the warmer months until September and then return south. This is evidenced in Hawaii by seasonal variations in the catch rate. In Hawaii the peak fishing season is March–April and October–November. In American Samoa peak months are July–October while in the Marianas and Guam fish landings are highest January–April. This reflects a migration pattern away from the equator during the warmer months in both hemispheres.

Dolphinfish also segregate into schools by sex and size. Females and young may be more closely associated with floating objects (see below). According to Palko and Beardsly et al.

(1982) seasonal variation may also be caused by ecological differences between adult spawning schools and young feeding schools.

Beardsly (1967), based on work in the Atlantic, notes that dolphinfish are closely associated with floating objects and that aggregations are common below windrows of floating *Sargassum* seaweed. He also reports that in the Atlantic a large school of dolphinfish was seen to follow a floating *Sargassum* mat northward some 260 km off the coast of Florida. It is apparent that dolphinefish are strongly attracted to floating objects, probably because of the availability of prey, and this may influence their movements also.

C. hippurus grow rapidly and have a short life span of about four years; no information is available on *C. equiselis* longevity. Lengths at age given by Kojima (1966) for Pacific specimens are first year: 38 cm FL; second year: 68 cm FL; third year: 90 cm FL; and fourth year: 108 cm FL.

Dolphinfish are heterosexual and sexually dimorphic: males have a steeper head profile in both species. Males are also heavier than females for any given length, and this difference increases with length (Beardsly 1967). Within schools significant variations in sex ratio occur; this is probably due to differential schooling of small and large fish and size related sexual dimorphism (Palko and Beardsley et al. 1982).

Dolphinfish have an extended spawning season: year round in the tropics and in the warmer months in sub-tropical areas (Palko and Beardsley et al. 1982). Ditty and Shaw et al. (1994) discuss larval distribution of dolphinfish in the Gulf of Mexico (see below). If larval abundance correlates with spawning activity then water temperatures of 24ºC and higher and salinities of 33 ppt and higher are preferred. Larvae were also more common offshore, particularly for *C. equisetis*. Shcherbachev (1973) notes that eggs of *C. hippurus* were found in Japanese waters during summer months when water temperatures were 21–29ºC.

Region-wide dolphinfish is not a major fishery, but it is important locally in recreational, subsistence and commercial fisheries. Fish aggregating devices are particularly effective for catching dolphinfish. In Japan a coastal “shiira-zuke” fishery targets fish with aggregating devices made from materials such as bundles of bamboo reeds.

	Longline	**Handline and Troll**	**Total**
American Samoa	5,761	7,194	12,955
Guam	NA	NA	303,957
Hawaii	230,000	475,000	700,000
Northern Mariana Islands	NA	NA	28,524
Total			1,045,436

In Hawaii dolphinfish are an important component of both the longline and troll fishery. Table 1 shows landing information from the Council’s most recent *Annual Report for the Pelagics*

Fishery.

Egg and Larval Distribution

The ova of *C. hippurus* are buoyant, colorless and spherical, measuring 1.2–1.6 mm diameter, with a single yellow oil globule (Mito 1960). Hatching occurs within 60 h after fertilization at 24–25ºC. At 26ºC larvae hatched within 40 h (Ditty and Shaw et al. 1994).

Ditty and Shaw et al. (1994) describe larval development and distribution in the Gulf of Mexico. In the Pacific, Mito (1960) describes larval development. Palko and Beardsley et al. (1982) state that dolphin gradually metamorphose from larvae into adults without clear breaks between phases. They describe juveniles as being between 9 to 200 mm in length. Ditty and Shaw et al. (1994) were able to distinguish between larvae of the two species as small as 3.5 mm SL based on morphometrics and pigmentation.

Palko and Beardsley et al. (1982) describe larval development. Descriptions indicate that the transition from larval to juvenile phase occurs between 15–30 days. During this period larvae grow at about 1 mm per day. (A 15-day-old larva is described as 15 mm in length; a 30-day-old larva/juvenile is described as 30 mm in length.)

Some information can be obtained on diet from rearing experiments. Hendrix (1983) found that "*C. hippurus* indicate a tendency for larvae to select for *Euterpina* copepods from fist feeding through day 7 when presented a diet of both rotifers and copepods". Larvae were also fed rotifers (*Brachionus plicatilis*), *Artemia salina* nauplii and dolphinfish yolk sac larvae. Shcherbachev (1973) reports that larvae feed mainly on crustaceans and especially Copepoda of the family Pontellidae.

Shcherbachev (1973) describes distribution based on plankton tows (see Figures 4–6 in that publication). In the Pacific they are widely if sporadically distributed. This could be an artifact of non-random collection. Occurrence is most frequent in the western Pacific between 10ºN and 30ºS and in the Panama Gulf in the east. Since dolphinfish are reported to spawn in summer months off of Japan (Palko and Beardsley et al. 1982) it is likely that eggs and larvae have a similar seasonal range expansion. From this data it is not possible to specify larval distribution beyond the known range for adults.

Ditty and Shaw et al. (1994) state "distribution of larvae, juveniles and adults is apparently limited by the 20ºC isotherm". Spawning occurs in oceanic waters beyond the continental shelf, even in the Gulf of Mexico. Larvae were collected at highest densities at 24ºC and above and 33 ppt salinity and above. This may adequately describe a hypothetical habitat.

No information is given on habitat features affecting the abundance of eggs and larvae, but given adults' preference for floating objects; earlier life stages may be more common near objects as well.

Juvenile

The onset of the juvenile stage is not clearly distinguished, as described above. Broadly, juveniles range in size between 15 mm and 55 cm FL. This corresponds to ages between about two weeks and one year.

No information is available on juvenile feeding habits; it is likely that at later stages food preference does not differ markedly from that of adults (see below).

Neither the hypothetical habitat for juveniles or particular features affecting abundance can be specified beyond that described above for adults.

Adult

Beardsly (1967) reports that males are heavier than females and that this difference increased with length. Maximum age is estimated at four years and the largest specimen examined by Beardsly (1967) weighed 35 kg, a sports-fishing record at the time. His data suggest that female dolphin become mature at sizes as small as 35 cm FL; most are mature by 55 cm FL.

Palko and Beardsley et al. (1982) summarize various studies on food preferences. The diet is varied; 32 species of fish from 19 families and one species of crab were reported in one study. Other studies suggest that flying fish are a common prey and that cephalopods are also consumed.

The habitat and particular features affecting abundance does not differ markedly for adults from that described earlier for the species as a whole.

Essential Fish Habitat: Tropical species complex

Dolphinfish are a wide-ranging pelagic species found throughout the tropics and sub-tropics. EFH can only be described based on its known range, temperature requirements and perhaps salinity preferences. Shcherbachev (1973) produced distribution maps (point data based on occurrence in research tows) for larvae and adults, which are reproduced in Palko and Beardsly et al. (1982).

There are no stable features that could be used to identify Habitat Areas of Particular Concern. Dolphinfish are known for their strong association with floating objects.

Habitat description for *Coryphaena hippurus* and *C. equiselis* (dolphinfish, mahimahi)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	36 hrs.	About 3 weeks	To 1 year	4 years total life span
Diet	NA	Zooplankton, larval fish	(See adult)	Varied diet of fish, flying fish a preferred prey, cephalopods
Distribution: General and Seasonal	Year around spawning in tropics, summer range expansion limited by 20º isotherm, preferred habitat 24º C and 33 ppt	Same as eggs	Same as adult	20º isotherms with occasional strays into cooler water. In western Pacific 38º N – 28º S, eastern Pacific California to 17º S
Location	Open ocean	Open ocean	not known to be different from adult	Offshore waters, occasional strays into coastal and estuarine areas
Water Column	Epipelagic	Pelagic, upper mixed layer	Pelagic, mixed layer	Pelagic, mixed layer
Bottom Type	NA	NA	NA	Variable for strays into coastal waters
Oceanic Features	Not known beyond adult preferences	Not known beyond adult preferences	Not known beyond adult preferences	Strong association with floating objects, which will be concentrated in eddies and similar ocean features

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2.2.2 Habitat description for wahoo (*Acanthocybium solandri*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reff, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Island.

Life History and General Description

Wahoo (*Acanthocybium solandri*) is a member of the Scombrid family. Although a popular game fish, wahoo are not a target species in fisheries and are thus relatively little studied.

Wahoo are found worldwide in tropical and warm-temperate seas. In the Pacific their distribution is restricted to coastal America and westward from Hawaii in a band between about 20ºN and 5ºS in the central Pacific to the eastern Australia coast and north to southern Japan (Collete and Nauen 1985). Nothing is known about their population structure in the Pacific.

Adult wahoo are surface oriented and are usually associated with banks, pinnacles and islands and are also found around flotsam in the open ocean. Nakano et al. (1997) studied catch rates of longlines at different depths; wahoo were commonly caught at shallow depths, on hooks between 60–160 m, based on measurements of maximum hook depths of shallow gear. Iversen and Yoshida (1957) state that longline gear fishing below 200 ft. and surface trolling catch rates rarely catches wahoo are much higher close to land. Amesbury and Babin (1990) report elevated catches around Guam in the winter months and describe this as the period when the surface mixed layer is deepest. The hypothetical habitat may thus be described as warm epipelagic and surface neritic waters (above 20ºC) in the tropics to the sub-tropics with a preference for areas of higher productivity including coastal shelves, banks and oceanic fronts.

Iversen and Yoshida (1957) state that wahoo are not found in large compact schools. Instead they travel in small groups of two to 20 fish. They appear to seasonably migratory, moving away from the equator in summer months (Iversen and Yoshida 1957). Hogarth (1976) reports one source stating that "wahoo traveled in a huge circle from Australia and New Zealand back to Ecuador and Costa Rica, and on to Baja, California" but no support is given for this assertion.

As noted above, coastal waters, particularly at the edge of steep drop-offs or reef faces are preferred habitat. Like many other fish, wahoo are attracted to floating objects. This is probably due to the micro-community that typically develops around and under such objects. Floating objects may also concentrate at oceanic fronts. These areas, along with banks and other shallow submerged features are areas of higher productivity, probably the basic reason for these habitat preferences.

According to Hogarth (1976) wahoo are short-lived. He reports the following average lengths based on a sample of 126 fish caught of Cape Hatteras, North Carolina: 1 year old—112 cm; 2 years old—128 cm; 3 years old—141 cm; 4 years old—153 cm. Four years old may be close to a maximum age, which would accord with a reported annual mortality rate of 38% reported by Hogarth (1976).

No special sexual characteristics are mentioned in the literature. Females are extremely fecund; Hogarth (1976) estimated that ovaries held between 0.56 and 45.3 million eggs. Iversen and Yoshida (1957) estimated the number as 6.1 million.

Wahoo are said to spawn year round in the tropics and seasonably in subtropical waters. Hogarth (1976) estimates that spawning occurs in the Gulf Stream off North Carolina from June to August.

In the Western Pacific Region, there are no commercial fisheries that target wahoo (Collete and Nauen 1985). They are a minor component of longline catches and are more frequently caught by surface trolling and are sought by recreational fishermen throughout the region. Wahoo are a popular food fish in Hawaii and are frequently served in restaurants.

In 1996, the most recent data available (WPRFMC 1997), the Hawaii-based longline fleet caught 130,000 lb of wahoo, about 2% of landings. Total commercial landings of wahoo were 500,000 lb, about 1.5% of total landings. Other reported landings for 1996 were 10,858 lb in American Samoa; 142,062 lb in Guam; and 8,626 lb in the Northern Mariana Islands—for a total of 161,546 lb.

Egg and Larval Distribution

Matsumoto (1966) describes a 23.7 mm individual as juvenile; smaller specimens are considered larvae. Chiu and Young (1995) also describe larvae from collections in Taiwan coastal waters.

No information is available on larval food preferences.

Based on collections in the central Pacific, Matsumoto (1966) concludes that larvae are not more abundant near land even though adults are more commonly caught inshore. He collected larvae in the tropical and subtropical Pacific between 30ºN and 25ºS and between 175º and 115ºW but notes that they were scarce in the equatorial countercurrent even though adults are caught there. The longitudinal extent reflects limits of sample stations. Chiu and Chen (1995) also found larvae in offshore areas of Taiwan in Kuroshio Current regions. Occurrences of the larvae were seasonal, caught mainly from May to August in these waters. None of these authors provide information on depth distribution. Hogarth, (1976) cites research in the Atlantic demonstrating a larval preference for water depths greater than 100 m.

Seasonal reproduction and larval occurrence in the subtropics indicates a requirement for warmer water temperatures than the limits of adult tolerance. Unlike adults, larvae have no describable habitat features (i.e., proximity to land and/or shallow depths) affecting abundance and density (Matsumoto 1966).

Juvenile

There is no information on differential characteristics of juveniles. As noted, Matsumoto, (1966) described a 23.7 mm specimen as juvenile. Hogarth (1976) states that wahoo reach sexual maturity and spawn in their first year. Males are mature at 86 cm TL and females at 101 cm TL. Given average lengths for age groups this would correspond to maturity at 9–12 months.

Adult

There are no special habitat characteristics to differentiate adults from other life stages beyond the general theoretical habitat description give above in Section 2.1.
Both Iversen and Yoshida (1957) and Hogarth (1976) examined the stomach contents of adult wahoo. A high percentage of stomachs were empty, ascribed to regurgitation during capture. Iversen and Yoshida (1957) found mackerel scad (*Decapturus* sp.) and skipjack tuna the main prey items. Other identifiable items included squid, pomfret, puffer, flying fish, lantern fish and sunfish. Hogarth (1976), researching in subtropical Atlantic waters, found mackerels to be the most common prey item, followed by Stromateids (butterfishes). Other families included herrings, Carangids and flying fishes.

Essential Fish Habitat: Tropical species complex

Although wahoo are distributed throughout tropical and subtropical waters, coastal and/or shallow depth areas represent important habitat features that can be used in identifying EFH. Collete and Nauen (1985) include a map (at very small scale) showing the worldwide distribution of wahoo. Habitat features that can be used in identifying Areas of Particular Concern include reef faces and steep drop-offs as these are preferred trolling areas.

Habitat description for wahoo (*Acanthocybium solandri*)

	Egg	Larvae	Juvenile	Adult
Duration	Unknown, probably days	Unknown, probably weeks to less than a month	Unknown	9-12 months to about four years
Diet	NA	Unknown	Unknown	Fish, especially skipjack tuna and mackeral scad, squid
Distribution: General and Seasonal	Tropical and seasonal (summer) in subtropical areas	Same as eggs	Unknown, unlikely to be different from adults	Tropical and subtropical with seasonal range extension; rare or possible absent in eastern Pacific except American coast
Location	Open ocean	Open ocean	Unknown, unlikely to be different from adult	Open ocean and coastal waters; also preference banks and flotsam
Water Column	Epipelagic	Epipelagic	Unknown, unlikely to be different from adult	Epipelagic (<200 m) and neritic
Bottom Type	NA	NA	Unknown, unlikely to be different form adult	Preference for steep dropoffs and reef faces
Oceanic Features	Unknown, does not occur near land	Unknown	Unknown	Shallow depths (banks and neritic waters), attracted to flotsam, possibly associated with oceanic fronts

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2.2.3 Habitat description for Indo-Pacific blue marlin (*Makaira mazara*)

Management Plan Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Blue marlin (*Makaira nigricans*) is the most tropical of all marlins. It has been variously described as a single pan-tropical species (Rivas 1974) or two distinct species, *Makaira nigricans* in the Atlantic and *Makaira mazara* in the Pacific (Nakamura 1983). Recent analysis of mitochondrial DNA (Finnerty and Block 1992) suggests that billfish (Istiophoridae and Xiphiidae) should be separated from the suborder Scombroidei—also containing mackerel and tuna—to which they have traditionally been assigned. Other researchers, using similar techniques, found that "[t]he lack of significant genetic differentiation between Atlantic and Indo-Pacific samples of blue marlin and sailfish does not support…recognition of distinct Atlantic and Indo-Pacific species" (Graves and McDowell 1995).

Catches of blue marlin in the Pacific have been reported by about 10 countries with Japan and Korea taking the largest catch (Nakamura 1985). Important fishing areas include the northwest Pacific (FAO Fishing Area 61) and the central Pacific (FAO Fishing Areas 71 and 77) (Nakamura 1985). The majority are caught in the longline fishery. The Japanese have the largest fleet, fishing Pacific wide, with smaller fleets operating from Taiwan and Korea. Since the 1980s the Japanese have increasingly targeted the deeper swimming bigeye tuna (*Thunnus obesus*) resulting in declining catch of surface swimming billfish (Ueyanagi, Shomura et al. 1990). Substantial numbers of billfish were also caught in the high seas drift-net fishery until it was suspended.

Total 1996 landings in the WPRFMC management area amounted to about 911 mt (2,004,966 lb). The vast majority (about 95%) was landed in Hawaii (see Table 1). Of these Hawaii landings, a little over half (1.05 million lb) were caught by longline vessels.

Entity	Landings (lb.)
American Samoa	37,682
Guam	60,500
Hawaii	1,900,00
Northern Mariana Islands	6,784
Total	2,004,966

Blue marlin is caught incidentally by longline vessels and commands a relatively low ex-vessel price (WPRFMC 1997). In Japan marlin are consumed as sashimi (Ueyanagi 1974). Marlin is consumed similarly in Hawaii (WPRFMC 1997). Blue marlin is also an important sport fish, and Kona, Hawaii, is a world-renowned center for big gamefishing. In Guam and the Northern Mariana Islands recreational small-boat trollers and charter boats catch marlin. American Samoa has both troll and longline fisheries, although these are small in comparison to Hawaii.

Because blue marlin is a wide-ranging pelagic species, fishing effort is offshore. Trollers on small, recreational boats and charter vessels make day trips and are thus restricted in their range to tens of miles offshore. Longliners, in contrast, make multi-day trips and may fish outside of the EEZ.

Egg and Larval Distribution

Based on a long-term study of reproductive condition of blue marlin caught in Hawaii billfish tournaments, Hopper (1990) argues that these fish congregate around the Hawaiian Islands during summer months in order to spawn. They migrate from more southerly latitudes, and "Hawaii may be a focus for blue marlin spawning in the northern central Pacific because oceanographic conditions are favorable to survival of marlin larvae and juveniles," Hopper contends. Other researchers (Nishikawa, Honma et al. 1985) note that areas where larvae occur more frequently correspond to the richest summer fishing grounds. It has also been suggested that marlin spawn year-round in tropical waters (see below), but there may be a preference for summer spawning in higher latitudes both north and south of the equator.

Nakamura (1985) states "ripe eggs in the ovary are transparent with a yellow oil globule, and measure about 0.8 to 0.9 mm in diameter." Post-larvae and young are found most abundantly in the western Pacific, especially around the Caroline and Marshall Islands (Howard and Ueyanagi 1965). These authors also state "from occurrence of larvae, condition of gonads, and sex ratio, spawning of this species is assumed to take place in the low latitudinal area (between about 20ºN to 10ºS) throughout the year; and in higher latitudinal areas (bounded by 30ºN and 30ºS) during summer seasons." Matsumoto and Kazama (1974) subsequently found blue marlin larvae heavily distributed around the Hawaiian Islands and westward between 7ºN and 24ºN in the North Pacific and south of the equator to 24ºS from Vanuatu in the west to the Tuamotu Archipelago in the east. At its western end this ties in with the distribution described by the earlier authors; however, "the intervening area (lat. 5º–10ºN and long. 140ºW–180º) appears to be devoid of blue marlin larvae, but this could be due to inadequate sampling; only a few surface day tows were made there" (Matsumoto and Kazama 1974).

In sum, blue marlin may spawn throughout the year in two-tropical/subtropical bands north and south of the equator. These bands expand away from the equator during summer seasons, roughly corresponding to the 24º–25ºC isotherms (Matsumoto and Kazama 1974). Rivas (1974) indicates that larval stage growth is up to at least 52 mm, with a gap in description from that size to about 194 mm.

Juvenile

Because methods of age determination have not been developed for this species, age at which sexual maturity is reached cannot be determined. However, more recently developed techniques may allow age determination (Wilson, 1984). A relation can be developed between otolith weight and age based on saggitae annuli (Wilson and Dean et al. 1991). Based on smallest captures of sexually mature fish Rivas (1974) suggests that males under 35 kg and females under 47 kg are sexually immature. The species exhibits marked sexual dimorphism in size. Females can exceed 540 kg while males usually do not exceed 160 kg (Rivas 1974). As noted above, smaller fish may be more abundant in the western Pacific. There is some evidence of an eastern migration with age; at least the size distribution of captured fish tends to increase to the east. However, this could be explained by differential north-south migration (Howard and Ueyanagi 1965).

Adult

Tracking experiments (Holland and Brill et al. 1990, Block and Booth et al. 1992) show that blue marlin in Hawaiian waters spend most of their time within 10 m of the surface but make frequent and regular dives to deeper depths. This indicated a preference for water temperatures in the 22–27ºC range found in the near surface mixed layer. When near the surface they swim very slowly (<25ms^{-1}). The highest sustained speed directly measured by Block and Booth et al. (1992) was around 100 m s^{-1}, much slower than estimates. Dives are to relatively shallow depths; Block and Booth et al. (1992) recorded a maximum dive depth of 209 m. from the six marlin tracked. It was during dives that short speed bursts of up to 200 m s^{-1} were typically recorded. The authors suggest that there may be a slight preference for surface waters during daylight hours but considerable variation exists among individuals. Based on course data they conclude "these fish are itinerant visitors [to the Hawaiian Islands] and are not part of a resident population." This conclusion is supported by genetic studies that suggest a single Pacific-wide cytochrome b DNA haplotype (Finnerty and Block 1992).

Au (1991) found that billfish were caught in about 9% of purse-seine sets in the eastern Pacific with somewhat higher catch rates for sets around logs. Out of all billfish caught, blue and striped marlin accounted for 68.6% of the total. He states that billfish "probably follow tuna both as parasitic foragers and predators; they share many prey species with tunas and also eat tunas, especially the smaller specimens."

Region wide distribution of blue marlin are given by Howard and Ueyanagi (1965) as follows:

	West of 180°	East of 180°
10–30°N	High density from May-October with a tendency for season of highest density to progress from west to east starting in June until September	
0–10°N	High density almost year round except in December and January.	High density in May and June 180°–170°W and shifts eastward to 130°W until October.
0–10°S	Density becoming low in July through to September.	Density low from June-September.
South of 10°S	High density November–March with much greater concentration east of 160°W	

As indicated in the table, there is a north-south seasonal migration of fish that corresponds to warmer waters. These migrations may be more northwesterly and southeasterly so that northward moving groups pass the equator around 150ºE–180º and southward migrants pass the equator between 160ºE–180º (Au 1991). Genetic uniformity, mentioned above, may mean that there is a single Pacific-wide stock that migrates seasonally as increasing water temperature expands habitat away from the equator. This would suggest a clockwise radial pattern of migration.

According to trolling information, marlin feed in the morning between 1000 and 1100 hours and again in the afternoon between 1300 and 1600 hours; they apparently do not feed at night (Rivas 1974). This behavior correlates with the weakly exhibited diel depth pattern detected by Block and Booth et al. (1992). There has been much discussion of whether the marlin's bill is used in feeding. A few cases of billfish impaling marine turtles have been documented, but incidents such as these are considered accidental and the bill is not considered essential to feeding (Rivas 1974, Frazier and Fierstine et al. 1994). Using the stomach content of marlin caught in the Hawaiian International Billfish Tournament (HIBT) as a sample source, Brock (1984) found the marlin diet to be composed, in general, largely of Scrombrids but also significantly of juvenile inshore fish. However, he notes that this analysis "may be a reflection of where and when these predators were captured. The majority of the marlin caught in the HIBT are taken within 8 km of land. Moreover, the tournament is held during the summer, when many Hawaiian inshore juvenile fish recruit from the plankton to the adult habitat." Squid are another food source. Although Brock considers them relatively unimportant in Hawaiian waters, Rivas (1974) notes that they are an important part of the diet in the Philippine Sea. The size range of food is relatively large; a 340 kg blue marlin was found with a 29 kg bigeye tuna in its stomach (Rivas, 1974). Conversely, Brock (1984) notes that "adult blue marlin are capable of feeding on very small prey," and small prey in the 5–60 mm range were commonly found in his study.

Habitat description for Indo-Pacific blue marlin (*Makaira mazara*)

Duration	**Egg** 24 hr.?	**Larvae** To at least 52 mm (about 3 weeks?)	**Juvenile** To 35 kg for males and 47 kg for females	**Adult**
Diet	NA	Zooplankton, small fish	Scrombrids, cephalopods, juvenile inshore fish	Scrombrids, cephalopods, juvenile inshore fish
Distribution: General and Seasonal	Year around in tropics, seasonally in waters above 24-25º C.	Year around in tropics, seasonally in waters above 24–25ºC.	Year around in tropics, seasonally in waters above 24–25ºC.	I. 10–30ºN: May–Oct in east and west II. 0–10ºN: higher density Dec–Jan in west, May–Jun in east, shifting eastward to Oct III. 0–10º S: low density Jul–Sep IV. South of 10ºS high density Nov–Mar V. Preference for 22-27ºC.
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Epipelagic	Pelagic, upper mixed layer	Pelagic, mixed layer
Bottom Type	NA	NA	NA	NA
Oceanic Features	Eddies, upwelling, oceanic fronts and other areas of high productivity	Eddies, upwelling, oceanic fronts and other areas of high productivity	Eddies, upwelling, oceanic fronts and other areas of high productivity	Eddies, upwelling, oceanic fronts and other areas of high productivity

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2.2.4 Habitat description for black marlin (*Makaira indica*)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

<u>Life History and General Description</u>

This summary is based on Nakamura (1975) and Nakamura (1985). Little has been published on the black marlin since those synopses.

Makaira are teleost fish of the order Perciformes (suborder Xiphiidae) and family Istiophoroidae. Two other *Makaira* species are recognized: the Indo-Pacific blue marlin *(M. mazara*) and the Atlantic blue marlin (*M. nigricans*). However, the separation of these populations into distinct species has recently been questioned based on genetic analysis (Graves and McDowell 1995). Howard and Ueyanagi (1965) argue that there must be two separate stocks of black marlin in the Pacific based on their widely separated centers of abundance in the eastern and western Pacific. Their sparse distribution across the oceanic Pacific may represent individuals moving out from these centers of abundance.

Howard and Ueyanagi (1965) state that the distribution of black marlin is "characterized by the greatest density of occurrence being on the periphery of distribution of the family in the Pacific.…In open sea areas, distribution is sparse. In tropical open seas areas, distribution is very scattered but continuous, whereas in temperate open sea areas, there is almost no occurrence of this species." Nakamura (1985) gives the range for black marlin as 35º–40ºN to 45ºS in the western Pacific and 30–35ºS in the eastern Pacific. Specifically mentioned areas of concentration are along continental margins and in Indo-Pacific archipelagic waters from Southeast Asia to Australia. Based on longline CPUE data alone, the area of greatest abundance would be in the waters north of Australia to New Guinea and the Indonesian archipelago. A second center of abundance lies of off Central America, centered on Panama. Merrett (1971) reports based on data from the western Indian Ocean, that the highest catch rate is in water depths between 250–500 fathoms (457.2–914.4 m). No fish are reported landed it waters deeper than 2,000 fathoms (3657.6 m). Black marlin usually occurs nearer the surface than most other billfish (Nakamura 1985). The reported range in SST for this species is relatively wide, 15º–30ºC, although optimum temperatures for a harpoon fishery in the East China Sea were reported as between 23º–25ºC (Morita 1952). Squire and Nielsen (1983) report an optimal temperature, based on longline CPUE off of northeast Australia, as 26.7ºC.

In terms of migration, Howard and Ueyanagi (1965) note a seasonal movement away from the equator during summer months in the respective hemispheres. Squire and Nielsen (1983) provide a hypothetical description of migration based on tag returns from sport-caught fish off of northeast Australia. Black marlin are theorized to move south and southeast towards southeast Australia and New Zealand in late (austral) summer, northeast to Kirabati waters and northeast of Papua New Guinea in winter, and back to spawning grounds in the Coral Sea in spring and early summer.

Koto and Kodama (1962, cited in Nakamura 1975) estimated growth rates at 50 cm per year for black marlin 150–200 cm, 30 cm for lengths 200–230 cm and 20 cm for lengths 230–250 cm. Estimates could not be made for sizes above and below this range. No information is provided on age and longevity.

Black marlin is heterosexual. Nakamura (1975) reports sex ratios from a number of studies; females tend to dominate in the samples listed, in most cases comprising 80%–95%. The overall ratio for these samples as reported by Nakamura is "53/514 male throughout a size range of 20 to 200 kg in body weight" for the waters around Taiwan. Although this statement is somewhat ambiguous it may mean that the male-female sex ratio is 1:9.7. He also states that females grow larger than males. Merrett (1971) suggests size at sexual maturity (based on a very few specimens) as 170–180 cm or 58.97–79.38 kg. De Sylva and Breder (1997) examined gonad histology of Atlantic specimens. Four adult males were examined; none of the females were yet adult. They state that "maturation of the oocytes must thus occur when female black marlin have reached a much larger size"; unfortunately they don't report the sizes of their specimens.

Reported spawning grounds are in the South China Sea in May or June and the Coral Sea between October and November. Given their sparse distribution in the oceanic Pacific it may be that spawning is confined to western Pacific continental margin/shelf areas.

Major fishing grounds are all on the western Pacific continental margin: around Taiwan, the East China Sea, and the Coral Sea and northwest Australian waters. In these areas harpooners and trollers catch black marlin. A major charter-boat sports-fishery captures black marlin in northeast Australian waters. Black marlin is also caught as bycatch by tuna longliners in these areas and across the Pacific. Statistics show that highest landings are in FAO Area 61, the northwest Pacific above 20ºN and west of 175ºW (FAO 1997) . Fewer fish are caught in the area of reported high abundance north of Australia (Area 71). Total landings in 1995 were 2,077 mt, substantially less than the 1991 high of 6,342 mt. In comparison to other billfish (much less the important tuna species) black marlin catches are minor. Taiwan, Japan and Korea are the main countries landing black marlin. Black marlin are not reported separately in the NMFS Hawaii longline logbook, nor are they reported from the other areas in the western Pacific region in the most recent WPRFMC annual report. It is thus difficult to quantify landings in the region, but they are apparently very minor.

Egg and larval distribution

No information was available on egg and larval stages beyond what is reported in Nakamura (1975). He only reports on morphological descriptions of larvae. Another paper describing the larval stage (Nishikawa and Ueyanagi 1992) is in Japanese. The abstract notes that the "larvae of *M. indica* are mainly distributed in the neighboring waters of reef areas. It is assumed that the peculiarly formed rigid pectoral fins of larvae may have functions as 'stabilizer' in their habitats where the water moves violently compared with offshore areas." The researchers' collections were from the East China Sea, and it seems likely that significant concentrations of eggs and larvae are confined to the spawning areas mentioned above.

Juvenile

No information is available on juvenile distribution.

Adult

Little is known about the feeding habits of adult black marlin. The few published studies (reviewed in Nakamura 1975) indicate that Scombrids (mackerel and tuna), Gempylids, dolphinfish (*Coryphaena spp*.) and other billfish are important parts of the diet. Decapod molluscs and the larvae of Decapods, Isopods and Crustacea are also reported in other studies.

Adult habitat and distribution cannot be specified with any more precision than the very general description provided above for the species as a whole.

Essential Fish Habitat: Tropical species complex

Black marlin, although present, occurs in relatively low abundance in the Council's management area waters. This species apparently does not spawn in these waters.

Habitat description for black marlin (*Makaira indica*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Unknown, days	Unknown, days to weeks	Unknown, to 170-180 cm	Unknown
Diet	NA	No information available	Unknown	Mackerels, tunas, Gempylids, dolphinfish, larvae
Distribution: General and Seasonal	East China Sea and Coral Sea (based on spawning areas)?	As with eggs	Unknown	Mainly on continental shelf areas, especially in western Pacific, sparsely distributed in oceanic areas, seasonal expansion away from equator
Location	Continental shelf areas	Continental shelf areas	Unknown, probably shelf areas	Mainly continental shelf areas
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features	Unknown	Unknown	Unknown	Unknown

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2.2.5 Habitat description for striped marlin (*Tetrapturus audax*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

In the Pacific the striped marlin (*Tetrapturus audax*) is distributed in two supra-equatorial bands that join at the eastern tropical margin. This has lead some researchers to divide the population into two separate stocks, at least for management purposes (Shomura 1975). Genetic analysis (of mitochondrial DNA) suggests a corresponding spatial partitioning in genotypes (Graves and McDowell 1994), confirming the belief in distinct stocks. This contrasts sharply with tuna species, which are comparatively uniform in their genetic composition. The authors suggest that this differentiation may be due to spawning site fidelity. Genetic divergence between striped marlin and white marlin (*T. albidus*), which occurs in the Atlantic Ocean, is apparently not much greater than variation within the Pacific striped marlin population (Graves and McDowell 1995). This suggests that striped and white marlin is not in fact be separate species (Graves and McDowell 1995). In addition, recent analysis of mitochondrial DNA (Finnerty and Block 1995) suggests that billfish (Istiophoridae and Xiphiidae) should be separated from the suborder Scombroidae—also containing mackerel and tuna—to which they have traditionally been assigned.

There is no significant sexual dimorphism in this species, in contrast to the blue marlin.

Region-wide major catches of striped marlin are made by Japan and Korea. Important fishing areas include FAO Fishing Area 61 (northwest Pacific) where about 50% of the catch is made. Most of the catch is made by surface longlining that targets tunas (Nakamura 1985).

In the management plan area striped marlin are only landed in appreciable numbers in Hawaii. About 453.5 mt (1.0 million lb) were landed in Hawaii in 1996 and 544 mt (1.2 million lb) in 1996 (WPRFMC 1997). Almost 90% of commercial billfish landings were made by the longline fleet (WPRFMC 1997). No landings were reported from other areas in either year.

Egg and Larval Distribution

Distribution of eggs is unknown. Larvae are reportedly found between 10º–30ºN and 10º–30ºS. Peak abundance is in May-June in the northwestern Pacific (Ueyanagi and Wares 1975). This corresponds to the spawning ground described by Squire and Suzuki (1990). Thus spawning is probably seasonal and confined to the early summer months in both hemispheres. As noted, there is probably a separate spawning ground in the southwest Pacific. This would seem to be supported by genotype variability based on mitochondrial DNA analysis mentioned earlier (Graves and McDowell 1994). Description of larvae is based on specimens 2.9–21.2 mm in length (Ueyanagi and Wares 1975). Like other billfish, striped marlin is generally confined to pelagic surface waters; larvae may make diurnal vertical migrations in the top 50 m of the water column. Little is known about time of first feeding or food preferences. Striped marlin larvae may consume copepods up to about 13 mm (observed in Atlantic sailfish larvae) and other fish larvae after reaching a size of about 7 mm (Ueyanagi and Wares 1975).

Juvenile

Since marlin cannot yet be accurately aged, the age and duration of different life stages cannot be determined. Females are reported to reach first maturity at 50–80 lb; it is not possible to determine onset of sexual maturity in males because change in the size of testes is slight. As noted above, striped marlin spawns in the northwest Pacific and migrate eastward as juveniles (Squire and Suzuki 1990). This would account for the abundance of smaller fish in Hawaiian waters.

Adult

Tracking of adult striped marlin in Hawaiian waters using ultrasonic telemetry (Brill and Holts et al. 1993) indicate that they spend a significant amount of time in the upper 10 m of the water column. The tracked fish spent about 40% of their time between 51–90 m. The authors conclude that depth preference is governed by temperature stratification, with striped marlin preferring to remain in the mixed layer above the thermocline; the fish they tracked spend spent the vast majority of time in waters within 2ºC of the mixed layer temperature and never ventured into waters 8ºC colder than the mixed layer temperature. Thus these fish spent about 80% of their time in waters between 25.1º and 27ºC and never ventured into waters below 18ºC. This generally corresponds to the upper mixed layer for Hawaiian waters. There was no discernible diurnal pattern in horizontal movement. Striped marlin are also reported to swim very slowly at the surface with strong wind and high waves (Nakamura 1985).

Au (1991) found that billfish were caught in about 9% of purse-seine sets in the eastern Pacific with somewhat higher catch rates for sets around logs. Out of all billfish caught, blue and striped marlin accounted for 68.6% of the total. He states that billfish "probably follow tuna both as parasitic foragers and predators; they share many prey species with tunas and also east tunas, especially the smaller specimens."

As noted, striped marlin is distributed in a horseshoe pattern with the base of the U in the eastern Pacific. Generally, distribution corresponds to the 20º and 25ºC isotherms (Howard and Ueyanagi 1965). These authors distinguish a Northern Pacific Group found west of 140ºW and north of 15ºN, an Eastern Pacific Group east of 120ºW and west of 120ºW and south of 15ºS. These authors and others (Squire and Suzuki 1990) indicate that striped marlin occur in the equatorial region (the center of the U) but in very low densities. El Niño-related warming of waters along the American coast apparently leads to a northerly shift in striped marlin range (Squire 1987).
Striped marlin are found in greater numbers in the North Pacific with higher catch rates found in the north central, northeast and southeast Pacific (Shomura 1975).

Squire and Suzuki (1990) argue that striped marlin make long-term migrations between spawning and feeding areas. The spawning areas are in the northwest and to a lesser extent the Southwest Pacific. Young fish migrate eastward to feeding areas off the Central American coast and the return westward as adults.

Seasonal patterns generally conform to water temperature related changes in range. In Hawaiian waters striped marlin are more common in the winter months (Ueyanagi and Wares

1975). Howard and Ueyanagi (1965) give the following seasonal distribution for the North Pacific Group for waters of the central Pacific:

From the above table it can be seen that Hawaii benefits from the southern migration during winter months. Size distribution of catch is bimodal. The smaller fish appear in catches in the winter season, and they grow to 50–60 lb in May and June while in this area. They disappear from these waters during the summer. This indicates the fish migrate to northern waters during this time. There the fish stay several months and grow. Then they migrate back to Hawaiian waters where they become part of larger fish in the next year (Howard and Ueyanagi 1965)

Adult marlin feed on a variety of pelagic species. Nakamura (1985) states that striped marlin "tends to feed more on epipelagic organisms and less on mesopelagic ones that the swordfish and the oceanic tunas." Common food items are squid, scombrids and gempylids (Nakamura 1985, Ueyanagi and Wares 1975). In California food species included *Cololabis saira*, *Engraulis mordax*, *Sardinops caeruleas* and *Trachurus symmetricus* (Nakamura 1985, Ueyanagi and Wares 1975).

Habitat description for striped marlin (*Tetrapturus audax*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 hr.?	to 22 mm (2–3 weeks)?	to 25–35 kg	above 25–35 kg
Diet	NA	zooplankton, fish larvae	cephalopods, scombrids, gempylids	cephalopods, scombrids, gempylids
Distribution: General and Seasonal	Seasonal, early summer months in both hemispheres	Seasonal, early summer months in both hemispheres	Migrating eastward from spawning area in western Pacific?	Very low density or absent in low tropics, except in east. 20–30ºN (and S?), seasonally to 42ºN (and S?). Prefer 20–25ºC, 18ºC apparent lower limit.
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Epipelagic	Pelagic, upper mixed layer	Pelagic, mixed layer
Bottom Type	NA	NA	NA	NA
Oceanic Features	Depends on adult distribution	Depends on adult distribution	Eddies, upwelling, oceanic fronts and other areas of high productivity	Eddies, upwelling, oceanic fronts and other areas of high productivity

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Pelagic Fisheries of the Western Pacific Region, 1996 Annual Report. Honolulu: Western Pacific Regional Fishery Management Council.

2.2.6 Habitat description for shortbill spearfish (*Tetrapturus angustirostris*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The shortbill spearfish is an Istiophorid billfish and shares the genus with five other species. Penrith (1964) identified a cline in pectoral fin length, increasing eastward in the Pacific. This was believed to be a result of geographic variation. No other information is available to suggest possible sub-populations.

Kikawa (1975), summarizing various works, describes the total distribution as sporadic between 10ºN and 10ºS with possible range extent to 30ºN and 30ºS, based on longline catch data. Nakamura (1985) gives a range of 40ºN to 35ºS for the Pacific. While dispersed throughout the tropics, density is always low. Nakamura further states that the shortbill spearfish "is an oceanic pelagic fish which does not generally occur in coastal or enclosed waters but is found well offshore. Longline fisheries in the equatorial Indian Ocean take relatively few individuals in the upper water layers (0–200 m) over depths shallower than 914 m (500 fm) while the highest catch rates are obtained above the 915 m to 1,830 m (501 to 1000 fm) isobaths." Boggs (1992), conducting research on longline capture depth, obtained different results. On a 1989 expeditions the highest catch rates were obtained at 120-360 m with a few fish caught as deep as 280–360 m. In 1990 the highest catch rates were shallow, 40–80 m with no catch below 200 m. This distribution is described as "into the middle of the thermocline" (Boggs 1992) that begins at 120 m and 20ºC. Nakano et al. (1997), analyzing catch depth data from research cruises in the mid-Pacific, classes shortbill spearfish among fish for which catch rate declines with depth. The hypothetical habitat for this fish may be described as open ocean epipelagic or mesopelagic waters (200–1000 m.) in the tropics and subtropics. No precise data can be given on limiting environmental parameter for this habitat.

No information was found in the literature about migration patterns or seasonal changes in abundance for this species. The species is distributed sparsely and no specific habitat features affecting abundance can be identified.

No information on age is available. In his review, Kikawa (1975) gives maximum sizes; fish over 20 kg are rare and the largest reported specimen was about 52 kg.

Spearfish are heterosexual and no sexual dimorphism is reported.

Shortbill spearfish apparently spawn in winter months in tropical and subtropical waters between 25ºN and 25ºS. Kikawa (1975) notes that unlike other billfish spawning does not "take place in large groups over a very short period of time, but probably is continuous over a long period and over a broad areas of the sea." As individual females become ripe the male fish follows the female.

There is no special fishery for spearfish; they are caught incidentally by longliners and rarely by surface troll. Nakamura (1985) states that catch statistics in Japanese longline fishery typically lump sailfish (*Istiophorus platypterus*) with the shortbill spearfish but the latter may be differentiated as those caught offshore. The spearfish proportion of the total is considered negligible.

In the western Pacific region spearfish are not differentiated in longline logbook reporting (WPRFMC 1997). Guam reported landings of 967 lb in 1996 based on its creel census. Obviously, this fish is a minor constituent of commercial fisheries and caught with extreme rarity, if at all, in recreational fisheries.

Egg and Larval Distribution

Merrett (1971) provides two estimates of fecundity: 6.2 and 2.1 million eggs for females 1.39 m long (from center of orbit to shortest caudal ray). Egg diameters range from 1.3 to 1.6 mm.

No upper limit is given for larval size although Kikawa (1975) reports a juvenile specimen as 514 mm SL. He also provides a description of larval development.

Uotani and Ueyanagi (1997) found that the *Corycaeus* copepod, *Evadne* and fish larvae were major food items for larval spearfish. (Although this paper is in Japanese, Table 1 (p 109) gives the frequency of occurrence for food items in roman text.) Fish larvae increase from 0% of the diet at 5.0 mm TL to about 40% at 15.0 mm TL.

No information is available for larval distribution beyond the presumed extent of spawning described above. The hypothetical habitat for larvae presumably accords to this spawning range.

Juvenile

No information is available on juvenile behavior or habitat.

Adult

Kikawa (1975) reports the lengths for three specimens in ripe condition; they were 1.52 m (bill tip to origin of lateral keels), 1.64 m (bill tip to caudal fork) and 1.39 m (center of orbit to shortest caudal ray). No more precise information is given for size or age at maturity.

Kikawa (1975), summarizing various studies, states that the diet of the spearfish is essentially similar to other billfish, which are in turn similar to that of tuna. Prey items include squid and fish of the Lepidotidae, Alepisauridae, Acinaceidae and Katsuwonidae.

The hypothetical habitat or known range for adults is not known to be significantly different from that for the species as described above. No features are known that affect abundance.

Essential Fish Habitat: Tropical species complex

In regards to this species, EFH is not a very useful concept because of its wide and sparse distribution. In addition, relatively little is known about its biology. EFH can only be described as epipelagic and mesopelagic tropical and subtropical waters. No features are known to identify Areas of Particular Concern. Howard and Ueyanagi (1965) provide a distribution map which is reproduced in Kikawa (1975).

Habitat description for shortbill spearfish (*Tetrapturus angustirostris*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Unknown	Unknown	Unknown, but juvenile described as 510 mm	Unknown, but mature females described as about 1.5 m.
Diet	NA	Fish larvae, copepods	Unknown	Similar to other billfish: squid, fish
Distribution: General and Seasonal	Tropics between 25º N and 25º S	Same as eggs	Unknown	Between 40ºN to 35ºS or less
Location	Open ocean	Open ocean	Open ocean	Open ocean
Water Column	Epipelagic	Epipelagic	Unknown, presumably epipelagic	Epipelagic or mesopelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features	Unknown	Unknown	Unknown	Unknown

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[WPRFMC] Western Pacific Regional Fishery Management Council. 1997. Pelagic Fisheries of the Western Pacific Region 1996 Annual Report. Honolulu: Western Pacific Regional Fishery Management Council. 26 p. + appendices.

2.2.7 Habitat description for broadbill swordfish (*Xiphias gladius*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Midway Island, Palmyra Atoll, Jarvis Island, Howland and Baker Islands and Wake Island.

Life History and General Description

Numerous studies on the taxonomy, biology, diet; stock structure and exploitation of broadbill swordfish have been conducted. Information on billfishes, including swordfish is summarized in Nakamura et al. (1968) and Nakamura (1985). Palko et al. (1981) provide a detailed synopsis of the biology of broadbill swordfish from literature available at the time of their publication. A more recent review is available in Joseph et al. (1994). Recent information on the species and research being conducted on Pacific swordfish can be found in papers submitted to the First International Pacific Swordfish Symposium (1994 Dec 11–14; Ensenada, Mexico) and the Second International Pacific Swordfish Symposium (1996 Mar 3–6; Kahuku, HI). A great deal of information on Pacific swordfish is available with the NMFS Honolulu Laboratory that is conducting research in several areas, including the age, growth, reproductive biology, distribution and abundance of north Pacific swordfish.

Broadbill swordfish are worldwide in distribution in all tropical, subtropical and temperate seas, ranging from around 50°N to 50°S (Nakamura 1985, Bartoo and Coan 1989). The adults can tolerate a wide range of water temperature, from 5°–27°C but are normally found in areas with SSTs above 13°C (Nakamura 1985). Larvae and juveniles occur in warmer tropical and subtropical regions where spawning also occurs. Swordfish occur throughout the entire region of the Council's jurisdiction and in all neighboring states, territories and adjacent high seas zones.

Broadbill swordfish have separate sexes with no apparent sexual dimorphism, although females attain a larger size. Fertilization is external and the fish are believed to spawn close to the surface. There is some evidence for pairing up of spawning adults as the fish apparently do not school (Palko et al. 1981).

Swordfish are voracious feeders at all life stages. Adults feed opportunistically on a wide range of squids, fish and crustaceans. Sex ratio appears to vary with fish size and spatial distribution. Most large sized fish are females and females appear to be more common in cooler waters. Beckett (1974) noted that few males were found in waters below 18°C but make up the majority of warm water landings. Details of growth, maturity, fecundity and spawning are given later in this report.

Little is known about migration in Pacific swordfish although limited tagging data supports a general west to east movement from Hawaii toward North America. An association with cephalopod prey concentrated near frontal boundaries appears more significant in determining the distribution of swordfish in the north Pacific, and further research on the role of food and frontal systems is ongoing (Seki 1993, 1996).

A Hawaii based longline fishery that occurs primarily to the north of the EEZ targets Broadbill swordfish. Longline and handline vessels fishing primarily for tuna species make incidental or targeted catches within the Hawaii EEZ. Incidental longline catches occur in other areas of Council jurisdiction but are not well documented.

<u>Egg and Larval Distribution</u>

Swordfish eggs measure 1.6–1.8 mm in diameter, are transparent and float at the sea surface due to the presence of a single oil droplet (Sanzo 1922). The incubation period is approximately 2.5 days (Palko et al. 1981). Newly hatched yolk sac larvae have been measured at 4.0–4.45 mm in length (Fritzsche 1978, Yasuda et al. 1978). Larvae have been noted in tropical and subtropical waters of the three major oceans between about 30°N and 30°S. In a survey of swordfish larvae collections, Grall et al. (1983) determined that larval swordfish were abundant in the Pacific within latitudes 35°N to 25°S. Peak spawning occurs in the north Pacific between May and August, from December to January in the south Pacific and March to July in the central Pacific (Nishikawa et al. 1978, Palko et al. 1981). Sexually mature and ripening female swordfish have been noted in Hawaiian waters during the spring and early summer (Uchiyama and Shomura 1974). This observation is in agreement with an estimated spawning period of April to July based on the collection of larvae and juveniles near Hawaii (Matsumoto and Kazama 1974). It is probable that some degree of spawning occurs throughout the year in tropical waters, between 20°N and 20°S, with the distribution of larvae associated with SSTs between 24° and 29°C (Tåning 1955, Yabe et al. 1959, Nishikawa and Ueyanagi 1974).

Larval swordfish are believed to occupy surface waters where almost all catches have been made using plankton and dip nets (Tåning 1955, Nishikawa and Ueyanagi 1974). Larval swordfish are found within a SST range of 24° to 29°C and have been found in the Pacific where salinity ranged from 34.4–36.4 ‰ (Matsumoto and Kazama 1974). Larval abundance is high along sharp thermal and salinity gradients. However, this phenomenon may be due to passive collection along boundary areas.

The larval and young actively feed on zooplankton during the day and become piscivorous by 11–12 mm in length, feeding on a variety of epipelagic fish larvae (Arata 1954, Grobunova 1969). The young swordfish are voracious feeders; an 8 mm specimen will swallow prey as long as themselves (Tåning 1955). In contrast, Yabe et al. (1959) observed that Pacific swordfish of 9.0–14.0 mm fed on crustacean zooplankton and did not graduate to fish prey until 21 mm in length.

Juvenile

Young swordfish gradually metamorphose from larval state to adult, and it is difficult to elect a length or age when the juvenile stage has been reached. However, early development is rapid and juvenile fish greater than approximately 55 cm resemble a miniature adult swordfish. In the Pacific, fish of this size (51–61 cm) have been estimated to be approximately one year old (Yabe et al. 1959, Dewees 1992).

There are few specific references on the distribution of juvenile swordfish in the Pacific. However, swordfish recruit to longline gear at juvenile sizes of approximately 50 to 80 cm (rear of orbit to caudal fork), which can be monitored by catch statistics. Dewees (1992) states that swordfish tend to concentrate along productive thermal boundaries between cold upwelled water and warmer water masses where they feed on fish and squid. Gorbunova (1969) suggested that juvenile swordfish in the Pacific are restricted to areas of upwelling and high productivity and do not move far during the first year of life. Yabe et al. (1959) state that young swordfish originate in tropical and subtropical regions and migrate to higher latitudes as they increase in size.

Adult

Adult swordfish are the most widely distributed of all billfish species, ranging from approximately 50°N to 50°S in the Pacific as indicated by catch records of commercial longline vessels. Adult swordfish are able to occupy a very wide range of water temperatures, from 5°–27°C with a preferred temperature range of 18°–22°C (Nakamura 1985). The species can exceed 500 kg in weight with females growing larger than males. The larger fish occupy cooler waters, with few fish less than 90 kg and few males found in waters less than 18°C (Palko 1981).

Information on age and growth of swordfish is the subject of intense study, and findings have been somewhat contradictory. Age studies based on otolith analysis and other methods (length frequency, vertebrae, fin rays, growth studies) are reviewed by Sosa-Nishizaki (1996) and Ehrhardt (1996). Wilson and Dean (1983) estimated a maximum age or 9 years for males and 15 years for females from otolith analysis. Radtke and Hurley (1983), using otoliths estimated a maximum age of 14 years for males and 32 years for females. The assumed daily and annular increments used in these analyses have not yet been validated.

Research on the reproductive biology and size at maturity of swordfish is reviewed by DeMartini (1996). Yabe et al. (1959) estimate that swordfish reach maturity between 5 and 6 years of age at a size of 150–170 cm (eye to fork length). Sosa-Nishizaki (1990) estimate that female swordfish in the Pacific mature at 140–180 cm based on gonad indices. Arocha and Lee (1995) estimated a length at 50% maturity of 179–189 cm and 119–129 cm for female and male swordfish from the northwest Atlantic fishery. Length at first maturity has been observed in females as small as 101–110 cm (Nakano and Bayliff 1992). Spawning occurs in the upper mixed layer of the water column from the surface to 75 m (Nakamura 1985). Additional information on swordfish spawning is discussed in the section describing egg and larval distribution.

Optimal SSTs for swordfish are around 25°–29°C (Tåning 1955), which implies swordfish spend the majority of their time in cooler sub-surface waters. Swordfish can forage at great depths and have been photographed at a depth of 1,000 m by deep diving submersible (Mather 1976). Carey (1982) and other researchers have suggested that specialized tissues warm the brain and eyes, allowing swordfish to successfully forage at great depths in frigid waters. Holts (1994) used acoustic telemetry to monitor an adult swordfish and notes that the fish spent about 75% of its time in or just below the upper mixed layer at depths of 10 to 50 m in water temperatures about 14°C and made excursions to approximately 300 m where the water was close to 8°C.

The horizontal and vertical movements of several swordfish tracked by acoustic telemetry in the Atlantic and Pacific are documented by Carey and Robison (1981). Studies have noted a general pattern of remaining at depth, sometimes near the bottom, during the day and rising to the near the surface during the night which is believed to be a foraging strategy. They further proposed that differences in preferred diving depths between areas were due to an avoidance of depth strata with low dissolved oxygen.

Adult swordfish are opportunistic feeders, preying heavily on squid and various fish species. It is generally accepted that swordfish in the pelagic environment feed on squid and mesopelagic fish and forage on demersal fish when in shallower waters (Scott and Tibbo 1968, Palko 1981, Nakamura 1985, Stillwell and Johler 1985, Bello 1990, Carey 1990, Moreia 1990, Holts 1994, Markaida and Sosa-Nishizaki 1994, Barreto et al. 1995, Clarke et al. 1995, Hernandez-Garcia 1995, Orsi Relini 1995, Barreto 1996).

Oceanographic features that tend to concentrate forage species apparently have a significant influence on adult swordfish distributions. Swordfish are relatively abundant near boundary zones where sharp gradients of temperature and salinity exist (Palko 1981). Sakagawa (1989) notes that swordfish are found in areas of high productivity where forage species are abundant near current boundaries and frontal zones. The relationship between large-scale frontal systems, forage species and swordfish distribution and abundance in the North Pacific is currently a research priority of the NMFS Honolulu Laboratory.

<u>Essential Fish Habitat</u>: Temperate species complex

Habitat description for broadbill swordfish (*Xiphias gladius*)

	Egg	Larvae	Juvenile	Adult
Duration	Approximately 2.5 days	Uncertain	Approximately 5 years	Females larger and longer lived than males, conflicting estimates of age, ranging 9–14 yr for males, 15 –32 yr for females
Diet	NA	Zooplankton, larval fish	Cephalopods and fish, few crustaceans	Cephalopods, mesopelagic and demersal fish, few crustaceans
Season/Time	Throughout the year 20°N–20°S, between 35°N and 25°S at SST between 24°– 29°C	Throughout the year 20°N–20°S, between 35°N and 25°S at SST between 24°–29°C	Tropical and subtropical regions, moving to higher latitudes with age	50°N –50°S, water temperatures 5°–27°C, prefer 18°–22°C. Male's perfer warmer waters. Spawning throughout the year in tropics at 20°N–20°S, seasonally where SST is above 24°C
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Epipelagic	Pelagic, upper mixed layer	Pelagic, normally subsurface, extensive vertical migration from mixed layer to well below thermocline. May employ deep day and shallow nigh foraging strategy. Known to forage for demersal prey on the sea floor.
Bottom type	NA	NA	NA	NA
Oceanic Features	Areas of sharp thermal and salinity gradients	Areas of sharp thermal and salinity gradients	Productive thermal boundary regions, areas of upwelling and convergence	Current boundaries, frontal zones, areas of high productivity and forage

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2.2.8 Habitat description for sailfish (*Istiophorus platypterus*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The main source for this description is Beardsley et al. (1975).

The sailfish is an Istiophorod billfish, sharing the genus with the Atlantic sailfish (*I. albicans*). Graves and McDowell (1995), using RFLP analysis of mitochondrial DNA, have called for a re-evaluation of the taxonomic separation of these two species (as well as other inter-oceanic distinctions among other Istophorod billfish), while noting considerable intra-oceanic genetic diversity, suggesting population structure. However, no information was found concerning possible sub-populations in the Pacific.

Howard and Ueyanagi (1965) emphasize that sailfish are more common near landmasses. In the western Pacific they identify areas of high density near the landmasses of Papua New Guinea, Caroline Islands and Solomon Islands, as well as in the Banda Sea, Timor Sea, East China sea and the waters east of Taiwan to southwestern Japan. They note that both adults and young are associated with the KuroshioCurrent, migrating to the coastal waters of southern Japan in this current. Beardsley et al. (1975) describe the Pacific distribution as more extensive in the western half than eastern and note that catch data show a distribution from 27ºS to 40ºN in the west and 5ºS to 25ºN in the east. In describing habitat parameters, they state, "The vertical zone of the community in which the sailfish lives is characterized by good illumination and is likely to be delimited below by temperature at the main thermocline (from 10–20 m to 200–250 m, depending on area). Temperature is apparently important also in the latitudinal distribution of the species.…" They suggest the 28º isotherm as optimal. Salinity may also have an effect. Kuwahara et al. (1982) note a negative correlation between catch and salinity for landings of Kyoto Prefecture in Japan. Nakamura (1985) notes that maximum abundance in the Indian Ocean is correlated with a maximum temperature of the East African Coastal Current of 29º–30º and low salinity of 32.2–33.3 º/00. He also notes that sailfish share habitat with the black marlin (*Makaira indica*), another managed species. Hypothetical habitat may be described based on these parameters, but only in general terms.

Howard and Ueyanagi (1965) note that there is limited information on which to postulate migration patterns. However, radioactively contaminated sailfish "began to occur throughout the entire western Pacific Ocean several months after the nuclear bomb test explosions at Bikini in 1954," they say. This suggests interchange of fish between low and high latitude areas. There may also be a seasonal component to migration. Nakamura (1985) states that in the Sea of Japan sailfish "migrate with the Tsushima current (a branch of the Kuroshio) during summer (peak later summer), and southward against the current during autumn (peak in early autumn)." As noted above, in the eastern Pacific, migration is correlated with seasonal movement of the 28º isotherm. Sailfish form schools of 3 to 30 individuals and apparently school by size, at least in coastal Japan (Nakamura 1985, Beardsley et al. 1975).

The only habitat feature consistently mentioned in the literature that affects abundance and density of population (indicating preferred habitat) is the sailfish's preference for continental coasts.

As with other billfish, the age of individual sailfish is difficult to determine by analysis of hard parts. They apparently grow rapidly; Beardsley et al. (1975) give the following lengths at age: 1 year—183 cm, 2 years—216 cm and 3 years—233.7 cm. Prince et al. (1986) suggest a revision of the maximum age of sailfish based on a tag recapture. They estimate a maximum age of 13–15 years or more in contrast to earlier estimates in the range of 7 years.

Sailfish are heterosexual and do not exhibit sexual dimorphism.

De Sylva and Breder (1997), discussing Atlantic billfish, note that sailfish can spawn up to four times in a single season and males year around. They found that the sailfish-spawning season of the US southeast Atlantic coast spanned April to October. They also state sailfish are largely coastal spawners. Nakamura (1985) states that in the Pacific sailfish spawn year around in the tropics with summer spawning at higher latitudes.

Most of the sailfish landings in the Pacific fisheries are made in the northwest and eastern central Pacific, mainly by Japanese and Korean vessels (Nakamura 1985). Longliners are undoubtedly the major gear type reflected in this description.

Hawaii commercial catch statistics do not separate out sailfish. The total for the “other billfish” category was 400,000 lb in 1996, the most recent published statistics (WPRFMC 1997). From the same source Guam reported no landings of sailfish; American Samoa reported 5,535 lb landed; and the Northern Marina Islands 545 lb. It can be seen that sailfish are a minor commercial species. Looking only at American Samoa, Guam and the Northern Mariana Islands, where landings for sailfish are reported separately, they represent less than half a percent of total PMUS landings. If this rate were applied to total Hawaii PMUS landings, 1996 sailfish landings would be about 130,000 lb. However, sailfish are an esteemed gamefish and is valuable to the charter boat fishery.

Egg and Larval Distribution

De Sylva and Breder (1997) give a recent detailed description of gonadal development based on Atlantic samples. Eggs are described as about 0.85 mm in diameter with a single oil globule surrounded by a pale yellow indefinite nimbus (Nakamura 1985, Beardsley et al. 1975). Duration of the egg phase is not stated in these sources but is probably similar to other billfishes.

Beardsley et al. (1975) summarize larval and juvenile development, stating that the transformation from larval to adolescent phase is without distinct break so the two phases are described together. Post et al. (1997) were able to capture larval sailfish and keep them alive in the laboratory for a maximum of 72 hours. However, they provide little information on larval behavior beyond noting that the larvae exhibited “extremely rapid swimming that led to contact wit the tank sides and bottom. Typically, fish maintained this pattern until their death.” The larvae successfully fed on *Artemia* in the laboratory tanks. Summarizing other studies, Beardsley et al. (1975) state that larvae feed on copepods and fish larvae. The authors reproduce a table from Gehringer (1956) detailing larval stomach contents. Based on drawing reproduced in Beardsley et al. (1975), the transition from larval to adolescent phase occurs between 30 mm and 100 mm.

Little can be said about the distribution or habitat of larval sailfish beyond what has already been summarized about distribution of spawning activity. Post et al. (1997) noted a higher CPUE for larval sailfish during the first quarter of the moon phase.

Juvenile

No information was found on juvenile distribution, behavior or preferred habitat beyond the aforementioned observation that sailfish tend to school by size.

Adult

Nakamura (1985) gives a maximum size of 340 cm and 100 kg. De Sylva and Breder (1997) give the weight at first maturity for females as 13–18 kg and males at 10 kg. This accords with an age of 12–18 months.

Beardsley et al. (1975) give a summary of the sailfish diet based on stomach content analysis. They suggest that there is “a general consensus that although fish and squid form the major portion of their diet, adult sailfish are fairly opportunistic feeders and eat whatever happens to be present.”

No additional habitat features affecting density and abundance can be described for adults that differ significantly from that of the species as a whole.

Essential Fish Habitat: Tropical species complex

In the western Pacific region, sailfish occur as a minor incidental catch in commercial fisheries. A few habitat parameters have been noted. This species seems to prefer continental margin areas. The description of EFH for sailfish has been based on the best available scientific information and the requirements of ecologically related managed species. Beardsley et al. (1975) reproduce a distribution map.

Habitat description for sailfish (*Istiophorus platypterus*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Unknown, hours or days	Unknown, weeks	To 12–18 months	Female: 13–18 kg, male: 10 kg, 12-18 months
Diet	NA	Copepods and fish larvae	Unknown	Fish, especially scombrids, squid
Distribution: General and Seasonal	Unknown, sailfish spawn year around in tropics, seasonally in cooler waters	Unknown, probably similar to eggs	Unknown, probably generally similar to adults	Range in western Pacific: 27ºS–40ºN; 5ºS–25ºN in east
Location	Higher density in coastal waters	Higher density in coastal waters	Unknown, probably similar to adults	Marked preference for continental margins
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features	Unknown	Unknown	Unknown	Unknown

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2.2.9 Habitat description for blue shark (*Prionace glauca*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands, Midway Island and Wake Island.

Blue shark within the jurisdiction of the Western Pacific Regional Fishery Management Council (Council) are managed within the requium shark category (family Carcharhinidae) under the Fishery Management Plan (FMP) for the Pelagic Fisheries of the Western Pacific Region. Blue sharks occur throughout the entire region of the Council's jurisdiction and in all neighboring states, territories and adjacent high seas zones.

Life History and General Description

Several studies have examined the life history, distribution and behavior of blue sharks at different locations worldwide (e.g., Strasburg 1958, Hazin et al. 1994, Gruber 1991, Nakano 1994). For a general review of blue shark life history and distribution see Compagno (1984). Information on elasmobranch fisheries and bycatch is given in Pepperell (1992) and Bonfil (1994).

The blue shark is an oceanic-epipelagic and fringe littoral species with a circumglobal distribution. The species is relatively fecund for a requium shark. It is found in all temperate and tropical oceans and is thought to be the most wide-ranging shark species. The basic environmental conditions favorable for survival include oceanic waters between 6°C and 28°C, but it prefers cooler water temperatures between 7°C and 16°C (Strasburg 1958, Compagno 1984). In tropical waters, blue shark exhibit submergence and are typically found at greater depths. In temperate waters, blue sharks are caught within the mixed layer and generally range between the surface and upper layer of the thermocline (Strasburg 1958, Nakano et al. 1985), but have been documented as deep as 650 m (Carey and Scharold 1990). In the Pacific blue sharks are most predominant between 35°N and 45°N (Nakano 1994, Stasburg 1958).

Age and growth studies of blue sharks indicate that they may reach maturity in 6 to 7 years (Compagno 1984, Nakano 1994), although there may be regional differences in growth rate (Tanaka et al. 1990, Cailliet and Bedford 1983). They are believed to be opportunistic feeders at all life stages and prey primary on small pelagic fishes, crustaceans and cephalopods (Strasburg 1958, Stevens 1973, Tricas 1979). Blue sharks have also demonstrated seasonal shifts in diet when prey such as squid becomes abundant during mass spawning events (Tricas 1979).

The blue shark is viviparous with a yolk-sac placenta. Litter size is relatively large but variable ranging from 4 to 135 pups and may be dependent on the size of female (Gubanov and Grigor'yev 1975, Pratt 1979, Nakano 1994). In the Pacific it is thought that mating occurs during the summer months in the equatorial region from May to August (Nakano 1994). Gestation period is thought to range from 9 to 12 months and may vary depending on location

(Suda 1953, Nakano 1994). Females have been demonstrated to store sperm, which may also explain variability in gestation period estimates (Pratt 1979). Late term pregnant females are found in the northern Pacific in summer months where they give birth to large, well-developed pups averaging 36 cm FL. The lengthy gestation period and geographic separation of mating and birthing grounds suggests that mature females in the Pacific may reproduce every other year (Nakano 1994).

Seasonal migrations are thought to occur in the Atlantic, Pacific and Indian Ocean populations with seasonal periods of sexual segregation (Casey 1985, Stevens 1992, Nakano 1994). A large-scale shark tag and recapture program has confirmed a clockwise migrations pattern in the North Atlantic population suggesting blue sharks may follow the Gulf Stream (Casey 1985). However, migratory behavior in the Pacific and Indian Oceans is not known but has been proposed from length frequency and sex ration analysis of shark catch. A shark-tagging program has recently been initiated by California Fish and Game further elucidates the migratory movements of blue sharks in the eastern Pacific (Laughlin 1997). However, only limited blue shark tagging has been conducted in the central Pacific, and thus, the extent of blue shark migrations in the central Pacific are still unconfirmed. Currently, the NMFS Honolulu Laboratory is collaborating with the National Research Institute of Far Seas Fisheries (Japan) to tag blue sharks in the north Pacific.

Blue sharks appear to aggregate in loose schools and are generally caught more frequently over depths greater than 1,000 m (Hazin et al. 1993, Ito and Machado 1997). They exhibit diel diving behavior similar to that of other pelagic teleosts and sharks (Sciarrota and Nelson 1977, Carey and Scharold 1990) and appear to show a fair degree of niche overlap with swordfish (C. Boggs, pers. comm.). Blue sharks are a bycatch of pelagic longline fisheries for tuna and swordfish in the Pacific and can seasonally comprise the largest percentage of the catch in some fisheries. In recent years there has been an increase in the number of blue sharks retained for their fins in the tuna and swordfish longline fishery in Hawaii (Ito and Machado 1997). The meat is seldom landed and sold at market because it has a low commercial value. Approximately 95% of shark fins landed in Honolulu by the pelagic longline fishery are from blue shark (WPRFMC 1997).

<u>Neonate and Juvenile Distribution</u>

Little is known about neonatal and juvenile blue sharks in the Pacific other than their general distribution. Young-of-the-year blue sharks (< 50 cm FL) were more frequently caught in large mesh drift-net fishery in the northern Pacific (35°N to 45°N), which is believed to be a parturition (birthing) area. It has been suggested that the separation of the parturition area from the adults habitats may serve to reduce predation on pups from adult sharks (Nakano 1994). Unfortunately, there is little known about the feeding habits or depth preferences of juveniles in their nursery grounds, although it has been speculated that nursery grounds are located in the more productive subarctic boundary where there may be more food for the young sharks (Nakano 1994).

Subadult

Subadult blue sharks appear to segregate according to sex in the Pacific. After leaving their parturition area, 2- to 5-year-old females are more frequently caught further northward (40°N to 50°N), while 2- to 4-year-old males move southward (30°N to 40°N) (Nakano 1994). Little is known about the feeding habits and depth preferences of subadults due to lack of study.

Adult

Adult blue sharks exhibit seasonal sexual segregation as well as possible migratory behavior. In the Pacific, adults range from equatorial waters to 40°N. In Nakano's study (1994), adult females were predominant in waters off Japan throughout the year and in areas near the subarctic boundary in the summer, while males were most common in waters south of the subarctic boundary. In early summer reproductively ready females reportedly move to southern waters to mate with males. Large numbers of females exhibiting bite marks associated with recent matings were seen at equatorial latitudes. After mating, pregnant females reportedly migrate north where they give birth the following year (Nakano 1994).

Based on spatial and temporal changes in blue shark abundance in the Pacific, it is suspected that the transition zone mediates the north-south difference in catch rates of blue sharks. This is the area of water between the cooler Aleutian Current and the warmer water from the North Pacific Current. This transition zone shifts from 31°N and 36°N in the winter to 41°N and 36°N in the fall. Most of the larger catches of blue sharks have been made in or just south of this zone (Strasburg 1958).

Diel movements of blue sharks acoustically tracked off Southern California and in the North Atlantic indicate that adult blue sharks increase their activity at night and make shallower dives than during the day. Sharks tracked off Southern California ventured inshore at night, presumably to feed on seasonally available spawning squid (Sciarrota and Nelson 1977). The cyclical diving behavior is thought to serve as a hunting, orientation and/or thermoregulatory function (Carey and Scharold 1990).

Although adult blue sharks are opportunistic feeders and prey mainly on small pelagic fishes, cephalopods and crustacean, they have also been observed scavenging on marine mammal carcasses at sea. Unfortunately, there are little data on the diet composition of blue sharks in the central Pacific.

Habitat description for blue shark (*Prionace glauca*)

	Gestation	**Juvenile**	**Subadult**	**Adult**
Duration	9-12 months	~ 1–2 years	~ 2–6 years	~ 6–20 years
Diet	NA	small fishes, cephalopods, crustaceans	small fishes, cephalopods, crustaceans	small fishes, cephalopods, crustaceans
Season/Time	Throughout year	Between 35°N and 45°N	Females: between 40°N and 50°N Males: between 30°N and 40°N	Females: in equatorial latitudes in summer or high latitude nursery grounds Males: equatorial latitudes
Location	Offshore	Offshore	Offshore	Offshore
Water Column	NA	Epipelagic	Epipelagic	Epipelagic with tropical submergence
Bottom type	NA	NA	NA	NA
Oceanic Features	NA	Subarctic boundary	Females: cooler waters Males: warmer waters	Transition zone between Aleutian Current and North Pacific Current

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2.2.10 Habitat description for pelagic sharks (Alopiidae, Carcharinidae, Lamnidae, Sphynidae)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Sharks are only identified at the family level for the purpose of management. The four families identified comprise some 65 species, although the vast majority (48 species) are Carcharinids. Table 1, derived from Compagno (1984), lists all species in these families occurring in FAO Fishing Areas 71 and 77, which cover the management area. However, of this total many do not or may not occur in the management area. The table below summarizes this information.

Family	Total Species	Number of species in FAO Area 71 and 77	Possibly in Management Area	Definitely in Management Area
Alopiidae	3	3	-	3
Lamnidae	5	4	1	3
Carcharinidae	48	38	9	12
Sphyrnidae	9	7	1	2

Table 1: Summary of species occurring in management area

According to logbook data from the Hawaii-based longline fishery about 93% of sharks landed are blue sharks (*Prionace glauca*). Of the remainder, about 1.5% is mako sharks (family Lamnidae) and about 3% are thresher sharks (family Alopiidae). This leaves a remainder of about 3% in the “other” category. Table 2 below is based on observer “raw” data, representing total sharks recorded 1994–1997. Since observer coverage is low and there may be uncorrected biases in the data it should be treated with caution. Nonetheless, it gives some indication of the relative frequency of capture for various sharks. Because of their predominance in the fishery, a separate habitat description has been prepared for the blue shark. Since the remainder of the species is caught in relatively small numbers, habitat and life history will only be discussed at a general or family level.

Strasburg (1958) reports shark landings during the fishery assessment cruises that were part of the Pacific Oceanic Fishery Investigations carried out by the US Fish and Wildlife Service from 1952 to 1955. Twelve species are mentioned in the text. One of these, *Galcorhinus zypterus* (the “soupfin shark”) now classed as *G. galeus* (the tope shark) (Compagno 1984), is in family Triakidae and therefore not MUS. Of the remainder three were considered common, *Prionace glauca*, *Carcharinus longimanus* (oceanic whitetip) and *Carcharinus falciformus* (the silky shark) Uncommon sharks were *Isurus oxyrinchus* (shortfin mako), the three species of threshers (family Alopiidae) and *Lamna ditropis*, the salmon shark. Eight *G. galeus*, four hammerheads (the two species in family Sphyrnidae that occur in the management area, *Sphyrna lewini* and *S. zygaena*) and two *Carcharinus melanopterus* (blacktip reef shark) were also landed.

Crow et al. (1996) give life history information on 11 species of shark caught in Hawaii during control programs carried out between 1959 and 1980. A total of 15 different species were caught in these programs. Three species, *Hexanchus griseus* (bluntnose six gill), *Echinorhinus cookei* (prickly shark) and *Pseudotriakis microdon* (false cat shark) are deepwater forms. None of these species fall into the four MUS families. Commonly caught species include *Carcharhinus altimus*, *C. limbatus* (blacktip reef shark), *C. plumbeus*, *C. amblyrynchos* (gray reef shark), *C. galapagensis*, *Sphyrna lewini* and *Galeocerdo cuvier*. The pelagic sharks *Isurus oxyrinchus*, *C. falciformis* and *Prionace glauca* were caught in very small numbers as was the great white, *Carcharodon carcharias*, an occasional visitor to the region. Kato (1964) describes seven Carcharhinid sharks caught by purse seiners in the eastern tropical Pacific: *C limbatus*, an inshore species; *C. azureus* (*now C. leucas*, the bull shark), a

Species	**Number**	**Percent**
Alopiidae		
Pelagic thresher (*Alopias pelagicus*)	19	0.08%
Bigeye thresher (*A. superciliosus*)	356	1.46%
Common thresher (*A. vulpinus*)	35	0.14%
Unidentified thresher (*Alopias sp.*)	38	0.16%
Subtotal	448	**1.84%**
Lamnidae		
Great white (*Charcharodon carcharias*)1	0.00%	
Shortfin mako (*Isurus oxyrinchus*)	312	1.28%
Longfin mako (*I. paucus*)	5	0.02%
Unidentifed mako shark (*Isurus sp*.)	8	0.03%
Salmon shark (*Lamna ditropis*)	57	0.23%
Subtotal	383	**1.57%**
Charcharhinidae		
Bignose shark (*Carcharhinus altimus*)	9	0.04%
Silky shark (*C. falciformis*)	56	0.23%
Galapagoes shark (*C. galapagensis*)	4	0.02%
Oceanic whitetip (*C. longimanus*)	629	2.58%
Dusky shark (*C. obscurus*)	2	0.01%
Sandbar shark (*C. plumbeus*)	27	0.11%
Tiger shark (*Galeocerdo cuvier*)	5	0.02%
Blue shark (*Prionace glauca*)	21,917	89.90%
Subtotal	22,649	**92.90%**
Sphyrnidae		
Scalloped hammerhead (*Sphyrna lewini*)2	0.01%	
Smooth hammerhead (*S. zygaena*)	8	0.03%
Unidentified hammerhead (*Sphyrna sp*.)5	0.02%	
Subtotal	15	**0.06%**
Unidentified sharks	885	3.63%
Total	24,380	100.00

Table 2: Observer data on sharks caught in the longline fishery

rarely caught shallow water and estuarine species*; C. galapagensis*; *C. platyrhyncus* (now *C. albimarginatus*), the silvertip, which aggregates near offshore islands; *C. lamiella* (now *C. obscurus*), a rarely caught coastal species; *C. malpeloensis*, the "net eater" (probably *C. falciformis,* which has *Eulamia malpeloensis* as a synonym), the most abundant species; and *C. altimus*, not common in the fishery and first reported in 1962.

The above information suggests that the fishery is dominated by a few species: *Prionace glauca*, *C. longimanus, A. superciliosus*, *Isurus oxyrinchus* and to a lesser extent *C. falciformis* and *Lamna ditropis*. However, numerous other Carcharhinid and Sphyrnid species are caught in low numbers. Many of the Carcharhinid species are coastal or reef dwelling but may on occasion venture far enough offshore to be captured by longliners operating near islands. In addition, seamounts and submerged banks outside of territorial waters may be habitat for some of these species. For example, Branstetter (1987) notes that female scalloped hammerheads are more oceanic and known to form offshore aggregations on seamounts.

The habitat, distribution and biology descriptions given in Compagno (1984) for each family are quoted below, supplemented by material from Strasburg (1958), and with information for specific species from various sources.

<u>Family Alopiidae</u>

Threshers are large, active, strong-swimming sharks, ranging in habitat from coastal to epipelagic and deepwater epibenthic. They are found worldwide in tropical, subtropical and cold-temperate waters. These sharks are apparently specialized for feeding on small to moderately large schooling fishes and squids. Threshers swim in circles around a school of prey, narrowing the radius and bunching the school with their long, strap-like caudal fins. The caudal fin is also used as a whip to stun and kill prey, and threshers are commonly tail-hooked on longlines after striking the bait with the caudal tip. The three species of this family broadly overlap in habitat and range, but differences in their structure, feeding habits and spatial and distribution suggest that they reduce interspecific competition by partitioning their habitat and available prey to some extent. *Alopias superciliosus*, with its huge eyes, relatively large teeth, broad caudal fin, and preference for deeper water (coastally near the bottom), take somewhat larger pelagic fishes (including billfishes and lancetfishes) as well as bottom fishes; *A. vulpinus*, with smaller eyes and teeth, a narrower caudal fin, and preference for the surface, takes small pelagic fishes (including clupeids, needlefishes and mackerels) and squids, but also bonitos and bluefishes. The oceanic *A. pelagicus* is poorly known, but its even smaller teeth and very slender caudal fin suggest that it may take smaller prey than *A. vulpinus* or *A. superciliosus* (Compagno 1984).

Strasburg (1958) reports that the three members of this family were uncommon so little about their distribution could be stated with confidence. He does, however, note a higher catch rate close to land, describing them as "definitely neritic [with] their abundance falling close to zero 40 miles from shore." He is uncertain about depth distribution except to say that they are possibly eurythermal and was most common at intermediate depths (49–85 m based on longline depth). Compagno (1984) gives the following depth distributions*: A. pelagicus* 0–152 m, *A. superciliosus* 0 to at least 500 m, *A. vulpinus* 0 to at least 366m.

Family Lamnidae

Lamnids are tropical to cold-temperate, littoral to epipelagic sharks with a broad geographic distribution in virtually all seas, in continental and insular waters from the surf line to the outer shelves and rarely down the slopes to at least 1,280 m. All the living species are of large size, with a maximum length of 3 to at least 6.4 m.

These sharks are fast swimming, active pelagic and epibenthic swimmers, some of which are capable of swift dashes and spectacular jumps when chasing their prey. Mackerel sharks are partially warm-blooded and have a modified circulatory system that enables them to retain a body temperature warmer than the surrounding water. This permits a higher level of activity and increases the power of their muscles. They feed on a wide variety of bony fishes, other sharks, rays, marine birds and reptiles, marine mammals, squids, bottom crustaceans and carrion. Development is ovoviviparous, with a yolk-sac placenta. (Compagno 1984).

The two species mentioned by Strasburg (1958) are *Isurus oxyrinchus*, the shortfin mako and *Lamna ditropis*, the salmon shark, both considered uncommon. He notes that the shortfin mako has “almost the same range as the great blue shark” (i.e., *Prionace glauca*) and their depth distribution is also eurythermal. Compagno (1984) notes that this shark is seldom found in waters below 16ºC and is “the peregrine falcon of the shark world,” the fastest shark and famed jumper. The salmon shark, as its name implies, is a temperate to boreal shark; according to Strasburg (1958), almost all were caught north of 35ºN. This shark may rarely occur at the northern margin of the Hawaii EEZ but are more likely occasionally caught by Hawaii-based vessels ranging outside the EEZ. There are two other species in the family. The longfin mako (*Isurus peucus*), which was first named fairly recently, in 1966. This suggests that it is a fairly rare species, or at least rarely caught. The great white shark (*Carcharodon carcharias*) is an infamous top-level predator. It tends to be more common on continental margins, although Campagno (1984) notes that “the occurrence of large individuals off oceanic islands far from land where breeding populations of the species apparently do not exist suggests that it can and does make occasional epipelagic excursions into the ocean basins, even though it has never been taken in longline catches there (unlike its relatives in the genera *Isurus* and *Lamna*).” It may therefore be considered an occasional visitor to or vagrant in the management area.

Pratt and Casey (1983) provide growth and age estimates for *I. oxyrinchus* based on specimens captured in the northeast Atlantic. They estimate a one-year gestation period. Growth is considered fast but the species exhibits low fecundity. Size at birth is about 60 cm. Males mature at about 180 cm or 2.5 years, and females, 260 cm or 6–7 years. Theoretical maximum size, based on the von Bertalanffy growth curve is 302 cm for males and 345 cm for females, suggesting a maximum age in excess of 15 years. Size dimorphism between sexes, with females being larger, is common in many shark species.

Family Carcharhinidae

This is one of the largest and most important families of sharks, with many common and wide-ranging species found in all warm and temperate seas. These are the dominant sharks in tropical waters, often both in variety and in abundance and biomass. Most species inhabit tropical continental coastal and offshore waters; several species prefer coral reefs and oceanic islands while a few, including the blue, silky and oceanic whitetip sharks, are truly oceanic and range far into the great ocean basins. Requiem sharks are active strong swimmers, occurring singly or in small to large schools. Some species are continually active while others are capable of resting motionless for extended periods on the bottom. All are voracious predators, feeding heavily on bony fishes, other sharks, rays, squid, octopi, cuttlefishes, crabs, lobsters, and shrimp, but also sea birds, turtles, sea snakes, marine mammals, gastropods, bivalves, carrion, and garbage. (Compagno 1984)

The oceanic species mentioned above does also Strasburg identify the three as common. The blue shark won't be discussed here, as a separate species description has been prepared. The silky (*Carcharinus falciformis*) and oceanic whitetip (*C. longimanus*) are described by Strasburg (1958) as equatorial species with a range practically restricted to within 10 degrees on either side of the equator. According to him, the whitetip is the more abundant of the two species and may be more abundant than the blue shark, even if it is caught less frequently. The whitetip is considered more oceanic while the silky shark was more abundant around the Line Islands (0ºN–10º N and 155ºW–165ºW). The oceanic nature of the whitetip may be due to a lower salinity preference or avoidance of competition with faster moving neritic species. Strasburg (1958) states, "In common with other species occurring in the equatorial area, neither the whitetip nor the silky shark shows much latitudinal change in vertical distribution. The whitetip appears to be principally a surface dweller north of the equator and more bathypelagic to the south, whereas the silky is almost uniformly distributed in depth to the north and is more deep-swimming in the south." Compagno (1984) gives a depth distribution for the silky of 0 to at least 500 m and preferring water temperatures of 23º–24ºC. The whitetip is described as occurring from 0 to at least 152 m and generally found in waters deeper than 184 m. It regularly occurs in waters 18º–20ºC but prefers 20ºC. Strasburg also notes the capture of two blacktips (*C. melanopterus*), but these were caught near shore and are unlikely to caught with any frequency in EEZ waters.

Branstetter (1987) discusses age and growth of *C. falciformis*, one of the more commonly caught species. Based on centrum annuli taken from sharks in the Gulf of Mexico he developed a growth curve for this species. Back calculated size at birth is 55–85 cm with probably a one-year gestation period. Males mature at 210–220 cm or 6–7 years while females mature at greater than 225 cm or more than 9 years. Theoretical maximum size is 290.5 cm or perhaps 20 years old or more, although a more typical maximum age is 10–15 years. Examination of stomach contents suggests that tuna, mackerel, mullet and squid are common prey items in the Gulf of Mexico.

Wetherbee et al. (1996) reviews the biology of the Galapagos shark based on specimens caught in Hawaii shark control programs. This species is essentially limited to oceanic islands and is common on around islands off the American coast but is also commonly found in Hawaii. It prefers rugged bottom terrain and strong currents. There is evidence of sex segregation by depth based on capture records with females preferring shallower water. In Hawaii it is not typically found in shallow water nursery areas, nor does it school, as is common elsewhere. Females are estimated to mature at 6.5–9 years and males at 6–8 years. Mating occurs in winter and spring and pupping in spring and summer of the following year.

This species may give birth only once every two to three years, suggesting overall low fecundity.

Tricas et al. (1981) studied the diel behavior of the tiger shark (*Galeocerdo cuvier*) using a tracking device. They found that the shark they studied (at French Frigate Shoals in the NWHI) spent daylight hours on the outer leeward reef, especially near steep drop-offs. At night the shark would move off the reef into deep water, frequently diving but in general following the contour of the reef front slope. They suggest that this behavior is associated with foraging.

Family Sphyrnidae

The hammerheads are a small but common family of wide-ranging, warm-temperate and tropical sharks found in continental and insular waters on or adjacent to their shelves but with none being truly oceanic. Depths range from the surface, surf-line and intertidal region down to at least 275 m depth. Hammerheads are very active swimmers, ranging from the surface to the bottom, and occur in all warm seas. Several species occur in schools, sometimes with hundreds of individuals. Some of the large species seem to find fish baits on longlines quicker than other sharks and expire more swiftly than most other species after being caught. Hammerheads are versatile feeders that take a wide variety of bony fishes, elasmobranchs, cephalopods, crustaceans and other prey; some habitually feed on other elasmobranchs. (Compagno 1984)

Hammerheads were caught very incidentally according to Strasburg (1958), so he provides no distribution information. Two species were caught, *Sphyrna lewini* and *S. zygaena*. Compagno (1984) describes the scalloped hammerhead (*S. lewini*) as probably the most abundant hammerhead, remaining close into shore, even ranging into enclosed bays and estuaries, and occurring along insular shelves. They are also reported over seamounts. The depth range is given from intertidal to at least 275 m. They are viviparous with a yolk-sac placenta and adults apparently move inshore to mate and young primarily occur close inshore. The habitat for the smooth hammerhead (*S. zygaena*) is essentially similar; however, Compagno gives the depth distribution as “the surface down to at least 20 m and probably much more.” Both species are omnivorous, feeding on a variety of inshore and reef species of fish, crustaceans and cephalopods. This information indicates that these are predominately inshore species and probably rarely caught in offshore fisheries.

Branstetter (1987) provides information on age and growth of *S. lewini* from the Gulf of Mexico. Size at birth is estimated 49 cm. Males mature at about 180 cm or 9–10 years and females at 250 cm or about 15 years. Theoretical maximum size is 329 cm, close to the largest known specimen, 309 cm, taken in Hawaii. The author estimates a maximum age for females of about 35 years and of males of 22–30 years.

Crow et al. (1996) provide information on *S. lewini* and *S. zygaena* captured around Hawaii during control programs. Juveniles of *S. zygaena* are common in coastal waters while adults may prefer offshore areas. Stomach content analysis from this and other studies suggest that teleost fish, crustaceans and pelagic cephalopods are common in the dies of *S. lewini*. *S.*

zygaena apparently prefers cephalopods. Clarke (1971) and Holland et al. (1993) studied scalloped hammerhead (*S. lewini*) pups in Kaneohe Bay, Oahu, Hawaii. The southern part of the bay is a major breeding and pupping ground for this species. Pups apparently tend to avoid light, preferring more turgid waters. Pups school in a core refuge area during the day and then disperses at night, foraging along the base of patch reefs. Juveniles may move out of the bay somewhat inadvertently during foraging activities. As the move out of turgid water they may seek deeper water offshore where light intensity is lower.

Life History Notes on Sharks

Readers are referred to the habitat description for the blue shark as representative of life history aspects of the most commonly caught pelagic species. A very general and brief life history description for the group as a whole is given here.

Sharks are notable in that they produce relatively small numbers of young, which are either oviparous (egg laying, where the young develop inside an egg case) or viviparous (where pups are hatched or are born fully developed). This method of reproduction reduces the susceptibility of young to predation but also makes them more vulnerable to overfishing. Hoenig and Gruber (1990) state that, unlike teleost fish, they can be characterized as “K-selected species” and “the relationship between stock and recruitment in the elasmobranchs is quite direct, owing to the reproductive strategy of low fecundity combined with few, well-formed offspring.” The authors further point out that this strategy is similar to marine turtles and baleen whales, other marine species that have been overfished. Most sharks, except for the exclusively pelagic, reproduce at specific nursery grounds, which are usually inshore and ideally represent a habitat different from likely predators. The main predators on juveniles appear to be other larger sharks (Castro 1987). Thus the availability of predator-free nursery grounds may be an important factor in regulating population (Springer 1967).

Branstetter (1990) describes Atlantic Carcharhinoid and Lamnoid sharks’ reproductive growth in terms of size at birth and growth rate. These strategies can be divided into various categories. There are slow growing types with large neonates that occupy coastal and surf areas and are exposed to predators. Slow growing species with smaller young use bays and estuarine areas as nursery grounds, where predators are absent. Among fast growing species are small and large sized coastal sharks and pelagic sharks, including species significant in the management area. The silky shark (*C. falciformis*) depends on rapid neonate growth for survival and also has relatively large neonates. According to Springer (1967) neonates are found on deep reef areas and move into the pelagic environment at about six months of age. Alopiids and Lamnids have similar strategies. Young tend to be large, although *Isurus oxyrinchus* has smaller neonates but compensates with large litter sizes. Alopiids produce two to four young of intermediate size. Rapid growth in the young of these species allows greater swimming efficiency and speed in order to escape predators. For truly pelagic species, nursery grounds are probably not used; thus the importance of large neonate size and rapid growth.

Sexual segregation in schools is often observed in sharks and is probably related to reproduction. Strasburg (1958) discusses sexual segregation in blue sharks based on longline data (refer to the blue shark habitat description).

Wetherbee et al., (1990) discuss feeding habits of sharks. Sharks are generally portrayed as opportunistic feeders but the authors wish to qualify this somewhat. First, in most species teleosts tend to dominate in stomach content. Diet also changes with ontogenetic development; juveniles, especially when they are at inshore nursery areas have a different diet, eating more crustaceans for example. There may also be seasonal variation due to changes in prey availability. Similarly prey may vary due to habitat; the authors cite a study (Clarke 1971) showing that scalloped hammerhead diet varied from one location to another in Kaneohe Bay, Oahu, Hawaii. Among their conclusions, Wetherbee et al. (1990) state that feeding occurs in short bouts followed by longer periods of digestion and there is not well-established periodicity for feeding. Sharks's daily ration is apparently lower than for teleosts.

Pacific fisheries

Determination of total catch for sharks is difficult since they are bycatch in Pacific region fisheries. In the Hawaii-based longline fishery there has been an increasing trend towards cutting off the dorsal fins as these may be dried and are valued in Asian markets. Mako and thresher shark carcasses are sometimes retained because their meat has some market value. (For a full discussion of the bycatch issue refer to section 4.1 of this amendment.) The total number of sharks caught in the longline and purse seine fisheries is thought to be large (Heberer and McCoy 1997). Pacific-wide, blue sharks are the most significant component of catches, as they are in the region's fisheries. Bonfil (1984) gives a regional summary but relies on Strasburg's report (1958) to derive a breakdown by species based on estimates of the total number of sharks hooked. For 1989, he estimates 19,897 mt of silky sharks (*C. falciformis*), 10,799 mt of whitetips (*C. longimanus*), 8,193 of blue shark and 1,545 mt of other species for South Pacific longline fisheries. For North Pacific (above 20°N) longline fisheries estimated catch is 39,059 mt of blue shark, 145 mt of whitetip and 1,789 of other species. The author is unable to make similar estimates for the purse-seine fishery but cites Au (1991) who describes the nature of associations in different types of tuna schools.

As noted above, the bycatch discussion in this amendment provides some data on shark catches in the Hawaii-based longline fishery. From Table 4.1.b the following numbers and percentages can be derived for 1997: blue sharks 79,712 (93.21%), mako sharks 1,164 (1.36%), thresher sharks 2,321 (2.71%), other sharks 2,326 (2.72%). Published data (WPRFMC 1997) does not break down shark landings by species. In addition, landings data does not account for discards. In 1996 (the most recent data available) an estimated 4.5 million lb (2,041 mt) were landed in Hawaii. (Shark landings represent an estimate of whole weight based on the number of fins landed in addition to any carcasses.) American Samoa estimated landings were 12,747 lb (5.78 mt), and 3,348 lb (1.52 mt) were estimated for Guam. The regional total is thus 4,516,095 lb (2,048 mt). Total landings for the western Pacific region are about 2.5% of the estimated Pacific regional total of 80,927 mt.

Essential Fish Habitat: Shark species complex

If all sharks in the four MUS families are used as a basis for delineating EFH then it will necessarily be large because the families contain both offshore and inshore species occupying a wide variety of habitats. It is probably more realistic to base the delineation only on the more commonly caught pelagic species. Even so, the designation will encompass all epipelagic and mesopelagic EEZ waters. This broad designation results from the wide-ranging nature of many species (taken together covering tropical, temperate and even boreal seas) and lack of knowledge about relative density, although for all species taken together densities are higher in neritic and inshore waters. Very small-scale distribution maps are found in Compagno (1984); Strasburg (1958) has two distribution maps for "common" and "uncommon" species based on hooking rates.

Habitat description for pelagic sharks (Alopiidae, Carcharinidae, Lamnidae, Sphynidae)

	Gestation	**Juvenile / Sub-Adult**	**Adult**
Duration		To 5–10 years or more	To 20 years or more
Diet	NA	Omnivorous, fish, squid	Omnivorous, teleost fish, notably scombrids, in some cases billfish, other elasmobranchs, squid, crustaceans, molluscs
Distribution: General and Seasonal	Major pelagic species gestation and parturition is probably wholly pelagic. Some species, such as Sphyrnids and probably many Carcharhinids have inshore nursery grounds	Highly variable/unknown, see adult distribution	• Alopiidae: 20ºN– 20º S to 50º N–40º S for *A. vulpinus* • Lamnidae: 50ºN-–45ºS *for I. oxyrinchus*, *I paucus* uncertain but more restricted subtropical tropical; *L. ditropis* boreal-temperate (above 35º) in North Pacific • Carcharhinidae: 10º N - 10º S. for *C. falciformis* and *C. longmanus*, other species highly variable
Location	Variable, depends on adults	Highly variable/unknown, see adult distribution	• Alopiidae: neritic to offshore, but not truly pelagic • Lamnidae: epipelagic to mesopelagic • Carcharinidae: highly variable, major captured species epipelagic • Sphyrnidae: *S. lewini*- circumglobal in coastal warm temperate and tropical seas; *S. zygaena*- amphitemperate and tropical
Water Column	NA	Inshore benthic, neritic to epipelagic	Inshore benthic, neritic to epipelagic, mesopelagic
Bottom Type	NA	Highly variable	Highly variable for inshore species
Oceanic Features	NA	Unknown	Unknown, captured species associate with tuna schools

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Name (Order, Family, Genus, species)	Occur in FAO Fishing Areas 71 or 77	Habitat/Range	Common name
ORDER LAMNIFORMES (Mackerel Sharks)			
Family Alopiidae (Thresher Sharks) (Strasburg 1958)			
Alopias pelagicus	71, 77	Oceanic and wide ranging in the Indo-Pacific, Hawaii	Pelagic thresher
superciliosus	71, 77	Oceanic and coastal, virtually cirumtropical, N and S of Hawaii	Bigeye thresher
vulpinus	71, 77	Oceanic and coastal, virtually cricumglobal in warm seas, Fanning Is., Hawaii	Thresher
Family Lamnidae (Porkbeagles, White Sharks			
Carcharodon carcharias	71, 77	Coastal and mostly amphitemperate, Marshall Is., Hawaii	Great white
Isurus oxyrinchus (Strasburg 1958, *I. glaucus*- bonito sh.)	71, 77	Coastal and oceanic, temperate and tropical, 50ºN–40º S	Shortfin mako
paucus	71, 77	Oceanic and tropical, Near Phoenix and north of Hawaii	Longin mako
Lamna ditropis (Strasburg 1951, mackerel shark)	77	Coastal-liitoral and epipelagic in boreal and cool temperate waters, not in management area?	Salmon shark
ORDER CARCHARINIFORMES (Ground Sharks)			
Family Carcharhinidae (Requiem Sharks)			
Carcharinus albimarginatus	71, 77	Coastal-pelagic tropical, Guam	Silvertip
altimus	77	Offshore, bottom-dwelling warm-temperate and tropical, Hawaii	Bignose

amblyrhynchoides	71	Little known, common tropical inshore and offshore	Graceful
amblyrhynchos	71, 77	Coastal pelagic frequenting continental and insular shelves, common on coral reefs, coastal areas throughout management area	Grey reef
amboinensis	71	Inshore, Indo-West Pacific, not in management area	Pigeye
borneensis	71	Rare coastal, inshore, tropical shark of Indo-West Pacific, probably not found in management area	Borneo
brachyurus	71, 77	Inshore to offshore warm temperate shark, possibly confined to continental margins? Not found in management area?	Copper
brevipinna	71	Common coastal-pelagic, warm-temperate and tropical shark of continental and insular shelves, not in management area?	Spinner shark
cautus	71	Little known South Pacific reef shark of shallow water on continental and insular shelves. not in management area?	Nervous shark
dussumieri	71	Common inshore shark of continental shelves, not in management area?	Whitecheek
falciformis (Strasburg 1951, *Eulamia floridanus*)	71, 77	Abundant offshore, oceanic and epipelagic and littoral, tropical, near the edge of continental and insular shelves and in open sea, Caroline, Hawaiian, Phoenix and Line Islands	Silky
fitzroyensis	71	Little known, Australian littoral. Not found in management area	Creek whaler
galapagensis	71	Common but habitat limited tropical shark inshore and offshore, Marianas, to Marshalls, Hawaiian group including NWHI	Galapagos
hemiodon	71	Little known Indo-West Pacific. Not in management area	Pondicherry
leucas	71	Coastal, estuarine continental. Not in management area?	Bull
limbatus	71, 77	Widespread in all tropical and subtropical shelves; not truly oceanic, Hawaii	Blacktip
longimanus (Strasburg 1951, *Pterolamiops*	71, 77	Common oceanic-epipelagic, occasionally coastal, tropical and warm temperate, throughout management area	Oceanic whitetip

longimanus)			
macloti	71,	Little known Indo-West Pacific, not in management area	Hardnose shark
melanopterus (Strasburg 1951)	71, 77	Common shallow water reef shark throughout management area	Blacktip reef
obscurus	71, 77	Common coastal-pelagic shark of continental margins. Not in management area?	Dusky
plumbeus	71, 77	Abundant inshore and offshore, coastal pelagic, temperate and tropical, Hawaii? Not in management area?	Sandbar
porosus	77	Common inshore shark of tropical America, not in management area	Smalltail
sealei	71	Common coastal shark of Indo-West Pacific, not in management area	Blackspot
signatus	77	Atlantic shark with possible extension to Pacific Panama, not in management area	Night
sorrah	71	Coastal, shallow-water shark of Indo-West Pacific, not in management area	Spot-tail
Galeocerdo cuvier	71, 77	Common wide-ranging coastal pelagic, tropical and warm temperate shark with wide habitat tolerance, found throughout management area	Tiger
Glyphis glyphis	71	Little known shark of Bornea, New Guinea and Queensland, not in management area	Speartooth
Lamniopsis temmincki	71	Little known continental shark, not in management area	Broadfin
Loxodon macrohinus	71	Common inshore shark of continental areas, Indo-West Pacific, not in management area	Sliteye
Negaprion acutidena	71, 77	Tropical inshore shark of continental and insular shelves and terraces, Palau Marshall Islands, not in management area?	Sicklefin lemon
brevirostis	77	Abundant inshore shark of tropical Americas and Atlantic, not in management area	Lemon shark
Prionace glauca	71, 77	Wide ranging, oceanic-epipelagic and fringe littoral to at least 152 m	Blue

(Strasburg 1951)			
Rhzoprionodon *acutus*	71	Abundant inshore and offshore shark of continental shelves, not in management area	Milk
longurio	77	Abundant on tropical littoral and continental shelf of America, not in management area.	Pacific sharpnose
oligolinx	71	Common but little known littoral, inshore and offshore tropical, Palau?, not in management area?	Grey sharpnose
taylori	71	Australia, not in management area.	Australian sharpnose
Scoliodon laticaudus	71	Common tropical shark of continental and insular shleves, close inshore. Not in management area.	
Triaenodon obesus	71, 77	Common tropical inshore shark of continental shelves and island terraces. Wide ranging from Indo-West Pacific to central Pacific.	Whitetip reef
Family Sphyrnidae (Bonnethead, Hammerhead, Scoopehead Sharks)			
Euphyra blochii	71	Shallow water on continental and insular shelves, Indo-West Pacific, not in management area.	Winghead
Sphyrna corona	77	Little known, tropical America, not in management area	Scalloped bonnethead
lewini (Strasburg, 1958)	71, 77	Abundant coastal-pelagic, warm temperate and tropical, Hawaii	Scalloped hammerhead
media	77	Little known, tropical America, not in management area.	Scoophead
mokarran	71, 77	Coastal pelagic and semi-oceanic tropical, not in management area?	Great hammerhead
tiburo	77	Abundant inshore, tropical America, not in management area	Bonnethead
zygaena (Strasburg, 1958)	77	Common, coastal pelagic, semi-oceanic, Hawaii.	Smooth hammerhead

2.2.11 Habitat description for albacore tuna (*Thunnus alalunga*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The main sources used in this description are Foreman (1980) and Collette and Nauen (1983). Other reviews include Bartoo and Foreman (1994) and Murray (1994).

The albacore is a member of the Scombridae family mackerels and tunas, composed of 15 genera and 49 species. *Thunnus* is one of four genera in the tribe Thunni, unique among bony fishes in having central and lateral heat exchangers. Separate northern and southern stocks, with separate spawning areas and seasons, are believed to exist in the Pacific. In the North Pacific there may be two sub-stocks, separated due to the influence of bathymetric features on water masses (Laurs and Lynn 1991). Growth rates and migration patterns differ between populations north and south of 40ºN (Laurs and Wetherall 1981, Laurs and Lynn 1991).

In the north Pacific albacore are distributed in a swath centered on 35ºN and as far as 50ºN in the west. In the south Pacific they are concentrated between 10º and 30ºS in the central Pacific (150ºE to 120ºW) and as far south as 50ºS. They are absent from the equatorial eastern Pacific, southeast of Hawaii (which apparently lies near the edge of its range) in an area stretching roughly from 165ºW to the American coast and between 15ºN and the equator. Temperature is recognized as the major determinant of albacore's distribution. Albacore are both surface dwelling and deep-swimming. The distribution maps in Foreman (1980) show the distribution of deep-swimming albacore, which are generally more concentrated in the western Pacific but with eastward extensions along 30ºN and 10ºS. Depth distribution is governed by vertical thermal structures, and they are found to a depth of at least 380 m. The 15.6º to 19.4º C SST isotherms mark the limits of abundant distribution although deep-swimming albacore have been found in waters between 13.5º and 25.2ºC (Saito 1973). Laurs and Lynn (1991) describe North Pacific albacore distribution in terms of the North Pacific Transition Zone, which lies between the cold, low salinity waters north of the sub-arctic front and the warm, high salinity waters south of the sub-tropical front. This band of water, roughly between 40º and 30–35ºN (the Transition Zone is not a perfectly stable feature) also helps to determine migration routes (see below). Telemetry experiments demonstrate that albacore will enter water as cold as 9.5ºC for short periods of time. Laurs and Lynn (1991) argue that acoustic tracking demonstrates that albacore have a wider temperature range than stated previously; their normal habitat is 10º–20ºC with a dissolved oxygen saturation level greater than 60%. The overall thermal structure of water masses, rather than just SST, has to be taken into account in describing total range. Albacore exhibit marked vertical movement and will move into water as cold as 9ºC at depths of 200 m. They move through temperature gradients of up to 10ºC within 20 minutes. This reflects the many advanced adaptations of this fish; it is a thermo-regulating endotherm with a high metabolic rate and advanced cardiovascular system. Albacore have differential temperature preferences according to size, with larger fish preferring cooler water, although the opposite is true in the northeast Pacific. They are considered epi- and mesopelagic in depth range. The minimum oxygen requirement is reckoned to be 2 ml/l.

Albacore are noted for their tendency to concentrate along thermal fronts, particularly the Kuroshio front east of Japan and the North Pacific Transition Zone. Laurs and Lynn (1991) note that they tend to aggregate on the warm side of upwelling fronts. Near continental areas they prefer warm, clear oceanic waters adjacent to fronts with cool turbid coastal water masses. It is not understood why they don't cross these fronts, especially given that they are able to thermo-regulate, but it may be because of water clarity since they are sight-dependent foragers. Further offshore fishing success correlates with biological productivity.

Albacore have a complex migration pattern with the North and South Pacific stocks having their own patterns. Pre-adults undertake most migration, 2–5 years old. A further sub-division of the northern stock, each with separate migration, is also suggested. The model suggested by Otsu and Uchida (1963) shows trans-Pacific migration by year class. Generally speaking, a given year class migrates east to west and then east again in a band between 30º and 45ºN, leaving the northeast Pacific in September–October, reaching waters off Japan the following summer and returning to the east in the summer of the following year. Four- to 6-year-old albacore enter sub-tropical waters south of 30ºN and west of Hawaii (Kimura, et al. 1997) where they spawn. Migration may also be influenced by large-scale climate events that affect the Kuroshio Current regime (Kimura, et al. 1997). Albacore may migrate to the eastern Pacific when the Kuroshio takes a large meander path. This also affects the southward extension of the Oyashio Current and may reduce the availability of forage, primarily saury, in the western Pacific.

The aforementioned sub-stocks apparently divide along 40ºN. Albacore tagged off the US West Coast north of 40ºN apparently undertake more westward migration (58% of tag returns come from the western Pacific west of 180º) versus those tagged to the south (only 10% were recovered in the western Pacific, 78% from the tagging area) (Laurs and Lynn 1991).

Murray (1994), summarizing the work of Jones (1991), describes migration in the South Pacific. Juveniles move from the tropics into temperate waters at about 35 cm LCF and then generally eastward along the Sub-Tropical Convergence Zone. They do not return to the tropics until they are about 85 cm LCF. As they move towards the tropics it is presumed they move deeper, probably due to water temperature. Seasonal patterns are similar to the North Pacific. Juveniles prefer cooler water and move south from sub-tropical waters to temperate in the austral spring. Adults occur from the tropics to temperate zone throughout the years.

Young albacore congregate in large, loosely aggregated schools, at least off the West Coast of North America. Larger fish are observed to form more compact schools, but the dense schools common to yellowfin and skipjack tuna are not true of albacore.

As noted above, the most noted habitat feature affecting abundance and density of albacore populations is their preference for oceanic fronts or temperature discontinuities.

Foreman (1980) summarizes estimates of von Bertalanffy equation parameter in tabular form (Table 2). Growth rates for fish below 38ºN are reportedly higher than those taken to the north. Reported age-length relationships are also summarized. Estimates of the size at one year range from 38 to 57.3 cm, about a third of estimates for size at the von Bertalanffy asymptote, 104–145.3 cm. Juvenile growth has been estimated at 3.12 cm per month (Yoshida 1979). Bartoo and Foreman (1994) give the following von Bertalanffy parameter as the most reasonable for assessment purposes: $L_\infty = 135.6$ cm, $K = 0.17$ and $t_o = -0.87$.

Albacore are heterosexual with no external characters to distinguish males from females. Immature fish generally have an even sex ratio but males predominate in catches of mature fish. Table 4 in Foreman (1980) summarizes published information on sex ratios. For mature fish, male-female ratios range from 1.63:1 to 2.66:1. Like many other pelagic fish, it is believed that albacore release their gametes indiscriminately without selecting partners. Ramon and Bailey (1996) report sexual dimorphism in South Pacific stocks, confirming findings by Otsu and Sumida (1968) with the males being larger. Fecundity is estimated at 0.8–2.6 million eggs per spawning.

Albacore spawn in the summer in subtropical waters. There is also some evidence of multiple spawning (Otsu and Uchida 1959). Foreman (1980) provides a map showing distribution of spawning areas. In the North Pacific the area centers on 25ºN and 160ºE and does not extend east of about 150ºW. In the south Pacific the band is narrower, centered at about 25ºS and stretching from the sea east of Queensland, Australia, to about 110ºW. Ramon and Bailey (1996) discuss spawning seasonality in the South Pacific, near New Caledonia and Tonga. October to December was found to be peak spawning season. Maturing albacore were mostly taken between 20º and 23ºS. The same map in Foreman (1980, Figure 4) shows larval distribution, which is more restricted in extent than estimates of total spawning area.

The review articles consulted for this description summarize the main albacore fisheries in the Pacific. They may be distinguished as either surface or deep water. The surface fisheries are trolling operations off the American coast from Baja to Canada, baitboat operations south of Japan at the Kuroshio Front and a fishery in New Zealand waters. A troll fishery has also developed south of Tahiti. Purse-seine is also considered a surface method but apparently is not a major fishery. Albacore are occasionally bycatch in other tuna fisheries. Elsewhere, mainly the northwest and South Pacific, longline gear is used to capture deep-swimming fish. Taiwanese and Japanese high seas drift gillnetters rapidly expanded effort in the South Pacific after 1988, targeting albacore. A number of regional and international initiatives were put forward to limit or ban this fishery, and by 1990 operations had ceased (Wright and Doulman 1991). Foreman (1980) and Bartoo and Foreman (1994) provide maps of the major fishing areas. Generally, surface fisheries occur in cooler waters and target immature fish; the longline fishery, targeting deep-swimming fish, occurs closer to the equator.

The most recent report for pelagic fisheries in the western Pacific region (WPRFMC 1997) notes that albacore landings in Hawaii by longline, handline and other gear types have increased dramatically in the past five years with much of the catch sent to the US West Coast as a fresh frozen product. Hawaii landings have increased from 300,000 lb (136 mt) in 1987 to 3 million lb (1,361 mt) in 1996, a tenfold increase. The only other area reporting landings in 1996 was American Samoa, with 232,721 lb (105.56 mt). American Samoa also reports

44,500 t (40,370 mt) of albacore landed at the canneries there. Albacore represent 10% of total pelagic landings in Hawaii and 11% of total pelagic landings in the region.

Egg and Larval Distribution

Ueyanagi (1955) and Otsu and Uchida (1959) describe the eggs of albacore, taken from maturing fish. Roe is reported to be the same size as cod roe and light reddish-brown in color. The incubation period is estimated at no more than four days (Matsumoto 1958). Foreman (1980) provides references for papers describing larval albacore. They are easily distinguished from other tuna larvae except yellowfin.

Davis et al. (1990) studied diel distribution of tuna larvae, including albacore in the Indian Ocean off of northwest Australia. They found that albacore migrate to the surface in the day and are deeper at night. This diel pattern was much more marked in albacore than southern bluefin tuna (*Thunnus maccoyii*) larvae. Total vertical range was limited by pycnocline depth, which was 16–22 m in the study area. They concluded that the pycnocline acts as a physical barrier to movement. Albacore may forage during daylight hours and simply sink to neutral depth at night when they cease swimming. Other studies indicate that the top boundary of the pycnocline can be an area of concentration for larvae.

Young and Davis (1990) report on larval feeding of albacore in the Indian Ocean. They found *Corycaeus spp*., *Farranula gibbula* (Cyclopoida) and *Calanoid nauplii* to be major prey items. Diet breadth was greatest for larvae less than 5.5 mm. *Calanoid nauplii* were more important in the diet of smaller larvae; Cyclopoids were eaten by larvae of all sizes but more frequently by larger larvae. As noted above, albacore feed only during the day, although there is some evidence of increased activity around dusk.

Leis et al. (1991) found high concentrations of tuna larvae, including albacore, at sample sites near coral reefs on three islands in French Polynesia. They note that tuna larvae are sparsely distributed in the open ocean, possibly because they congregate near islands. Their findings are similar to Miller's (1979) findings around Oahu, Hawaii. Since their sampling had not been intended for tuna larvae (they were studying reef fish larvae), it was not possible to establish a inshore-offshore gradient from the data. They speculate on why larvae might be concentrated inshore and warn that "anthropogenic impact on near-reef waters will be of concern to tuna fishery management."

As noted above, Foreman (1980) provides a map showing distribution of larval albacore, which gives some idea of their preferred habitat. If the suggestion made by Leis et al. (1991) can be confirmed, it may be that inshore areas represent a habitat feature of special value to larval stage albacore.

Juvenile

Small juvenile albacore range from 12 to 300 mm in length and have been found in coastal waters from a number of areas in the western Pacific including the Mariana Islands, Japanese coastal waters, Fiji, waters east of Australia and Tuvalu. They have also been reported from Hawaiian waters. Albacore are not mature until about 5 years old. As noted above, immature fish prefer cooler water and enter the tropics as adults.

Adult

The size range of adults has already been discussed. Based on age groups it is believed that maximum longevity is around 10 years. Female albacore reach maturity by about 90 cm, while mature males are somewhat larger. Ueyanagi (1957) postulates that males reach maturity at 97 cm. This length would accord with ages between 5 and 7 years, based on length-at-age estimates.

Based on stomach content analysis, the type of food consumed varies among fisheries. Other fish and squid tend to predominate; crustaceans are the other major constituents, although minor in comparison (Iversen 1962). Iversen (1962) also discusses variation in forage based on age, latitude and distance from land. Smaller (younger) fish had a higher proportion of squid in their diet. Gempylids and Bramids were more prevalent in the diet of fish nearer the equator, sauries predominated in temperate waters. This may be due to differences in vertical distribution. Squid were also more prevalent in the diet of fish further from the equator (outside of 5ºS–5ºN). In the tropics squid increased as a part of the diet with greater distance from land. Foreman's (1980) summary emphasizes that albacore feed steadily during both night and day, although less so at night since they are dependent on sight for foraging. Species composition of forage varies by area, and there is a direct relationship between the amount of food in stomachs and the biomass of micronektonic animals (Laurs and Nishimoto 1973). Albacore are considered opportunistic feeders.

The habitat features affecting density and abundance of adults are poorly understood. As discussed above, water temperature, D.O, and salinity are of primarily importance

Essential Fish Habitat: Temperate species complex

EFH can be described in terms of the 15.6º and 19.4ºC SST isotherms that circumscribe the areas of major catches. In the North Pacific the transition zone represents an area of preferred habitat. Albacore are described as epi- and mesopelagic so EFH may be depth limited to about 400 m. Albacore occur throughout the EEZ waters of the western Pacific region. Deep-swimming adults are probably more prevalent, although overall albacore are concentrated away from the tropics and outside of the region's EEZ waters. It is recognized that oceanic fronts are areas where albacore congregate, but it is probably not practical to identify these features, which are not temporally stable with respect to location, as HAPC. Given the findings of Leis et al. (1991), inshore areas, particularly near coral reefs, might be considered of HAPC although findings are still preliminary in this matter. Foreman (1980) provides a wide variety of distribution maps, as noted in this description, for albacore life stages and the location of major fisheries.

Habitat description for albacore tuna (*Thunnus alalunga*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	About 4 days	Weeks (?)	To 4–6 years	To about 10 years
Diet	NA	*Corycaeus spp*. and *Farranula gibbula* (Cyclopoida) and Calanoid nauplii (from studies in Indian Ocean)	See adult	Fish (sauries away from tropics, Gempylids and Bramids near equator), squid, crustaceans
Distribution: General and Seasonal	Based on spawning: sub-tropical, north Pacific area centers on 25ºN and 160ºE to about 150ºW; in south Pacific narrower band centered at about 25ºS from Australia to about 110ºW	Somewhat more restricted than spawning area, possible preference for inshore areas	Preference for cooler waters in comparison to adult, seasonal movement to temperate waters	In north Pacific centered on 35º N, south Pacific 10º–30ºS, seasonal movement to sub-tropical waters
Location		Possibly inshore	Offshore	Offshore
Water Column	Epipelagic	Epipelagic above pycnocline	Epi- to mesopelagic	Epi- to mesopelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features			Oceanic fronts	Oceanic fronts

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2.2.12 Habitat Description for Bigeye tuna (*Thunnus obesus*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Island.

Bigeye tuna occur throughout the entire region of Council jurisdiction and in all neighboring states, territories and adjacent high seas zones.

Life History and General Description

Several studies on the taxonomy, biology, population dynamics and exploitation of bigeye tuna have been carried out, including comprehensive reviews by Alverson and Peterson (1963), Collette and Nauen (1983), Mimura and Staff (1963) and Whitelaw and Unnithan (1997). Calkins (1980), Martinez and Bohm (1983) and Miyabe (1994) provide descriptions of bigeye tuna biology and fisheries specific to the Pacific or Indo-Pacific region. Solov'yev (1970) provides information specific to Indian Ocean bigeye tuna.

During November 1996, the Inter-American Tropical Tuna Commission (IATTC) held the first world meeting on bigeye tuna at their headquarters in La Jolla, California, with participation from the Food and Agriculture Organization of the United Nations (FAO), the Indian Ocean Tuna Commission (IOTC), the Institut Français de Recherche Scientifique pour le Developpement en Coopération (ORSTOM) of France, the Instituto Español de Oceanografía (IEO) of Spain, the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan, the South Pacific Commission (SPC; currently, the Secretariat of the Pacific Community), the US National Marine Fisheries Service (NMFS), the University of the Azores, and the University of Hawaii. The objectives of the meeting were to review and discuss current information on the species and associated fisheries and to make recommendations for necessary areas of research. Review papers on the biology and fisheries for bigeye tuna in the Atlantic, Indian and Pacific Oceans were tabled by Pallarés et al. (1998), Stobberup et al. (1998) and Miyabe and Bayliff (1998) and published in the proceedings to the meeting. Information provided in this document relies heavily on these review papers, which represent the latest published information on bigeye tuna worldwide.

Bigeye tuna are trans-Pacific in distribution, occupying epipelagic and mesopelagic waters of the Indian, Pacific and Atlantic Oceans. The distribution of the species within the Pacific stretches between northern Japan and the north island of New Zealand in the western Pacific and from 40°N to 30°S in the eastern Pacific (Calkins 1980).

A single, Pacific-wide stock has been proposed as well as a two stock hypothesis separating the eastern Pacific from a central/western Pacific stock. Mitochondrial DNA and DNA microsatellite analyses have been conducted on bigeye otoliths from nine geographically scattered regions of the Pacific (SPC 1997b). The results of this study are not conclusive but do support a single stock hypothesis for areas of jurisdiction within the Council's jurisdiction. Although there is currently not enough information available to determine the stock structure of bigeye in the Pacific (Miyabe and Bayliff 1998), a single stock hypothesis is generally accepted for Pacific bigeye tuna and, for the purposes of the region of the Council, a single stock is assumed.

High value sub-surface fisheries seek large, mature-sized bigeye tuna, primarily longline fleets landing sashimi grade product. Smaller, juvenile fish are taken in many surface fisheries, either as a targeted catch or as a bycatch with other tuna species (Miyabe and Bayliff 1998). Basic environmental conditions favorable for survival include clean, clear oceanic waters between 13°C and 29°C. Hanamoto (1987) estimated optimum bigeye habitat to exist in water temperatures between 10° to 15°C at salinities ranging between 34.5‰ to 35.5‰ where dissolved oxygen concentrations remain above 1 ml/l. He further suggested that bigeye range from the surface layers to depths of 600 m. However, evidence from archival tagging studies indicates that greater depths and much lower ambient temperatures can be tolerated by the species. Juvenile bigeye occupies an ecological niche similar to juvenile yellowfin of a similar size. Large bigeye generally inhabits greater depths, cooler waters and areas of lower dissolved oxygen compared to skipjack and yellowfin, occupying depth strata at or below the thermocline at water temperatures of 15°C or lower.

The species is a mixture between a tropical and temperate water tuna, characterized by equatorial spawning, high fecundity andrapid growth during the juvenile stage with movements between temperate and tropical waters during the life cycle. It is believed that the species is relatively long lived in comparison to skipjack and yellowfin tuna.

Feeding is opportunistic at all life stages, with prey items consisting primarily of crustaceans, cephalopods and fish (Calkins 1980). There is significant evidence that bigeye feed at greater depths than yellowfin tuna, utilizing higher proportions of cephalopods and mesopelagic fishes in their diet thus reducing niche competition (Whitelaw and Unnithan 1997). Spawning spans broad areas of the Pacific and occurs throughout the year in tropical waters and seasonally at higher latitudes at water temperatures above 23° or 24°C (Kume 1967). Bigeye are serial spawners, capable of repeated spawning at near daily intervals with batch fecundities of millions of ova per spawning event (Nikaido et al. 1991. Sex ratio is commonly accepted to be essentially 1:1 until a length greater than 150 cm after which the proportion of males increases.

There have been far fewer bigeye tagged in the Pacific in comparison to skipjack and yellowfin, and movement data from tagging programs is not conclusive. Miyabe and Bayliff (1998) present summary information of some long distance movements of tagged bigeye in the Pacific. Hampton et al. (1998) describes 8,000 bigeye releases made in the western Pacific during 1990–1992. Most of the fish were recaptured close to the point of release, approximately 25% had moved more than 200 nm and more than 5% had moved more than 1,000 nm. No tag recoveries have been made in the Indian Ocean or eastern tropical Pacific. Conventional tagging projects on bigeye tuna began in Hawaiian waters in 1996 and will continue into the year 2000 (Itano 1998b). The NMFS Honolulu Laboratory is conducting archival tagging of bigeye tuna in the Hawaiian EEZ.

Bigeyes are clearly capable of large-scale movements, which have been documented by tag and recapture programs, but most recaptures have occurred within 200 miles of the point of release. The tuna appear to move freely within broad regions of favorable water temperature and dissolved oxygen values. If the majority of spawning takes place in equatorial waters, then there must be mass movements of juvenile fish to higher latitudes and return movements of mature fish to spawn. However, the extent to which these are directed movements is unknown and the nature of bigeye migration in the central and western Pacific remains unclear.

Bigeye tuna, especially during the juvenile stages, aggregate strongly to drifting or anchored objects, large marine animals and regions of elevated productivity, such as near seamounts and areas of upwelling (Blackburn 1969; Calkins 1980; Hampton and Bailey 1993). Major fisheries for bigeye exploit aggregation effects either by targeting biologically productive areas and deep and shallow seamount and ridge features or by utilizing artificial fish aggregation devices (FADs) to aggregate commercial concentrations of bigeye. Bigeye tuna are exploited by purse-seine, longline, handline and troll gear within the Council area of jurisdiction (WPRFMC 1997, SPC 1997a).

Egg and Larval Distribution

The eggs of bigeye tuna resemble those of several scombrid species and cannot be differentiated by visual means. Therefore, the distribution of bigeye eggs has not been determined in the Pacific Ocean. However, the duration of the fertilized egg phase is very short and egg distributions can be assumed to be roughly coincident with documented larval distributions. Eggs are epipelagic, buoyed at the surface by a single oil droplet until hatching occurs.

Kume (1962) examined artificially fertilized bigeye eggs in the Indian Ocean, noting egg diameters ranging from 1.03 to 1.08 mm with oil droplets measuring 0.23 to 0.24 mm. Hatching began 21 hours post-fertilization, and larvae measured 1.5 mm in length. Larval development soon after hatching has been described by Kume (1962) and Yasutake et al. (1973). Descriptions of bigeye larvae and keys to their differentiation from other *Thunnus* species are given by Matsumoto et al. (1972) and Nishikawa and Rimmer (1987). However, the early larval stages of bigeye and yellowfin are difficult or impossible to differentiate without allozyme or mitochondrial DNA analyses (Graves et al. 1988). An indexed bibliography of references on the eggs and early life stages of tuna is provided by Richards and Klawe (1972).

The distribution or areas of collection of larval bigeye in the Pacific has been described or estimated by Nishikawa et al. (1978), Strasburg (1960) and Ueyanagi (1969). Bigeye larvae are most common in warm surface waters between 30°N and 20°S in the Pacific. Data compiled by Nishikawa et al. (1978) indicates that bigeye larvae are relatively abundant in the western and eastern Pacific compared to central Pacific areas and is most common in the western Pacific between 10°N and 15°S. The basic environment of bigeye larvae can be characterized as warm, oceanic surface waters at the upper range of temperatures utilized by the species, which is a consequence of preferred spawning habitat. Kume (1967) noted a correlation between mature but sexually inactive bigeye at SSTs below 23° or 24°C, which may represent a lower limit to spawning activity. In the eastern Pacific, bigeye spawning occurs between 10°N and 10°S throughout the year and during summer months at higher latitudes (Collette and Nauen 1983). Hisada (1979) noted from a study in the Pacific that a temperature of 24°C and a maximum depth of 50 m were necessary for maturity and spawning, suggesting a similar seasonal pattern of spawning in the western Pacific. The study by Boehlert and Mundy (1994) in Hawaiian waters and McPherson (1991a) in eastern Australian waters supports the concept of equatorial spawning throughout the year and seasonal spawning of bigeye at higher latitudes. Additional information on the maturity and spawning of western and central Pacific bigeye is provided by Kikawa (1953, 1957, 1961, 1962, 1966), Nikaido et al. (1991) and Yuen (1955). Additional information on the maturity and spawning of eastern Pacific and Atlantic bigeye is given in Goldberg and Herring-Dyal (1981), Pereira (1985, 1987) and Rudomiotkina (1983). It can be assumed that bigeye larvae are common at SSTs above 26°C but may occur in some regions with SSTs of approximately 23°C and above.

Bigeye larvae appear to be restricted to surface waters of the mixed layer well above the thermocline and at depths less than 50 to 60 m, with no clear consensus on diurnal preference by depth or patterns of vertical migration (Matsumoto 1961, Strasburg 1960, Ueyanagi 1969). Prey species inhabit this zone, consisting of crustacean zooplankton at early stages, shifting to fish larvae at the end of the larval phase and early juvenile stages. The diet of larval and juvenile bigeye tuna is similar to that of yellowfin tuna, consisting of a mix of crustaceans, cephalopods and fish (Uotani, et al. 1981).

The age and growth of larval, post-larval and early juvenile bigeye is not well known or studied. Yasutake et al. (1973) recorded newly hatched larvae at 2.5 mm in total length, growing to 3.0 and 3.1 mm at 24 and 48 hours. The early post-larval stage was achieved at 86 hours after hatching. However, it is likely that the early development of bigeye tuna is similar to that of yellowfin tuna, which is the subject of current land based tank studies by the IATTC (IATTC 1997). The larval stages of bigeye tuna likely extend for approximately two to three weeks after hatching.

The short duration of the larval stage suggests that the distribution of bigeye larvae is nearly coincident with the distribution of bigeye spawning and eggs. It has been suggested that areas of elevated productivity are necessary to support broad spawning events that are characteristic of skipjack, yellowfin and bigeye tuna whose larvae would subsequently benefit from being in areas of high forage densities (Sunc et al. 1981, Miller 1979, Boehlert and Mundy 1994).

Juvenile

The juvenile phase of bigeye is not clearly defined in the literature. Calkins (1980) suggests grouping bigeye into larval, juvenile, adolescent, immature adult and adult stages. For the purposes of defining EFH, this report will utilize the categories of egg, larval, juvenile and adult. The juvenile phase extends from the time of transformation from the post-larval phase into a small tuna up to the onset of sexual maturity at approximately 3 years of age. For the purposes of discussion, the juvenile phase will include sexually immature fish to approximately 60 cm FL; pre-adult, 61 to 99 cm FL; and adult, greater than or equal to 100 cm FL.

The distribution of juvenile bigeye tuna less than 35 cm FL is not known but is assumed to be similar to that of larval bigeye, i.e. occupying warm surface waters. The distribution of juveniles greater than 35 cm FL is better understood as they begin to enter catch statistics of purse-seine, pole-and-line and handline fisheries worldwide. Bigeye as small as 32 cm are taken in the Japanese coastal pole-and-line fishery (Honma et al. 1973). Juvenile and pre-adult bigeye of 35 cm to approximately 99 cm are regularly taken as a bycatch in the eastern and western Pacific purse-seine fisheries, usually on sets made in association with floating objects (Hampton and Bailey 1993). Bigeye tuna enter a seamount-associated handline fishery and FAD-based pole-and-line and handline fisheries in Hawaii at approximately 40 cm FL (Boggs and Ito 1993, Itano 1998). Juvenile and pre-adult bigeye of increasing sizes appear in higher latitude fisheries, so one can infer a movement away from equatorial spawning grounds as the fish grow and begin to utilize greater amounts of sub-surface habitat.

Juvenile bigeye form mono-specific schools at or near the surface with similar-sized fish or may be mixed with skipjack and/or juvenile yellowfin tuna (Calkins 1980). Yuen (1963) has suggested that the mixed-species schools are actually separate single-species schools that temporarily aggregate to a common factor such as food. Echo sounder, sonar traces and test fishing strongly support a separation of bigeye, yellowfin and skipjack schools that are aggregated to the same floating object, with the bigeye beneath the other species (Itano, pers. observ.). It is well known that juvenile bigeye aggregate strongly to drifting or anchored objects or to large, slow-moving marine animals, such as whale sharks and manta rays (Calkins 1980, Hampton and Bailey 1993). This phenomenon has been exploited by surface fisheries to aggregate juvenile yellowfin and bigeye tuna to anchored or drifting FADs (Sharp 1978). Juvenile and adult bigeye tuna are also known to aggregate near seamounts and submarine ridge features where they are exploited by pole-and-line, handline and purse-seine fisheries (Fonteneau 1991, Itano 1998a).

The majority of feeding studies conducted on bigeye tuna have examined large longline-caught fish. However, juvenile bigeye is generally recognized to feed opportunistically during day and night on a wide variety of crustaceans, cephalopods and fish in a manner similar to yellowfin of a similar size (Collette and Nauen 1983). Prey items are epipelagic or mesopelagic members of the oceanic community or pelagic post-larval or pre-juvenile stages of island-, reef- or benthic-associated fish and crustaceans. Alverson and Peterson (1963) state that juvenile bigeye less than 100 cm generally feed at the surface during daylight, usually near continental landmasses, islands, seamounts, banks or floating objects.

Adult

Estimates of size at maturity for Pacific bigeye vary between authors (Whitelaw and Unnithan 1997). Kikawa (1957,1961) estimate size at first maturity for males at 101–105 cm and 91–95 cm for females and select 100 cm as a general size for "potential maturity" for Pacific bigeye. The following description will use 100 cm as a rough definition for adult bigeye.

Adult bigeye are distributed across the tropical and temperate waters of the Pacific, between northern Japan and the north island of New Zealand in the western Pacific, and from 40°N to 30°S in the eastern Pacific (Calkins 1980). Numerous references exist on the distribution of Pacific bigeye tuna in relation to general distribution and migration (Hanamoto 1986; Kume 1963, 1967, 1969a, 1969b; Kume and Shiohama 1965; Laevastu and Rosa 1963); the oceanic environment (Blackburn 1965, 1969; Hanamoto 1975, 1976, 1983, 1987; Nakamura and Yamanaka 1959; Suda et al. 1969; Sund et al. 1981; Yamanaka et al.1969); the physiology of tunas (Magnuson 1963; Sharp and Dizon 1978; Stretta and Petit 1989); and fish aggregation devices (Holland et al. 1990).

There is some consensus that the primary determinants of adult bigeye distribution are water temperature and dissolved oxygen levels. Salinity does not appear to play an important role in tuna distribution in comparison to water temperature, dissolved oxygen levels and water clarity. Hanamoto (1987) reasons that optimum salinity for bigeye tuna ranges from 34.5‰ to 35.5‰ given the existence of a 1:1 relationship between temperature and salinity within the optimum temperature range for the species. Alverson and Peterson (1963) state that bigeye tuna are found within SST ranges of 13°to 29°C with an optimum temperature range of 17° to 22°C. However, the distribution of bigeye tuna can not be accurately described by SST data since the fish spend a great deal of time at depth in cooler waters. Hanamoto (1987) analyzes longline catch and gear configurations in relation to vertical water temperature profiles to estimate preferred bigeye habitat. He notes that bigeye are taken by longline gear at ambient temperatures ranging from 9° to 28°C and concludes from relative catch rates within this range that the optimum temperature for large bigeye lies between 10° and 15°C if available dissolved oxygen levels remain above 1ml/l. In a similar study in the Indian Ocean, the optimum temperature for bigeye tuna was estimated to lie between 10° and 16°C (Mohri et al. 1996).

According to several authors, bigeye can tolerate dissolved oxygen levels as low as 1 ml/l, which is significantly lower than the dissolved oxygen requirements of skipjack and yellowfin tuna (Sund et al. 1981). Brill (1994) has proposed a physiological basis to explain how bigeye are able to utilize oxygen in a highly efficient manner thereby allowing them to forage in areas that are not utilized by other tuna species. He theorizes that bigeye tuna spend the majority of their time at depth, making short excursions to the surface to warm up. This vertical movement pattern, which has been clearly demonstrated by sonic tracking experiments of bigeye tuna, is exactly the opposite pattern demonstrated by skipjack and yellowfin tuna (Holland et al. 1992). Sonic tracking and archival tagging of bigeye tuna consistently indicate deep foraging during the daytime near or below the thermocline and shallow swimming behavior during at night.

Hanamoto (1987) examines vertical temperature profiles of water masses within the known range of bigeye in the Pacific and proposes that bigeye range from the surface to as deep as 600 m in areas where suitable temperatures exist at that depth. However, evidence from archival tagging experiments (Boggs, pers. comm.) suggests that bigeye tuna are capable of diving to greater depths and to temperatures well below the values cited by Alverson and Peterson (1963) or estimated by Hanamoto (1987). This work is still in progress and currently unpublished.

The fact that large bigeye take longline hooks at greater depths than yellowfin coupled with a rising demand for sashimi-grade tuna and improved storage techniques prompted a shift to deep longline gear to target bigeye tuna during the late 1970s and early 1980s (Sakagawa et al. 1987, Suzuki et al. 1977). This development promoted numerous studies on differential catch rates and gear configurations to define productive hooking depths for bigeye given different oceanographic conditions (Bahar 1985, 1987; Boggs 1992; Gong et al. 1987, 1989; Hanamoto 1974; Nishi 1990; Saito 1975; Shimamura and Soeda 1981; Suzuki and Kume 1981, 1982; Suzuki et al. 1979).

Several investigators have proposed that the greater depth distribution of bigeye is a foraging strategy to exploit regions less utilized by yellowfin or skipjack tuna, thus reducing niche competition. Bigeye tuna are opportunistic feeders like yellowfin, relying on a mix of crustaceans, fish and cephalopods with feeding taking place during the day and night (Calkins 1980; Collette and Nauen 1983). However, several authors support the notion that the composition of bigeye diet differs significantly from that of similar-sized yellowfin (Watanabe 1958, Talbot and Penrith 1963, Kornilova 1980). Adult bigeyes appear to forage at significant depths, utilizing a higher proportion of squid and mesopelagic fishes compared to yellowfin. Solov'yev (1970) suggests that the preferred feeding depth of large bigeye is 218–265 m, which is the most productive depth for longline catches. Miyabe and Bayliff (1998) summarize diet items of bigeye in the Pacific in tabular form from studies by Alverson and Peterson (1963), Blunt (1960), Juhl (1955), King and Ikehara (1956) and Watanabe (1958). Bigeye tuna are also known to aggregate to large concentrations of forage, such as the spawning aggregations of lanternfish (*Diaphus* sp.) [MYCTOPHIDAE] that occurs seasonally in the Australian Coral Sea (Hisada 1973, McPherson 1991b).

Whitelaw and Unnithan (1997) provide a useful summary of studies on the age and growth of bigeye tuna in the Pacific and Indian Oceans. Pertinent references include Iverson (1955), Kume and Joseph (1966), Marcille and Stequert (1976), Peterson and Bayliff (1985), Tankevich (1982) and Talbot and Penrith (1960). There is some consensus, which is supported by tagging data, that the bigeye's growth is rapid during the first couple of years similar to yellowfin's and then slows down and that the bigeye's lifespan is longer than the yellowfin's. Age studies of bigeye tuna are not complete and the subject requires further work. A recent study by Matsumoto (1998) analyzing presumed daily otolith increments finds a relationship indicating 200 and 400 increments corresponding to fish 40 and 55 cm FL.

Currently, the IATTC and the Commonwealth Scientific & Industrial Research Organization (CSIRO) of Australia are conducting an age validation study using daily growth increments on otoliths. The Offshore Fisheries Programme of the Secretariat of the Pacific Community (SPC) using presumed daily increments on otoliths and tagging data is investigating bigeye age and growth. (Hampton and Leroy 1998, IATTC 1997, SPC 1997b). Preliminary results indicate that bigeye may be relatively slow growing and long lived after year 4.

Estimates of length at maturity for Pacific bigeye vary, and a large-scale study using histological methods is required. Kikawa (1957, 1961) proposed 100 cm as the length for potential to be sexually mature, which appears to be a reasonable estimate. Kume (1962) recorded a length at first maturity of 92 cm, and McPherson (1988) recorded mature bigeye of 100 cm. A 100 cm fish corresponds approximately to a fish of age 3 according to the best available estimates of age and growth reviewed in Whitelaw and Unnithan (1997).

Information on sex ratios of bigeye are inconsistent though there is general agreement that males are more abundant in the larger size classes, > 150 cm. Spawning occurs throughout the year in tropical waters and at higher latitudes when SSTs rise above 23° to 24°C (Kume 1967). Bigeyes are serial spawners, capable of near daily spawning periodicity during spawning seasons of unknown length (Nikaido et al. 1991). Spawning takes place during the afternoon or evening hours at or near the surface (McPherson 1991a).

Adult bigeye tuna aggregate to drifting flotsam and anchored buoys, though to a lesser degree than juvenile fish. Bigeyes also aggregate over deep seamount and ridge features where they are targeted by some longline and handline fisheries. Regions of elevated primary productivity and high zooplankton density—such as near regions of upwelling and convergence of surface waters of different densities that are very important to the distribution of skipjack and yellowfin tuna—are less important to the distribution of adult bigeye. This is logical if one assumes skipjack and yellowfin are inhabitants of the upper mixed layer while adult bigeye are sub-surface in nature, more closely tied to the thermocline and organisms of the deep scattering layer. Water temperature, thermocline depth and season appear to have much stronger influences on the distribution of large bigeye (Calkins 1980). Hanamoto (1987) proposes that productive longline fishing grounds for bigeye do not necessarily equate to regions of higher abundance, but "are nothing more than areas where the hook depths happened to coincide with the optimum temperature layer and where the amount of dissolved oxygen happened to be greater than the minimum required for bigeye tuna (1ml/l)." Nakamura (1969) suggests that bigeye are closely associated with particular water masses or current systems during different life stages. Fish taken in the northern longline fishing grounds around 30°N are reproductively inactive young adults or pre-adults or spent spawners while the fish taken in the equatorial longline fishery are actively spawning adults (Calkins 1980).

Essential Fish Habitat: Temperate species complex

Habitat Description for Bigeye tuna (*Thunnus obesus*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Approximately 24 hours	To approximately 3 weeks	Approximately 3 years	Approximately 6 years (Longevity of 9+ years)
Diet	NA	Zooplankton, larval fish	Crustaceans, cephalopods, fish	Crustaceans, cephalopods, fish
Season/Time	Throughout the year in tropics, seasonally where SST is above 23°–24°C	Throughout the year in tropics, seasonally where SST is above 23°–24°C	Little information available Approximately 25°N to 25°S	Pacific-wide, from northern Japan to north island of New Zealand in western Pacific and 40°N to 30°S in eastern Pacific
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Epipelagic	Pelagic, surface to region of thermocline	Pelagic, surface to below thermocline, optimum water temperature between 10° to 15°C, dissolve oxygen > 1ml/l
Bottom type	NA	NA	NA	NA
Oceanic Features	Areas of upwelling, convergence, oceanic gyres, general productivity	Areas of upwelling, convergence, oceanic gyres, general productivity	Known to concentrate in areas of high productivity, upwelling, convergence including seamount and ridge features	Known to concentrate in areas of high productivity, upwelling, convergence including seamount and ridge features

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2.2.13 Habitat Description for Yellowfin tuna (*Thunnus albacares*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Island.

Yellowfin tuna within the jurisdiction of the Council are managed under the FMP for the Pelagic Fisheries of the Western Pacific Region. Yellowfin tuna occur throughout the entire region of council jurisdiction and in all neighboring states, territories and adjacent high seas zones.

Life History and General Description

Several studies on the taxonomy, biology, population dynamics and exploitation of yellowfin tuna have been carried out, including comprehensive reviews by Cole (1980), Collette and Nauen (1983), Wild (1994) and Suzuki (1994). The information in this brief synopsis of yellowfin tuna distribution and habitat relies heavily on these works.

Yellowfin tuna are trans-Pacific in distribution, occupying the surface waters of all warm oceans and form the basis of large surface and sub-surface fisheries. Basic environmental conditions favorable for survival include clean oceanic waters between 18°C and 31°C within salinity ranges normal for the pelagic environment with dissolved oxygen concentrations greater than 1.4 to 2.0 ml/l (Blackburn 1965, Sund et al. 1981). Larval and juvenile yellowfin

occupy surface waters with adults increasingly utilizing greater depth strata while remaining within the mixed layer, i.e., generally above the thermocline (Suzuki et al. 1978).
The species is a tropical tuna characterized by a rapid growth rate and development to maturity and high spawning frequency and fecundity with a high natural mortality and relatively short life span. Feeding is opportunistic at all life stages, with prey items consisting primarily of crustaceans, cephalopods and fish (Cole 1980). Spawning spans broad areas of the Pacific and occurs throughout the year in tropical waters and seasonally at higher latitudes at water temperatures over 24°C (Suzuki, 1994). Yellowfin are serial spawners, capable of repeated spawning at near daily intervals with batch fecundities of millions of ova per spawning event (June 1953, Nikaido 1988, McPherson 1991, Schaefer 1996). Sex ratio is commonly accepted to be essentially 1:1 until a length of approximately 120 cm after which the proportion of males increases (Kikawa 1966, Yesaki 1983).

Yellowfin are clearly capable of large-scale movements, which have been documented by tag and recapture programs, but most recaptures occur within a short distance of release. The tuna appear to move freely within broad regions of favorable water temperature and are known to make seasonal excursions to higher latitudes as water temperatures increase with season. However, the extent to which these are directed movements is unknown, and the nature of yellowfin migration in the central and western Pacific remains unclear (Suzuki 1994).

Yellowfin tuna are known to aggregate to drifting flotsam, large marine animals and regions of elevated productivity, such as near seamounts and regions of upwelling (Blackburn 1969, Wild 1994, Suzuki 1994). Major fisheries for yellowfin exploit aggregation effects either by utilizing artificial fish aggregation devices (FADs) or by targeting areas with vulnerable concentrations of tuna (Sharp 1979). Yellowfin are exploited by purse-seine, longline, handline and troll gear within the Council area (WPRFMC 1997, SPC 1996).

Egg and Larval Distribution

The eggs of yellowfin tuna resemble those of several scombrid species and cannot be differentiated by visual means. (Cole 1980). Therefore, the distribution of yellowfin eggs has not been determined in the Pacific. However, the duration of the fertilized egg phase is very short, and egg distributions can be assumed to be roughly coincident with documented larval distributions. Eggs are epipelagic, floating at the surface until hatching. The observation of yellowfin spawning and the development of yellowfin egg and early larval stages is now possible at shore-based facilities where yellowfin spawning was first observed during late 1996 (IATTC 1997). Egg diameter ranged from 0.90 to 0.95 mm, and the duration of the egg stage was approximately 24 hours. The notochord lengths of larvae at hatching ranged from 2.2 to 2.5 mm. The duration of the larval stage has been variable in laboratory-reared specimens. Research on yellowfin larvae collected at sea and identified as yellowfin tuna by mitochondrial DNA analysis indicate that wild larvae grow at a rate approximately twice that of laboratory reared larvae and average sizes are 1.5 to 2.5 larger than laboratory reared specimens of a similar age (Wexler 1997).

The larval development from artificially fertilized eggs has been described by Harada et al. (1971), Mori et al. (1971) and Harada et al. (1980). A review of research on the development, internal anatomy and identification yellowfin larvae and early life stages is available in Wild (1994). The early larval stages of yellowfin and bigeye are difficult or impossible to differentiate without allozyme or mitochondrial DNA analyses. The distribution of larval yellowfin in different regions of the Pacific has been described by several authors (Matsumoto 1958, Strasburg 1960, Sun´ 1960). Studies on the larval distribution of yellowfin by Yabe et al. (1963), Matsumoto (1966), Ueyanagi (1969) and Nishikawa et al. (1985) encompass broad areas of the Pacific.

Yellowfin larvae are trans-Pacific in distribution and found throughout the year in tropical waters but are restricted to summer months in sub-tropical regions. For example, peak larval abundance occurs in the Kuroshio Current during May and June and in the East Australian Current during the austral summer (November to December). Yellowfin larvae have been reported close to the MHI in June and September but were not found in December and April (Beohlert and Mundy 1994).

Warm, oceanic surface waters can characterize the basic environment of yellowfin larvae with a preference toward the upper range of temperatures utilized by the species, which may be a reflection of preferred spawning habitat. It can be assumed that yellowfin larvae are common at SST above 26°C (Ueyanagi 1969) but may occur in some regions with SST of approximately 24°C and above. Harada et al. (1980) found the highest occurrence of normally hatched larvae at water temperatures between 26.4°C to 27.8°C with no normal larvae found in water less than 18.7°C or greater than 31.9°C from laboratory observations.

Yellowfin larvae appear to be restricted to surface waters of the mixed layer well above the thermocline and at depths less than 50 to 60 m, with no clear consensus on diurnal preference by depth or patterns of vertical migration (Matsumoto 1958, Strasburg 1960, Ueyanagi 1969). Prey species inhabit this zone, consisting of crustacean zooplankton at early stages of the yellowfin larval phase with some fish larvae at the end of the larval phase.

Age and growth of yellowfin larvae has been investigated under a variety of laboratory conditions and from field collections. Observations from both laboratory raised and wild specimens indicate highly variable growth rates, with wild fish consistently exhibiting higher growth rates compared to laboratory reared specimens (IATTC 1997). It was suggested the differences in growth rates and size at age were due to less than optimal growth conditions in the laboratory environment. Two critical periods of larval mortality have been identified, the first at 4–5 days and the second at about 11 days after hatching; the latter corresponds to the time period when the diet of yellowfin larvae is proposed to shift from crustaceans to fish larvae (FSFRL 1973).

The distribution of yellowfin larvae has been linked to areas of high productivity and islands, but how essential these areas are to the life history of the species is not known. Grimes and Lang (1991) note high concentrations of yellowfin larvae in productive waters on the edge of the Mississippi River discharge plume, and *Thunnus* larvae (most likely yellowfin due to spawning distributions) have been noted to be relatively abundant near the Hawaiian Islands compared to offshore areas (Miller 1979, Boehlert and Mundy 1994).

Juvenile

The distribution of juvenile tuna less than 35 cm FL has not been well documented but is assumed to be similar to that of larval yellowfin. Juveniles occupy warm oceanic surface waters above the thermocline and are found throughout the year in tropical waters. Published accounts on the capture of juvenile tuna have been summarized by Higgins (1967). Juveniles have been reported in the western Pacific between 31°N near the east coast of Japan to 23°S and 23°N near the Hawaiian Islands to 23°S in the central Pacific region. Juvenile yellowfin form single species schools at or near the surface of similar-sized fish or may be mixed with other tuna species such as skipjack or juvenile bigeye tuna. Yuen (1963) has suggested that the mixed-species schools are actually separate single-species schools that temporarily aggregate to a common factor such as food. Juvenile fish will aggregate beneath drifting objects or with large, slow moving animals such as whale sharks and manta rays (Hampton and Bailey 1993). Surface fisheries to aggregate yellowfin tuna, most of which are juvenile fish, to anchor or drifting FADs, have exploited this characteristic. Juvenile and adult yellowfin tuna are also known to aggregate near seamounts and submarine ridge features (Fonteneau 1991).

Juvenile yellowfin feed primarily during the day and are opportunistic feeders on a wide variety of forage organisms, including various species of crustaceans, cephalopods and fish (Reintjes and King 1953, Watanabe 1958). Prey items are epipelagic or mesopelagic members of the oceanic community or pelagic post-larval or pre-juvenile stages of island-, reef- or benthic-associated organisms. Significant differences in the composition of prey species of FAD- and non-FAD–associated yellowfin have been noted in Hawaii (Brock 1985), American Samoa (Buckley and Miller 1994) and the southern Philippines (Yesaki 1983).

Adult

The habitat of adult yellowfin can be characterized as warm oceanic waters of low turbidity with a chemical and saline composition typical of tropical and sub-tropical oceanic environments. Adult yellowfin are trans-Pacific in distribution and range to higher latitudes compared to juvenile fish. The adult distribution in the Pacific lies roughly within latitudes 40°N to 40°S as indicated by catch records of the Japanese purse-seine and longline fishery (Suzuki et al. 1978). SSTs play a primary role in the horizontal and vertical distribution of yellowfin, particularly at higher latitudes. Blackburn (1965) suggests the range of yellowfin distribution is bounded water temperature between 18°C and 31°C with commercial concentrations occurring between 20°C and 30°C. Salinity does not appear to play an important role in tuna distribution in comparison to water temperature and clarity.

Estimates of length at maturity for central and western Pacific yellowfin vary widely with some studies supporting an advanced maturity schedule for yellowfin in coastal or archipelagic waters (Cole 1980). However, most estimates suggest that the majority of yellowfin reach maturity between 2 and 3 years of age on the basis of length-age estimates for the species (Ueyanagi 1966). Longevity for the species has not been defined, but a maximum age of 6 to 7 years appears likely based on growth estimates and tag recapture data. Observations of length at first maturity for female yellowfin range widely from 56.7 cm in the

Philippines (Buñag 1956) to 112.0 cm for western Pacific yellowfin (Sun and Yang 1983). However, most of these studies were based on macroscopic staging techniques that are far less accurate compared to histological methods for determining maturity in serial spawning fishes. Using histological analysis of yellowfin ovaries, McPherson (1991) estimates that the length at 50% maturity for yellowfin in the Australian Coral Sea is 107.9 cm in the inshore handline fishery and 120.0 cm in the offshore longline fishery. These results are similar to Kikawa (1962) who notes from the central and western tropical Pacific that a few longline caught yellowfin were reproductive at 80–110 cm and estimates a length at 50% maturity between 110 and 120 cm from GI analysis. Itano (1997) notes that 50% of yellowfin sampled form purse-seine and longline gear at 105 cm were histologically classified as mature from a large data set from the western tropical Pacific and predicts a length at 50% maturity of 107.9 cm.

Spawning occurs throughout the year in tropical waters at least within 10 degrees of the equator and seasonally at higher latitudes when SSTs rise above 24°C (Suzuki 1994). Several different areas and seasons of peak spawning for yellowfin have been proposed for the central and western equatorial Pacific. Koido and Suzuki (1989) propose a peak spawning period for yellowfin in the western tropical Pacific from April to November. Kikawa (1966) report the peak spawning potential of yellowfin in the western tropical Pacific (120°E–180°) to occur December–January and April–May east of the dateline (180°–140°W). Fish taken by purse-seine gear are more reproductively active with a higher spawning frequency than longline caught fish in the same areas. A positive relationship between spawning activity and areas of high forage abundance has been noted (Itano 1997). Yellowfin spawn in Hawaiian waters during the spring to fall period. June (1953) notes well-developed ovaries in yellowfin caught by longline close the MHI from mid-May to the end of October. Spawning in Hawaiian waters has been histologically confirmed from April to October, and spawning frequency estimates approach a daily periodicity during the peak spawning period of June to August (Itano 1997).

Adult yellowfin tuna are opportunistic feeders, relying primarily on crustaceans, cephalopods and fish as has been described for juvenile fish. However, the larger size of adult fish allows the exploitation of larger prey items, with large squid and fish species becoming more important diet items. For example, Yesaki (1983) notes a high degree of cannibalism of large FAD-associated yellowfin on juvenile tunas in the southern Philippines. The baiting of longlines with saury, mackerel and large squid also implies that mature fish will take large prey items if available.

Yellowfin tuna are known to aggregate to drifting flotsam, anchored buoys, porpoise and large marine animals (Hampton and Bailey 1993). Adult yellowfin also aggregate in regions of elevated productivity and high zooplankton density, such as near seamounts and regions of upwelling and convergence of surface waters of different densities, presumably to capitalize on the elevated forage available (Blackburn 1969, Cole 1980, Wild 1994, Suzuki 1994). However, the degree to which these regions are essential or simply advantageous to yellowfin is not known.

Essential Fish Habitat: Tropical species complex

Habitat Description for Yellowfin tuna (*Thunnus albacares*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 hours	To approximately 3 weeks	Approximately 2 years	Approximately 4–5 years
Diet	NA	Zooplankton, larval fish	Crustaceans, cephalopods, fish	Crustaceans, cephalopods, fish
Season/Time	Throughout the year in tropics, seasonally where SST is above 24°–25°C	Throughout the year in tropics, seasonally where SST is above 24°–25°C	31°N near Japan, at least 23°N–23°S in central Pacific	40°N –40°S, within SST range 18°–31°C, abundant between 20°–30°C Spawning throughout the year in tropics, seasonally where SST is above 24°–25°C
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Epipelagic	Pelagic, upper mixed layer	Pelagic, throughout mixed layer, occasional excursions below thermocline
Bottom type	NA	NA	NA	NA
Oceanic Features	Areas of upwelling, convergence, oceanic gyres, general productivity	Areas of upwelling, convergence, oceanic gyres, general productivity	Known to concentrate in areas of high productivity, upwelling, convergence	Known to concentrate in areas of high productivity, upwelling, convergence

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2.2.14 Habitat description for northern bluefin tuna (*Thunnus thynnus*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Material for this habitat description is drawn from Bayliff (1994) and Collette and Nauen (1983). Bayliff provides an extensive list of references, which are not, in general, re-cited here.

There are seven species in the genus *Thunnus*, a member of the Thunnini tribe of the subfamily Scombrinae. Three of these species, *T. thynnus*, *T. alabacares* (yellowfin tuna) and *T. obsesus* (bigeye tuna) are PMUS. Tunas of this genus are unique in their high metabolic rate and vascular heat exchanger systems allowing thermo-regulation and endothermy. The Pacific northern bluefin is considered sub-species. *T. thunnus orientalis* (Temminck and Schlegel) along with an Atlantic sub-species, *T. thynnus thynnus* (Linnaeus). The Pacific population is considered a single stock but with a long range, complex migratory pattern (see below).

The range of the species is between about 20º and 40º N in the eastern and central Pacific, but with a northern extension to the Gulf of Alaska in the east. In the western Pacific they are found as far south as 5º N and north to Sakhalin Island near the Asian mainland. This represents the limits of distribution; based on historic fish landings they are concentrated between about 25º and 40ºN in the central and western Pacific. In the eastern Pacific bluefin are caught mostly between Cabo San Lucas, Baja California, Mexico and Point Conception, California. They are occasionally caught further north along the California coast, in Oregon and Washington and to Shelikoff Straight in Alaska. This probably represents an occasional range extension due to elevated SST. In the eastern and central Pacific preferred habitat as defined by temperature is between 17º and 22º or 23ºC. In the western Pacific off Japan optimal temperature is reported as between 14º and 19º or 15º and 17º. Japanese coastal fishermen in warmer water, as high as 29ºC for fish 15 to 31 cm. Temperature range reportedly increases with size, catch juvenile fish. Bayliff (1994) provides maps of the areas of the North Pacific bounded by the 17º and 23ºC isotherm by season. Roughly, in winter it is a band centered on 30ºN latitude and in summer on 40ºN.

In addition to the review article cited earlier, migration is described in Bayliff, et al. (1991) and Bayliff (1993). Bluefin spawn in the western Pacific, off of the Philippines (April–June) and Japan (July–August). Larvae, postlarvae and juveniles are transported northward in the Kuroshio Current. Some fish remain in the western Pacific while others migrate eastward after their first winter. Bayliff suggests that the isotherm band described above, which coincides roughly with the North Pacific Subarctic-Subtropical Transition Zone (see the habitat description for albacore tuna for more discussion of this oceanographic feature), bounds their migration path. The migration time is relatively brief, seven months or less. It is unclear how long fish remain in the eastern Pacific or whether they make multiple migrations back and forth, although this seems unlikely. Eventually fish return to the western Pacific to spawn; the return journey takes longer, around two years, as the minimum time based on tag returns is 674 days. Some juvenile fish also move southward from the spawning areas off the Philippines and Japan. Northern bluefin have been caught as far south as New Zealand and are occasionally caught off of Papua New Guinea, the Solomon Islands and the Marshall Islands. However, there is no evidence of spawning in these areas.

In addition to the temperature ranges discussed above, habitat features mentioned by Bayliff that may affect population abundance and density include the California Current in the eastern Pacific, the aforementioned Pacific Transition Zone and the Kuroshio Current off of Japan.

The papers by Bayliff cited above discuss age and growth. While von Bertalanffy parameter estimates have been made, Bayliff et al. (1991) argue for a two-stage model with separate parameter estimates for fish less than 564 mm following the Gompertz model and linear growth for fish greater than 564 mm. The parameters are also presented in Bayliff (1994) but will not be reproduced here. Estimates for size at age for 1-year-old fish range from 43 to 76.3 cm and for 4-year-old fish, 113.1 to 178 cm (see Table 1 in Bayliff (1991)). Bayliff (1993) presents age at length—by month—for bluefin in the eastern Pacific. The maximum size fish caught in the North Pacific is reported as 300 cm. Using the growth equations presented by Bayliff this corresponds to an age of about 9.5 years, but bluefin from the Pacific have lived as long as 16 years in captivity. Bayliff (1993) discusses the coefficient of natural mortality and arrives at a range of 0.161–0.471 for the 90% confidence interval. Using these figures, at 10 years about 79% and 99%+ mortality is achieved respectively.

Bluefin may be sexually dimorphic with respect to size as is common in other tunas; fish raised in captivity reached a size of 1,190 mm for males and 1,353 mm for females at 3 years of age (Hirota et al. 1976). Male-female sex ratios reported in Bayliff (1993) range from 45:0 for fish caught in the eastern Pacific by purse seine to 28:47 (1:1.68) for longline caught fish landed off of Taiwan. Fecundity has been estimated at 10 million eggs for fish 270–300 kg.

Spawning areas and seasons were discussed above. Larvae were reported off of Oahu, Hawaii, by (Miller, 1979) but other unpublished sampling data (from 1984–85) reported by Bayliff (1993) found no bluefin larvae off of Oahu.

The major fisheries for bluefin in the eastern Pacific are a sport fishery and commercial purse seining off the US West Coast; foreign longliners also catch a small number of fish in this region. In the western Pacific a variety of gear is used, primarily in coastal fisheries but also by purse seiners in an area about 30º–42ºN and 140º–152ºE. Bayliff (1993) discusses landing trends; CPUE trend is only available for the eastern Pacific. There both CPUE and effort declined during the 1980s and early 1990s.

In the western Pacific region only Hawaii reported commercial bluefin tuna landings in 1996. This entire total of 100,000 lbs (45.36 mt) was landed by the longline fleet (WPRFMC 1997). No information is given on catch areas, but they are most likely north and west of the Hawaiian Islands and mostly in international waters. Total landings in managed fisheries are small in comparison to total catch in the Pacific. For example Bayliff (1993) reports 13,183 mt landed in 1986 by all Japanese vessels, almost 300 times 1996 Hawaii landings.

Egg and Larval Distribution

Eggs and larvae are probably confined to known spawning areas in the western Pacific, outside of the management area. As noted above, Miller (1979) reports larvae from Hawaiian waters but later more extensive sampling in Hawaii failed to turn up larvae. Given the distance from known spawning areas it would seem unlikely the bluefin larvae normally occur in Hawaiian waters. Larvae reportedly feed on small zooplankton, mainly copepods (Uotani et al. 1990).

Bayliff (1994) provides no details on larval growth and habitat. More information may be found in Yabe and Ueyanagi (1962) and Yabe et al. (1966).

Juvenile

Bluefin are estimated to reach maturity at 3–5 years, with the latter age more likely according to Bayliff and equivalent to a size of about 150 cm. As already noted, some juvenile fish migrate across the Pacific, probably within the Transition Zone, and remain off the American West Coast from Baja to southern California. Juvenile fish migrate seasonally (November to April) offshore, perhaps into the central Pacific but probably not returning all the way to the western Pacific. Fish stay in the eastern Pacific for several years, up until 5 or 6 years of age, but return to the western Pacific at or before sexual maturity, eventually to spawn.

Feeding habits of bluefin in the eastern Pacific would represent juvenile food preferences. These are reviewed by Bayliff (1994). Major prey items include anchovies, red crabs (*Pleurocodes planipes*), sauries (*Cololabis saira*), squid (*Loligo opalescens*) and hake (*Merluccius productus*); anchovies make up 80% of stomach contents by volume. Anchovies, crustaceans and squid are also reported as the main prey items for immature fish caught in the western Pacific.

The distribution and preferred habitat of juveniles has already been discussed in connection with migration.

Adult

As already noted, bluefin reach maturity at about 5 years of age or possibly somewhat earlier. Their distribution and habitat preferences have already been discussed. Prey items are squid and a variety of fish including anchovies (*Engraulis japonica* and *Stolephorus zollingeri*), herring (*Etrumeus teres*), pampanos (Carangidae), mackerel (*Scomber spp*.) and other tunas (*Auxis spp*. and *Katsuwonus pelamis*). In the western Pacific, Bluefin are also reported to associate with schools of sardine (*Sardinops melanosticta*), which are probably also an important prey item.

Essential Fish Habitat: Temperate species complex

Bluefin is caught in significant quantifies by the Hawaii-based longline fleet. The North Pacific Transition Zone, areas off the west coast of America and off of East Asia are all important habitat areas outside of the region.

Habitat description for northern bluefin tuna (*Thunnus thynnus*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	Days	Weeks	To 5 years or somewhat less	To about 10 years
Diet	NA	Copepods	Fish, squid, crustaceans, especially anchovies	Fish and squid, especially anchovies, mackerels, other tunas and sardines
Distribution: General and Seasonal	Western Pacific, Philippines to Japan	Western Pacific, Philippines to Japan	Western Pacific off of Japan and north, North Pacific Transition Zone and off the American coast Baja to southern California	North and west Pacific and south in west Pacific to spawning areas
Location	Offshore?	Offshore?	Offshore and inshore outside management area	Offshore and inshore outside management area
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features	Kuroshio Current	Kuroshio Current	Kuroshio Current, North Pacific Transition Zone, California Current	Kuroshio Current, North Pacific Transition Zone

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2.2.15 Habitat description for skipjack tuna (*Katsuwonus pelamis*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reff, Palmyra Atoll, Jarvis Island, Howland and Baker Islands Midway Island and Wake Island.

Life History and General Description

Major reviews of skipjack tuna life history and distribution used in the preparation of this description include Matsumoto et al. (1984), Forsburgh (1980) and Wild and Hampton (1991).

Morphological and genetic research indicates that *Katsuwonis pelamis* is one worldwide species, and no subspecies are recognized. Serological and genetic analysis of Pacific populations has not conclusively determined the sub-population structure. The species is genetically heterogeneous across the Pacific. A longitudinal variation in the esterase Est 1 gene was argued to be discontinuous, at least in the southern hemisphere, supporting the argument that there are at least two sub-populations in the eastern and western Pacific (Fujino 1972, 1976). A longitudinal cline has also been detected in Est 2 gene frequency between 140ºE and 130ºW (SPC 1981). Sharp (1978) argued that there are at least five sub-populations, but Ianelli (1993) consider this improbable. Richardson (1983) argues that skipjack exist in a series of semi-isolated "genetic neighborhoods" enclosing a group of randomly breeding adults. However, it is difficult to reliably delimit the size and location of these neighborhoods. In sum, two hypotheses are currently considered: an isolation by distance model where the probability of two individuals mating is inversely proportional to the distance between them at birth and a discrete sub-population model where breeding groups are relatively distinct. Wild and Hampton (1991) state that "the difficulties that are encountered in applying either the isolation-by-distance or discrete–sub-population hypotheses prevent the choice of a single, descriptive model of the skipjack population at this time."

Skipjack tuna are found in large schools across the tropical Pacific. They prefer warm, well-mixed surface waters. Barkley (1969) and Barkley et al. (1978) describe the hypothetical habitat for skipjack as areas where a shallow salinity maximum occurs seasonally or permanently. Matsumoto et. al. (1984) describe the habitat in terms of temperature and salinity: "1) a lower temperature limit around 18ºC, 2) a lower dissolved O_2 level of around 3.5 p/m, and 3) a speculative upper temperature limit, ranging from 33ºC for the smallest skipjack tuna caught in the fishery to 20ºC or less for the largest." These limits represent constraints on activity based on available dissolved oxygen and water temperature. Wild and Hampton (1991) suggest a minimum oxygen level of 2.45 ml/l in order to maintain basal swimming speed. (Since skipjack lack a swim bladder Sharp (1978) calculated that a 50 cm skipjack must swim 60.5 km/d just to maintain hydrodynamic stability and respiration.) A maximum range is proposed as an area bounded by the 15ºC or roughly between 45ºN and S in the western Pacific and 30ºN and S in the east. This range is more restricted in the eastern Pacific due to the basin-wide current regime, which brings cooler water close to the equator in the east. (See Figure 10 in Matsumoto et al. (1984) for a map of skipjack distribution.)

Wild and Hampton (1991) note the a variety of other oceanographic and biological features influence distribution, including thermocline structure, bottom topography, water transparency, current systems, water masses and biological productivity. In the tropics these factors may be more important in determining distribution than temperature. Temperature change in sub-tropical regions affects seasonal abundance. Large-scale climatic features, of which El Niño is the most well known, also affect distribution. This primarily affects localized distribution in the eastern tropical Pacific.

Vertical distribution is generally limited by the depth profile of the temperature and oxygen concentrations given as minimums above. Dizon et al. (1978) found that skipjack move between the surface and 263 m during the day but remain within 75 m of the surface at night.

Although skipjack form large schools, these are not stable and often break up at night. Tagging data indicate that school membership is not stable over time (Bayliff 1988, Hilborn 1991). From analysis of parasite fauna, Lester et al. (1985) determine that school half-life is likely to be only a few weeks.

Pre-recruits disperse from the central Pacific, arriving in the eastern Pacific at 1 to 1 ½ years old and return to the central Pacific at 2 to 2 ½ years old (Wild and Hampton 1991). Migrants to the eastern Pacific split between a northern and southern group off of Mexico and Central and South America respectively. Ianelli (1993) reviews three possible migration models that might account for this north-south distribution. These models are based on large-scale current patterns in the region.

In the western Pacific substantial work has been carried out, although Wild and Hampton (1991) note that many issues have not been resolved. In some cases data indicate that there is relatively little movement, particularly in the Papua New Guinea and Solomon Islands area. There is also evidence of an eastward migration in the Micronesian region (Mullen 1989, Polacheck 1990).

A reliable means for establishing an age-length relationship does not exist. Matsumoto et al. (1984) estimate a maximum age for skipjack of 8–12 years based on the largest individual documented in the literature (Miyake 1968) as in 106.5–108.4 cm size class. Matsumoto et. al. (1984) provide an extensive review of growth estimates. Estimates for a 1-year-old are 26–41 cm and 54–91 cm for 4-year-olds.

Skipjack are heterosexual with a few instances of hermaphroditism being recorded. Sex ratio is variable: young fish have ratios dominated by females, and older fish have a higher proportion of males (Wild and Hampton 1991). Observations by Iversen et al. (1970) suggest courtship behavior between pairs of tuna. Mating is most likely promiscuous (Matsumoto et al. 1984). Although relatively little has been published on the fecundity of skipjack, in the Pacific the reported range is between 100,000 and 2 million ova for fish 43–87 cm.

Skipjack spawn more than once in a season, but the frequency is not known. They spawn year-round in tropical waters and seasonally, spring to early fall, in sub-tropical areas.

Historically bait boats (pole-and-line) were the main gear used in catching skipjack. Since the 1950s purse seiners have come to dominate the fishery. (Longliners targeting on yellowfin tuna also catches some skipjack incidentally.)

There are two major fisheries in the eastern Pacific. The most important is located east of 100ºW off of Central and South America. The northern fishery, separated by a region of low abundance (described above) occurs near Baja California, the Revillagigedo Islands and

Clipperton Island. In the western Pacific the fishery is diverse, occurring in the waters of a number of island nations and carried out by both small domestic fleets and distant water fleets from developed nations, primarily Japan and the US. Fishing effort is concentrated in the waters around Micronesia and northern Melanesia.

Skipjack tuna are caught throughout the management plan area by a variety of methods. The

	1995	**1996**
American Samoa	179,104	75,967
Guam	192,218	21,5944
Hawaii	1,700,000	2,300,000
Northern Mariana Islands	105,423	132,155
Total	2,178,740	2,726,062

largest fishery is in Hawaii utilizing bait boats. The other principle method of capture is by trolling. Skipjack are also caught by longliners although they are usually not the target species. For comparison, 666,834 mt of skipjack tuna were caught in the SPC statistical area in 1995. The management plan area landings represent about 0.2% of this amount. A significant amount of tuna caught outside of the management plan area is delivered to canneries in American Samoa.

Egg and Larval Distribution

Matsumoto et al. (1984) summarize larval development; Ueyanagi et al. (1974) is the primary source. Ripe eggs are described as spherical smooth, transparent and usually containing a single yellow oil droplet. Diameter range from 0.80 to 1.135 mm. They are comparable in appearance to the eggs of other tunas and thus difficult to distinguish in plankton tows. Therefore, distribution cannot be determined although it is assumed to be coincident with larval distribution since eggs hatch rapidly. Spawned eggs are buoyant and thus epipelagic. Once fertilized, eggs hatch in about 1 day, depending on temperature.

Matsumoto et al. (1984) describe the typical characteristics of larvae as “a disproportionately large head which is bent slightly downward in relation to the body axis, the appearance of 2 or 3 melanophores over the forebrain area when the larvae are about 7 mm long (the number of melanophores increase to about 12 in larvae 14.5 mm in length), heavy pigmentation over the midbrain area throughout all sizes, and the appearance of the first dorsal fin spines in larvae about 7 mm long (the number increases to about 12 in larvae about 14.5 mm in length), heavy pigmentation over the mid-brain area throughout all sizes, and the appearance of the first dorsal fin spines in larvae about 7 mm long (the number of spines increase to about 13 in larvae 11 mm TL).”

Matsumoto et al. (1984) state that the onset of the juvenile stage is evidenced by “attainment of the full complement of 15 spines and 15 rays in the first and second dorsal fins, respectively, and 15 rays in the anal fin.…” These developments occur by the time larvae reach about 12 mm, which conflicts somewhat with the earlier description of larvae up to about 14.5 mm. No age for this size is given but it is probably about 2–3 weeks.

No information was given on feeding and food, but likely food are phytoplankton and for larger-sized larvae, zooplankton also.

As noted earlier, skipjack spawn year-round in tropical waters so it would be expected that in tropical waters eggs and larvae would be present much of the time. The distribution of larvae has been documented by Japanese research vessel net tows (Ueyanagi 1969, Nishikawa et al. 1985). (See Matsumoto et al., 1984, Fig. 11 for a map of larval distribution.) Like adults, larvae have a wider latitudinal distribution in the western Pacific than in the east. Kawasaki (1965) suggests that the center of abundance of skipjack tuna larvae in the Pacific Ocean lies between 5ºN and 4ºS and 160ºE and 140ºW. Matsumoto (1975) later reports the center of abundance between 160ºE and 140ºW but moderate between 100ºW and 140ºW and 120ºE and 160ºE. Areas above 20ºN with relatively high larval abundance include the Hawaiian Islands. Klawe (1963) did not find any larvae below the mixed layer. Larvae apparently migrate to the surface at night while staying deeper at night (Wild and Hampton 1991).

Wild and Hampton (1991) state that skipjack larval distribution is strongly influenced by temperature. Forsbergh (1989) demonstrates that the concentration of larvae in the Pacific approximately doubles with each 1ºC increase in SST between 24º–29ºC and then begins to decrease above 30ºC. Matsumoto et al. (1984) present a limit for larval distribution based on the 25ºC isotherm. As noted above, larvae remain in the mixed layer.

Leis et al. (1991) found particularly high concentrations of skipjack larvae near coral reefs of islands in French Polynesia. It may be that the more productive waters around oceanic islands and reefs provide preferred habitat for larval development.

Juvenile

Mori (1972) defines juveniles as smaller than 15 cm (but above 12–15 mm as the upper limit for larvae as defined by Matsumoto et al. (1984)) while young are 15–35 cm. Skipjack first spawn at about 40 cm length (see below). Relatively little is known about the juvenile phase (especially the adolescent or pre-adult stage) since they do not turn up in plankton tows and are too small to enter any fishery. Most have been collected from the stomachs of larger tunas and billfish (Wild and Hampton 1991).

Skipjack have closely spaced gillrakers, allowing them to consume a variety of prey (Ianelli 1993). Matsumoto et al. (1984) note that smaller skipjack tuna mainly rely on crustaceans for food, presumably zooplankton.
No information on juvenile habitat is available although the range appears to be similar to that of larvae. Matsumoto et al (1984) note that the distribution in the Pacific Ocean is generally from 35ºN to 35ºS in the west and between 10ºN and 5ºS in the east. (See figure 13 in this publication for a distribution map based on captures.)

No information is available on special habitat features that affect density and abundance.

Adult

Matsumoto et al. (1984), reviewing a variety of sources, argue that the minimum size for female skipjack at maturity is 40 cm and initial spawning occurs between 40–45 cm. Based on growth estimates, skipjack are about 1-year-old at this size.

Skipjack are opportunistic foragers, and an extensive range of species has been found in their stomachs. Matsumoto et al. (1984) document taxonomic groups found in various studies analyzing stomach contents; 11 invertebrate orders and 80 or more fish families are listed. In the western and central Pacific fishes are the most important prey, followed by molluscs and crustaceans. Scombrids are the most important group of fish consumed by skipjack.

Experiments with captive skipjack indicate that an intense feeding period occurs in the early morning (Magnuson 1969). Despite intense feeding these fish did not immediately fill their stomachs; apparently they ate slowly over the entire 2-hour feeding. Fish ate about 15% of their body weight per day. In another experiment it was observed that fish feed intensively at first and then in smaller amounts throughout the day; they could not feed effectively at night; introduced fish learned feeding methods from other fish that had been in the experimental tanks for some time; and fish never fed off the bottom of the tank (Nakamura 1965).

In the wild skipjack exhibit feeding peaks in the early morning and late afternoon.

The hypothetical habitat for skipjack tuna has already been described and the adult range encompasses all of the areas where earlier life stages are concentrated. Figures 56–60 in Matsumoto et al. (1984) provide information on the distribution of this habitat.

Essential Fish Habitat: Tropical species complex

EFH encompasses the whole EEZ of the management plan area in the near surface waters of the mixed layer. Figure 57 in Matsumoto et al. (1984) suggests that the deepest habitat depth attained in the Pacific is around 300 m but in the management plan areas is probably half that or less. Since skipjack occur in schools, they are not distributed uniformly across the EEZ at any given time. However, all of these waters meet habitat criteria, and it is not possible to determine what part of this habitat is occupied at any given time, except perhaps for seasonal variations in sub-tropical areas.

Waters close to islands, banks and reefs may be areas of larval concentration and could be considered as HAPC.

Habitat description for skipjack tuna (*Katsuwonus pelamis*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration		To 12–15 mm (2–3 weeks?)	15 mm–40 cm	Above 40 cm
Diet	NA	Zooplankton	Similar to adult diet?	Highly variable, fish, molluscs, crustaceans
Distribution: General and Seasonal	Center of spawning abundance: 5ºN-4º S and 160º E–140ºW.	From 24º to 29ºC with preference at higher temperatures but decreasing above 29ºC.	35ºN–35ºS in the west and 10ºN–5ºS in the east	Warm well mixed oceanic waters. 15º–33ºC maximum range. Above 3.5 p/m dissolved O_2. 45ºN–45ºS in the west and 30ºN and 30ºS in the east. Warm well mixed upper oceanic waters. 15º–33ºC maximum range. Above 3.5 p/m dissolved O_2. 45ºN–45ºS in the west and 30ºN–30ºS in the east.
Location	Offshore waters	Offshore waters	Offshore waters	Offshore waters
Water Column	Epipelagic	Pelagic, upper mixed layer	Pelagic, mixed layer	Pelagic, mixed layer
Bottom Type	NA	NA	NA	NA
Oceanic Features	Depends on adult preferences	Depends on adult preferences	Eddies, upwelling, oceanic fronts and other areas of high productivity	Eddies, upwelling, oceanic fronts and other areas of high productivity

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2.2.16 Habitat Description for kawakawa (*Euthynnus affinis*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

The main sources for this description were the review documents Yesaki (1994), Collette and Nauen (1983) and Yoshida (1979). Both Yesaki and Yoshida contain extensive reference lists; in general those references are not re-cited here.

The genus *Euthynnus* is a member of the Thunni tribe of the subfamily Scombrinae. There are three species in the genus. Of the other two species, *Euthynnus lineatus* is reported from the American west coast from southern California to Peru and Hawaii but is not a management unit species. For kawakawa no sub-species are recognized and no information is reported on stock separation.

Kawakawa is an epipelagic neritic species, mainly of the west and south Asian and east African continental margin. It is found throughout the archepelagic waters of Southeast Asia to northern Australia. Most reports emphasize its association with continental margins, but it also occurs around oceanic islands and island archipelagoes. Strays have also been reported from the American continental margin. Generally, its distribution is tropical-subtropical between 35ºN and 35ºS. In Hawaiian waters, kawakawa are reportedly confined to the 20–30 fm (36.5–54.8 m) contour. Trolling studies in Thailand indicate that kawakawa are most commonly taken in the outer neritic zone (50–200 m depth) with almost none caught in deeper waters. Fish of 20–40 cm are more common in the inner neritic zone (less than 50 m depth) and apparently move into deeper water after 50 cm (Yesaki 1982). In Japan and Hong Kong favorable habitat characteristics include relatively low salinity (31.22 to 33.80 ppt in Japan, as low as 26 ppt during the monsoon in Hong Kong) and higher productivity either due to upwelling or estuarine influence. However, kawakawa are not found in brackish (i.e., very low salinity) water. The species has a relatively wide temperature range, 18º–29ºC according to Collette and Nauen (1983) or 14º–29ºC for Hong Kong waters as reported by Williamson (1970).

Seasonality in landings is reported throughout the kawakawa's range, although generally it is not strong. However, no definitive migration pattern is reported. Kawakawa tend to form mixed schools, co-occurring with other tunas including yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and the frigate tuna (*Auxis thazard*). It also schools with the carangid *Megalaspis cordyla*. Juveniles are commonly preyed upon by yellowfin and skipjack, and Yesaki (1994) suggests that all these species are probably competitors.

Yesaki (1994) reviews age and growth studies for kawakawa and concludes, "studies of kawakawa completed to date give conflicting results" (p 392). Lengths at age based on these studies rang from 19–47 cm for 1-year-olds, 41–65 cm for 2-year-olds and 41–72 cm for 3-year-olds. The range in growth parameters given are K 0.37–0.96 (with an outlier of 2.23), L_{∞} 59.5–81.0 cm and t_o -0.15 and -0.344 (only two studies reported this parameter). Yesaki (1994) emphasizes that all studies suggest rapid growth during the juvenile stage. Maximum age for the species is 5 or 6 years. The largest specimen reported by Yoshida (1979) is 87 cm and 8.6 kg although specimens over 100 cm have reportedly been taken from Japanese waters.

Kawakawa are heterosexual, and sexual dimorphism is not reported. Fecundity estimates range from .202 to 2.5 million eggs. Kawakawa apparently spawn inshore based on captures of larval fish. Yesaki (1994) states that they are widely but very patchily distributed and generally taken close to landmasses. Larvae are reported from Hawaii and French Polynesia, indicating spawning around oceanic islands where they occur, but the highest concentrations of larvae are found off of Australia, Java, Papua New Guinea, the Solomon Islands and the Ryukyu Islands of southern Japan. According to Yesaki (1994) there are two spawning seasons in the tropics, a main season in the first half of the year and a secondary season in the latter half.

Total landings for kawakawa throughout its range are reported at 122,893 mt in 1989. The Philippines generally reports the highest landings, and in 1989 they were 57,899 mt, or close to half total landings. Kawakawa are captured by a variety of gear in coastal fisheries including troll, gillnet, purse seine and ringnet. In general they are part of multi-species, small-pelagic coastal fisheries that are most intense in the Southeast Asian Indo-Pacific. Kawakawa is not an important commercial species in the western Pacific region. In Hawaii, landings of kawakawa are lumped in the "miscellaneous pelagics" category based on longline logbook reports. However, it is likely inshore small boat fishermen more commonly catch that kawakawa. However, these landings do not appear in the Council's annual report. Guam reported 1996 landings of 4,043 lb (1,833.87 kg), but gear type is not specified; American Samoa reported 225 lb (102.10 kg), all troll caught (WPRFMC 1997). In comparison to total commercial landings in the western Pacific region or total landings of kawakawa throughout its range it can be seen that landings of kawakawa in the Council's management area are negligible.

Egg and Larval Distribution

The distribution of eggs and larvae has already been discussed in connection with spawning. There is little information about kawakawa eggs. Reported egg diameter from one study are 0.85–0.95 mm. Yoshida (1979) provides an extensive treatment of egg and larval development. Eggs take less than 24 hours to hatch.

The key descriptive paper on kawakawa larvae is Matsumoto (1958). The transition from larval to juvenile stage occurs between 10 and 20 mm. No information on larval diet is given in the literature. As already noted, eggs and larvae are found close inshore. At the end of the juvenile stage fish move offshore, although adults are still found in the neritic environment.

Juvenile

Yenagi (1994), summarizing various studies, states that kawakawa reach maturity at about 38 cm. Based at length at age estimates this would correspond to about a 1-year-old fish. As already noted, adult and juvenile kawakawa do not differ markedly in habitat.

Adult

Age and growth have already been discussed. Kawakawa are opportunistic feeders; according to Yoshida (1979) "these fishes feed primarily on whatever is available at any particular place and time." He gives an extensive list of prey items, based on earlier studies. In excess of 17 kinds of fish, some only identified to family or genus, are listed as well as various cephalopods (squid) and crustaceans.

Habitat has already been discussed. As Yoshida (1979) points out for the genus as a whole, they "are generally coastal fishes and judging from the distribution of the various life stages of these species, the entire life cycle is completed within the coastal province."

Essential Fish Habitat: Tropical species complex

The neritic environment can be considered EFH for this species. All of the review articles used in preparing this description contain a variety of distribution maps.

Habitat Description for kawakawa (*Euthynnus affinis*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	24 hours	Weeks	To about 1 year	5–6 years
Diet	NA	Unknown	Similar to adult	Highly opportunistic
Distribution: General and Seasonal	Coastal-neritic	Coastal-neritic	Coastal-neritic	Coastal-neritic
Location	Inshore	Inshore	Inshore	Inshore
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	NA	NA	NA	NA
Oceanic Features	Unknown/coastal	Unknown/coastal	Unknown/coastal	Unknown/coastal

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Yoshida HO. 1979. Synopsis of biological data on tunas of the genus *Euthynnus*. Washington: NOAA (NMFS). 57 p. NOAA technical report nr NMFS Circular 429 (FAO Fisheries Synopsis nr 122).

2.2.17 Dogtooth tuna (*Gymnosarda unicolor*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

Very little is known about the biology of dogtooth tuna (*Gymnosarda unicolor*), although it is widely distributed throughout much of the Indo-Pacific faunal region, from the Red Sea eastward to French Polynesia (Collette and Nauen 1983). This species is not found in the Hawaiian Islands, although fishermen do refer to catches of the meso-pelagic snake mackerel

(Gempylidae) as “dogtooths.”

G. unicolor is an epipelagic species, usually found individually or in small schools of six or less (Lewis et al. 1983). Dogtooth tuna are found in deep lagoons and passes, shallow pinnacles and off outer-reef slopes (Collette and Nauen, 1983). It occurs in mid-water, from the surface to depths of approximately 100 m, and has a preference for water temperatures ranging from 20° to 28°C.

G. unicolor is one of the few species of tuna that is found primarily in association with coral reefs (Amesbury and Myers 1982) and probably occupies a niche similar to other reef-associated pelagic predators such as Spanish mackerel (*Scomberomorus* spp) and queenfish (*Scomberoides* spp). Like the Spanish mackerels, large dogtooth tunas can become ciguatoxic from preying on coral reef herbivores, which themselves have become toxic through ingestion of the dinoflagellate, *Gambierdiscus toxicus* (Myers 1989).

A positive correlation between size and depth has been observed in the distribution of this species based on limited information from Tuvalu, with larger individuals being found at progressively greater depths (Haight 1998). This species reportedly reaches a maximum size of 150 cm FL and 80 kg (Lewis et al. 1983).

Observations from Fiji suggest that dogtooth tuna obtain sexual maturity at approximately 65 cm (Lewis et al. 1983), while Silas (1963) reported a partially spent 68.5-cm male dogtooth tuna from the Andaman Islands. Females outnumbered males by nearly 2:1 in Fiji, and all fish larger than 100 cm were females, suggesting sexual size dimorphism in this species (Lewis et al. 1983). Lewis et al (1983) suggest that the vulnerability of female dogtooth tuna to trolling declines as the fish approach spawning condition.

In Fiji, spawning reportedly occurs during the summer months, i.e., between October and March (Lewis et al. 1983). Dunstan (1961) observed spawning dogtooth tuna in Papua New Guinea during March, August and December, and various other authors (Silas 1963) have provided some evidence of summer spawning for this species. Okiyama and Ueyangi (1977) note that the larvae of dogtooth tuna occurs over a wide area of the tropical and subtropical Pacific Ocean, between 10°N and 20°S, with concentrations along the shallow coastal waters of islands, such as the Caroline Islands, Solomon Islands and Vanuatu. Dogtooth larvae were collected in surface and subsurface tows, with greater numbers in the sub-surface tows at depths between 20–30m. Older, better-developed larvae appear to make diurnal vertical migrations, rising to the surface during the night. On the basis of larval occurrence throughout the year, Okiyama and Ueyangi (1977) postulate year round spawning in tropical areas.

There are no fisheries specifically directed at dogtooth tuna in the western Pacific region. The primary means of capture include pole and line, handlines and surface trolling (Severance 1998, pers. comm; Collette and Nauen 1983). Dogtooth tuna have been sold in local markets in American Samoa and the Northern Mariana Islands, but currently has little market value (Severance 1998, pers. comm.).

Dogtooth tuna are voracious predators, feeding on a variety of squids, reef herbivores such as tangs and unicorn fish (Acanthuridae), small schooling pelagic species including fusiliers

(*Caesio* spp) and roundscads (*Decapterus*) (Myers 1989).
Essential Fish Habitat: Tropical species complex

Dogtooth tuna are unique among the family Scombridae in having such a close association with coral reefs, although they are also found around rocky reefs in higher latitudes such as in Korea and Japan (Myers 1989). Within the western Pacific region, waters on and adjacent to coral reefs down to a depth of about 100 m should designated EFH for this species.

Habitat Description for Dogtooth Tuna (*Gymnosarda unicolor*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration			Dogtooth tuna obtain sexual maturity at approximately 65 cm	Unknown
Diet	N/A	Unknown	Unknown, unlikely to be different from adult	Dogtooth tuna are voracious predators, feeding on a variety of squids, reef herbivores such as tangs and unicorn fish (Acanthuridae), small schooling pelagic species including fusiliers (*Caesio* spp) and roundscads (*Decapterus*)
Distribution: General and Seasonal	Unknown	The larvae of dogtooth tuna occurs over a wide area of the tropical and subtropical Pacific Ocean, between 10°N and 20°S, with concentrations along the shallow coastal waters of islands, such as the Caroline Islands, Solomon Islands and Vanuatu. Dogtooth larvae were collected in surface and subsurface tows, with greater numbers in the sub-surface tows at depths between 20–30m	Unknown, unlikely to be different from adult	Dogtooth tuna (*Gymnosarda unicolor*) is widely distributed throughout much of the Indo-Pacific region, from the Red Sea eastward to French Polynesia. This species is not found in the Hawaiian Islands. Dogtooth tuna are unique among the family Scombridae in having a such a close association with coral reefs, although they are also found around rocky reefs in higher latitudes
Water Column	Epipelagic	Epipelagic	Epipelagic	*G. Unicolor* is an epipelagic species. Dogtooth tuna are found in deep lagoons and passes, shallow pinnacles and off outer-reef slopes. It occurs in mid-water, from the surface to depths of approximately 100 m, and has a preference for water temperatures ranging from 20° to 28°C.
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Eggs subject to advection by prevailing currents	Larvae subject to advection by prevailing currents	Unknown	Unknown

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2.2.18 Habitat Description for Moonfish (*Lampris guttatus*): Opah or Moonfish

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands and Wake Islands.

For management purposes, opah are generally classified under the miscellaneous pelagics. In the Hawaii-based longline fishery, miscellaneous pelagics make up only a small portion of total revenue; however, revenue from this group (led by moonfish) has increased for the three most consecutive years of data (1994-96). Opah landings have increased consistently from 1992 to a high of 760,000 lbs in 1996 averaging 0.52 fish/1000 hooks set; mean ex-vessel price 1987-96 (based on whole weight) was $1.07/lb (Ito and Machado 1997).

Life History and General Description:

The opah, also commonly known as moonfish, are not a target species in any fishery and as a result, very limited biological and ecological information pertaining to the species is currently available in the published literature. Opah was, however, a common incidental take in the now defunct Asian high-seas driftnet fisheries and is a common bycatch in pelagic longline fisheries targeting tunas and swordfish and to a lesser degree in U.S. coastal albacore and salmon fisheries. On Japanese research cruises to waters east of Hawaii and to the equatorial eastern Pacific, mean catch rate for opah was 0.98 and 0.57 fish/hooks, respectively.

Opah are typically found well offshore in temperate and tropical waters of all the world's oceans, including the Mediterranean and Caribbean Seas (Russo 1981, Heemstra 1986). In the Hawaii-based longline fishery where nearly 5000 opah are landed each year, catches and catch rates for the species tend to be highest within the 200 mile EEZ around the main Hawaiian Islands as compared to more distant waters offshore (outside the EEZ) or in the EEZ around the atolls and islets that comprise the Northwestern Hawaiian Islands (Ito and Machado 1997). Off the coast of Europe, Orkin (1950) reported opah to be often taken in 183 m (100 fathoms) near the edge of the Continental Shelf.

Through the water column, opah reportedly inhabit waters from the surface to the lower epipelagial-mesopelagic in excess of 500 m (Miller and Lea 1972, Nakano et al. 1997). On longlines set in the morning and retrieved during the afternoon-evening, opah were among species that are caught more frequently as the depth of the fished hooks increased; i.e., higher catch rates at deeper depths (Nakano et al. 1997). Regular captures in high seas driftnets set in the evening and retrieved in the morning provide evidence those opah frequent waters within 10 m of the surface at night (Seki, in prep). Because captures in driftnets took place exclusively in the northern Transition Zone, it is still not clear whether this species exhibits diel vertical migration or more likely exhibit broad horizontal migrations and/or distributions within a preferential temperature range. In the northeast Atlantic, opah moves northward into the waters of the North Sea and off Norway in the summer (Muus and Dahlstrom 1974). Opah catch around Hawaii is usually highest in the fourth quarter of the calendar year (Ito and Machado 1987).

Opah are generally solitary fish (Orkin 1950, Palmer 1986) and attains 185 cm in length and reportedly reach 227-282 kg in weight (Eschmeyer et al. 1983, Palmer 1986). Mean whole weight of opah taken in the Hawaii-based longline fishing fleet (1991-96) was 47.4 kg (104.5 lbs) (Ito and Machado 1997). Little to no information is available on spawning habits, age, or growth or migrations. A single large female caught in the early spring off the west coast of North America appeared to be nearly ready to spawn suggesting that spawning probably takes place during the spring months (Fitch and Lavenberg 1968). Off Scotland, ovaries in a 137 cm (4.5 ft) gravid female measured 290x70 mm and 240x70 mm and weighed 276 and 255 grams, respectively. The largest ova measured 0.82 mm in diameter (Herald 1939). Opah eggs and larvae are pelagic; larvae range from less that 4.7 mm to 10.5 mm at which size fin ray development is complete and juveniles resemble miniature adults in form (Olney 1984). Size at maturity is not known.

As adults, opah are midwater predators that feed on cephalopods (particularly oceanic squid), bony fishes (small pelagics) and to a lesser extent, crustaceans (Orkin 1950, Fitch 1951, McKenzie and Tibbo 1963, Eschmeyer et al. 1983, Heemstra

1986). Predators of opah are not known; no information is available on the diet and trophic relationships of larvae or juveniles.

Habitat Description for Moonfish (*Lampris guttatus*): Opah or Moonfish

Duration	**Egg** Not known	**Larvae** Not known	**Juvenile** Size at maturity is not known	**Adult** Size at maturity is not known
Diet	Not known	Not known	Not known	As adults, opah are midwater predators that feed on cephalopods (particularly oceanic squid), bony fishes (small pelagics) and to a lesser extent, crustaceans
Distribution: General and Seasonal	Not known	Not known	Not known, unlikely differnet from adults	Opahs are typically found well offshore in temperate and tropical waters of all the world's oceans, including the Mediterranean and Caribbean Seas. Orkin (1950) reported opah to be often taken in 183 m (100 fathoms) near the edge of the Continental Shelf.
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Eggs subject to advection by prevailing currents	Larvae subject to advection by prevailing currents	Not known	Not known

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2.2.19 Habitat Description for Oilfish Family (Gempylidae): the escolar (*Lepidocybium flavobrunneum*) and the oilfish (*Ruvettus pretiosus*)

Management Plan and Area:

American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

In the Pacific, several species of snake mackerels (Family Gempylidae) are caught in pelagic fisheries. Of particular interest are the two most commonly taken in western Pacific longline fisheries: the escolar, *Lepidocybium flavobrunneum*, and the oilfish, *Ruvettus pretiosus*. For management purposes, the escolor and oilfish are generally classified under the miscellaneous pelagics.

Life History and General Description:

Neither species of snake mackerel is a target species in any fishery and as a result, very limited biological and ecological information pertaining to the species is currently available in the published literature. Both species were, however, among the more common incidental takes in the now defunct Asian high-seas driftnet fisheries and are a common bycatch in pelagic longline fisheries targeting tunas and swordfish. On Japanese research cruises to waters east of Hawaii, mean catch rate for escolar was 0.98 fish/1000 hooks; no oilfish were caught (Nakano et al. 1997). In two areas off the west coast of Africa, escolar catches were 0.20 and 0.17 fish/1000 hooks (Maksimov 1970). Between the two snake mackerel species, the escolar is more frequently caught and possesses the greater commercial value. Excessively high oil content in the flesh of the oilfish renders the species unpalatable as a food fish but historically has possessed value as a laxative (Fitch and Schultz 1978).

Both the escolar and the oilfish are widely distributed, typically found over the continental slope and offshore in all tropical and subtropical waters of the world's oceans but is apparently nowhere abundant (Parin 1986). In a commercial scale fishing effort conducted in the western Pacific, catch rates were highest where topographic relief was steepest, namely in the vicinity of shoals, reefs, and seamounts (Nishikawa and Warashina 1988).

Through the water column, escolar inhabit epipelagic waters from the surface to about 200 m, oilfish to the lower epipelagial-mesopelagic in excess of 700 m (Parin 1978, Nakano et al. 1997). In the vicinity of New Caledonia and New Hebrides, Fourmanoir (1970) reported catching escolar (74.3 to 91.8 cm SL) while fishing at depths of 110 to 195 m. Nakano et al. (1997) found similar catch rates for escolar throughout the water column and concluded no clear trend in escolar depth of capture. Escolar are also believed to vertically migrate upward at night to feed on pelagic fishes, crustaceans and especially squids (Nakamura and Parin 1993). Captures in high seas driftnets set in the evening and retrieved in the morning provide evidence that both the escolar and oilfish frequent waters within 10 m of the surface at night (Seki, in prep). Oilfish are typically solitary or in pairs when near the bottom. Like the escolar, oilfish feed predominantly on squids, also fishes and crustaceans (Parin 1986, Nakamura and Parin 1993). Predators of juvenile escolar include yellowfin and albacore tuna, swordfish, and other escolars (Fourmanoir 1970, Maksimov 1970). Predators of adult escolar and oilfish are not known.

Little information is available on other life history aspects. From length frequencies, Maksimov (1970) concluded that escolar females grew faster than males but no ages were assigned. Based on the capture of larvae and juvenile stages of escolar, spawning seems to take place in the vicinity of oceanic islands or the coasts of large islands (Nishikawa 1982, 1987). Nishikawa (1982) also found all postlarvae forms of escolar were taken in horizontal subsurface net tows while all juveniles were caught at the surface suggesting differential ontogenetic habitats. In a similar pattern, oilfish were collected near topography particularly in warm waters of the western Pacific (Nishikawa 1987).

Escolar attain about 200 cm SL , most commonly to 150 cm (Nakamura and Parin 1993). Nakamura and Parin (1993) reports escolar weigh 6.5 kg at 77 cm SL (89 cm TL) and 13 kg at 91 cm SL (105 cm TL). Nishikawa and Warashina (1988) reported the relationship between body (fork) length (FL) and weight (in kg) for escolar as:

$$W = 1.46 \times 10^{-5} \cdot FL^{2.96} \quad (n=46,\ 59\text{-}95 \text{ cm FL}).$$

Habitat Description for Oilfish Family (Gempylidae)

	Egg	Larvae	Juvenile	Adult
Duration	Not known	Not known	Not known	Not known
Diet	Not known	Not known	Not known, unlikely different than adults	Feed predominantly on squids, also fishes and crustaceans.
Distribution: General and Seasonal	Not known	Not known	Not known	Both the escolar and the oilfish are widely distributed, typically found over the continental slope and offshore in all tropical and subtropical waters of the world's oceans but is apparently nowhere abundant
Water Column	Epipelagic	Epipelagic, based on the capture of larvae and juvenile stages of escolar, spawning seems to take place in the vicinity of oceanic islands or the coasts of large islands	Epipelagic, juveniles are caught at the surface suggesting differential ontogenetic habitats.	Epipelagic, Through the water column, escolar inhabit epipelagic waters from the surface to about 200 m, oilfish to the lower epipelagial-mesopelagic in excess of 700
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Eggs are subject to advection be prevailing currents	Larvae are subject to advection be prevailing currents	Not known	Not known

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2.2.20 Habitat Description for Pomfret (family Bramidae): the sickle pomfret (*Taractichthys steindachneri*) and the lustrous pomfret (*Eumegistus illustris*)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands, Midway Island, and Wake Islands.

In the Pacific, several species of pomfret (Family Bramidae) are caught in pelagic fisheries. Of particular interest is the sickle pomfret, *Taractichthys steindachneri*, and the species most commonly taken in western Pacific longline fisheries and the lustrous pomfret, *Eumegistus illustris*, caught both in the longline fishery and in the deep bottomfish snapper fishery. For management purposes, both the sickle and lustrous pomfret are generally classified under the miscellaneous pelagics and marketed commercially as "monchong".

Life History and General Description:

Neither species of pomfret is a target species in any fishery and as a result, very limited biological and ecological information pertaining to the species is currently available. Both species, as mentioned above however, are common incidental bycatch in western Pacific fisheries.

Adult and juvenile (30-150 mm SL) sickle pomfret are widely distributed in the tropical waters of the Pacific and Indian Oceans (Mead 1972). Lustrous pomfret are also known from the tropical Pacific and eastern Indian Ocean but unlike other bramids, are typically found in association with topography (e.g., near islands and over seamounts or submarine ridges) (Mead 1972, Prut'ko 1986, Chave and Mundy 1994).

Through the water column, sickle pomfret inhabit epipelagic waters to at least 300 m (Nakano et al. 1997). On longlines set in the morning and retrieved during the afternoon-evening, sickle pomfret were among the species that are caught more frequently as the depth of the fished hooks increased; i.e., higher catch rates at deeper depths (Nakano et al. 1997). Most of the lustrous pomfrets caught in exploratory deep-water bottomfishing at seamounts off Hawaii were taken in depths less than 549 m (300 fathoms); no pomfret were caught at seamounts when the summit exceeded 457 m (250 fathoms) (Okamoto 1982).

There are no descriptions of food or feeding habits of the sickle pomfret. A single stomach collected by a NMFS research cruise contained a pelagic squid, *Moroteuthis* spp. (NMFS, unpubl.) Lustrous pomfret taken on bottom handline rigs off Hawaii (Okamoto 1982) as well as those caught in the Indian Ocean with trawl nets (Prut'ko 1986) fed on midwater fishes such as lanternfishes, crustaceans and some squid. Predators of juvenile pomfrets (both species) include tunas and swordfish (NMFS, unpubl.).

Sickle pomfret attain about 80 cm TL (Dotsu 1980). No maximum size for lustrous pomfret has been reported but a single 70 cm FL individual was taken bottomfishing at Johnston Atoll (Ralston et al. 1986). The range of pomfret weights in Okamoto's (1982) exploratory study off Hawaii was 2.2 - 9.6 kg and averaged 5.5 kg. He further reported the relationship between body (fork) length (FL) and weight (in kg) for escolar as:

$$W = 3.0 \times 10^{-6} \cdot FL^{3.442} \quad (n=75, 59\text{-}95 \text{ cm FL}).$$

Trawl caught lustrous pomfret (n=100) in the Indian Ocean ranged from 44.0 to 67.0 cm SL and 2.36 to 7.05 kg in weight (Prut'ko 1986).

Little information is available on other life history aspects. A 60 cm sickle pomfret weighing 11 kg was estimated to be 8 years old (Smith 1986). A 78 cm TL mature female (originally identified as *T. longipinnis* but now considered a misidentified *T. steindachneri)*, taken in the Southeast Pacific possessed ova spherical in shape and 1.2 mm in diameter (Dotsu 1980). The mature varies were small and about 90 g in weight; the gonadosomatic index (GSI) was less than 1 and the ovaries contained about 7.0 x 10^5 eggs (Dotsu 1980). The male to female ratio in the Indian Ocean collection of lustrous pomfrets was 1:1 and judging from the advanced maturation stages observed in the gonads, the school was in spawning condition (Prut'ko 1986).

Habitat Description for Pomfret (family Bramidae)

	Egg	Larvae	Juvenile	Adult
Duration	Not known	Not known	Not known	A 60 cm sickle pomfret weighing 11 kg was estimated to be 8 years old
Diet	N/A	Not known	There are no descriptions of food or feeding habits of the sickle pomfret.	There are no descriptions of food or feeding habits of the sickle pomfret. A single stomach collected by a NMFS research cruise contained a pelagic squid, *Moroteuthis* spp.
Distribution: General and Seasonal	Not known	Not known	Not known	Adult and juvenile (30-150 mm SL) sickle pomfret are widely distributed in the tropical waters of the Pacific and Indian Oceans. Lustrous pomfret are also known from the tropical Pacific and eastern Indian Ocean but unlike other bramids, are typically found in association with topography (e.g., near islands and over seamounts or submarine ridges)
Water Column	Epipelagic	Epipelagic	Epipelagic	Through the water column, sickle pomfret inhabit epipelagic waters to at least 300 m. Most of the lustrous pomfrets caught in exploratory deep water bottomfishing at seamounts off Hawaii were taken in depths less than 549 m (300 fathoms); no pomfret were caught at seamounts when the summit exceeded 457 m (250 fathoms.
Bottom Type	N/A	N/A	N/A	N/A
Oceanic Features	Eggs are subject to advection by prevailing ocean currents	Larvae are subject to advection by prevailing ocean currents	Not known	Not known

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2.2.21 Habitat description for bullet tuna (*Auxis rochei*) and frigate tuna (*A. thazard*)

Management Plan and Area: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

Life History and General Description

This description is based on the following summary documents: Yesaki and Arce (1994), Collette and Nauen (1983) and Uchida (1981).

The genus *Auxis* is a member of the Thunni tribe and the subfamily Scombrinae. For management purposes, regulations identify these fish only to the generic level, but only two cosmopolitan species are currently recognized in this genus. However, there has been a lot of synonymy in scientific names for the species; the two species are very similar in appearance and usually only reported to the generic level in landings reports. *Auxis* are considered both the most primitive and the smallest of tunas in the Thunni tribe. No sub-species are recognized. No information on stock separation is given in the review articles. Hybrids of the two species have been produced under artificial rearing conditions, but none lived beyond a month.

The genus is distributed worldwide in tropical and subtropical waters. Because of their similar appearance, differential distribution is hard to determine. They are confined to neritic waters of continental margins but have also been reported from coastal waters of oceanic islands in the Pacific including Hawaii. Total latitudinal range extends from northern Japan (about 45ºN) to southern New Zealand (almost 50ºS) in the west and from northern California to northern Chile along the American coast. The 20ºC isotherm has been suggested as a range limit, but optimal temperature is probably higher. In any case, it seems clear that they have a fairly wide temperature tolerance. Preference for high fertility coastal waters has been reported from East Africa.

There is little information on migration. Studies conducted in Japan suggest seasonal migration with northward movement in summer and southward movement in winter. *Auxis* have a strong schooling instinct and form dense schools segregated by size. The two species often form mixed schools and have also been reported to school with other tunas and tuna-like fishes.

The largest reported frigate tuna (*A. thazard*) is 53 cm; bullet tuna (*A. rochei*) rarely exceed 30 cm. Maximum ages are estimated to be 2 years and 1 year, respectively.

Auxis are heterosexual and do not exhibit sexual dimorphism. Fecundity estimates are 78,000–717,900 eggs for frigate tuna and 52,000–162,00 for bullet tuna. They generally spawn inshore, although (Klawe 1963) found that while spawning occurred inshore at Baja, California, it occurred in oceanic waters further south. *Auxis* also spawn around oceanic islands, including Hawaii, based on larval distribution and the occurrence of males of both species with freely flowing milt caught at Oahu. In general is appears that these tunas spawn in the warmer regions of their total range, but the precise distribution is unknown.

Yesaki and Arce (1994) state “there are two spawning seasons for bullet tuna, and most probably frigate tuna, at least in the equatorial regions of their distributions.”

Worldwide most *Auxis* are caught in the Philippines; in 1988, total of 107,000 mt were landed there, 61% of the world total. Yesaki and Arce (1994) provide a detailed review of the Philippine fishery. These authors also state “the world catch is low considering it is generally acknowledged that *Auxis* is the most abundant tuna, in numerical terms, in the world’s oceans.” The landings for these species are not reported separately in the western Pacific region; however, total “miscellaneous tunas” reported for the region in 1996 is 12,558 lbs (5.70 mt) (WPRFMC 1997). Clearly commercial landings of *Auxis* are negligible both in terms of total western Pacific region landings and for *Auxis* in the Pacific.

<u>Egg and Larval Distribution</u>

Eggs are pelagic and described by (Uchida 1981) as “perfectly spherical, [having] a colorless homogeneous yolk mass and an average diameter of 0.87 mm (range of 0.88–1.09 mm.” The eggs of both species hatch within 2 days. Larval/post-larval stages last to about 2 weeks. Uchida (1981) provides a comprehensive description of larval morphological characteristics, including differentiation among the species and larval and juvenile development.
Uchida (1981) states that temperature “is clearly a highly important variable in explaining the distribution of *Auxis* larvae.” Optimum temperature is reported as 27.0º–27.9ºC. The larvae are reported as only occurring above the thermocline. Salinity may also affect distribution, and larvae are reported for a relatively narrow range, 33.2–35.4 ppt. They may also undergo diel migration, being more common near the surface at night. Larval habitat is generally coastal, as with adults.

Juvenile

No information is provided in the review papers on juvenile distribution, but as a neritic epipelagic species juveniles probably occur in the same coastal habitat as adults. Planktonic crustaceans and fishes are the main prey items of juveniles, including larval copepods and decapods.

Adult,

Frigate tuna reach maturity at about 30–35 cm. In one study all fish measured were mature by 42.1 cm. Bullet tuna were found to reach first maturity in the Philippines 17.0 cm. A study from India indicated that 50% maturity was 24.0 cm for males and 23.8 cm for females.

Adults feed on a wide variety of organisms with fish the most common item, followed by crustaceans. Common prey fishes include herring and herring-like fish, anchovies and other small fishes. Adults also cannibalize their young and are reported to feed on plankton in Japanese waters. In a study from Indian waters fish formed the major constituent of the juvenile diet, while crustaceans were prevalent in the diet of adults. Frigate tuna also are known to occasionally prey on squid.

Essential Fish Habitat: Tropical species complex

There is relatively little information on the habitat preferences of these two species. They are also not important to managed fisheries in the western Pacific region. Nonetheless, given that they are cosmopolitan neritic epipelagic species, the inshore waters may be considered EFH, although it cannot be defined with any precision.

Habitat description for bullet tuna (*Auxis rochei*) and frigate tuna (*A. thazard*)

	Egg	**Larvae**	**Juvenile**	**Adult**
Duration	About 40 hours	2 weeks	1 year or less	*A. Thazard*—2 years, *A. rochei*—1 year
Diet	NA	Not reported	Planktonic crustaceans and fish	Opportunistic feeders: fish, crustaceans
Distribution: General and Seasonal	Neritic, coastal areas in the warmer waters throughout range	As with eggs	Differential distribution not known	Cosmopolitan in tropical and subtropical neritic / coastal waters, Pacific latitudinal range roughly 45ºN–45ºS in west, somewhat less in east
Location	Nereitc/inshore? Also found offshore but generally not mid-ocean	As with eggs	Neritic / inshore	Neritic
Water Column	Epipelagic	Epipelagic	Epipelagic	Epipelagic
Bottom Type	NA or unknown	NA or unknown	NA or unknown	NA or unknown
Oceanic Features	Unknown	Unknown	Unknown	Unknown

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3 PRECIOUS CORALS SPECIES

3.1 General Distribution of Precious Corals

Besides the references noted, the Council's 1979 environmental impact statement and FMP for the precious corals fisheries in the western Pacific region as well as Amendments 1 and 2 to the FMP and their accompanying environmental assessments were sources for the following sections.

Precious corals are known to exist in American Samoa, Guam, Hawaii and the Northern Mariana Islands, as well as other US possessions in the Pacific (Tables 1 and 2). However, very little is known about their distribution and abundance. A summary of the known distribution and abundance of precious corals in the western Pacific region follows.

American Samoa

There is little information available for the deepwater species of precious corals in American Samoa. Much of the information available comes from the personal accounts of fishermen. All known commercial quantities of *Corallium* sp. occur north of 19^{o}N (Grigg 1984). In the South Pacific there are no known commercial beds of pink coral (Carleton and Philipson 1987). Survey work begun in 1975 by the Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC) has identified three areas of *Corralium* off Western Samoa: off eastern Upolu, off Falealupo and at Tupuola Bank (Carleton and Philipson 1987). Pink coral has been reported off Cape Taputapu, but no information concerning the quality or quantity of these corals or the depths where they occur is available. Unidentified precious corals have also been reported in the past off Fanuatapu at depths of around 90 m. Precious corals are known to occur at an uncharted seamount, about three-fourths of a mile off the northwest tip of Falealupo Bank at depths of around 300 m.

Commercial quantities of one or more species of black coral are known to exist at depths of 40 m and deeper. However, these are found in the territorial waters of American Samoa and, therefore, are not subject to the Council's authority.

Guam and the Commonwealth of the Northern Marianas

There are no known commercial quantities of precious corals in the Northern Mariana Islands archipelago (Grigg and Eldredge 1975). In the past, Japanese fishermen claimed to have taken some *Corralium* north of Pagen Island and off Rota and Saipan.

Hawaii

In the Hawaiian Islands there are six known beds of pink, gold and bamboo corals (Grigg 1974). These six locations are as follows:

- In the MHI, precious coral beds have been found only in the deep inter-island channels and off promontories such as Keahole Point on the Big Island of Hawaii.

Species	Common name
Corallium secundum	Pink coral
Corallium regale	Red coral
Corallium laauense(sp)	Red coral
Gerardia sp.	Gold coral
Narella sp.	Gold coral
Calyptrophora sp.	Gold coral
Callogorgia gilberti	Gold coral
Lepidisis olapa	Bamboo coral
Acanella sp.	Bamboo coral
Antipathes dichotoma	Black coral
Antipathes grandis	Black coral
Antipathes ulex	Black coral

Table 1: Precious corals covered under the FMP.

- Also in the MHI, the Makapuu bed is located off Makapuu, Oahu, at depths of between 350 and 450 m. Discovered in 1966, it the only precious coral bed that has been accurately surveyed in the Hawaiian chain. Its total area is about 4.5 km^2. Its substrate consists largely of hard limestone (Grigg 1988). Careful examination during numerous dives with a submersible has determined that about 20% of the total area of the Makapuu bed is comprised of irregular lenses of thin sand, sediments and barren patches (WPRFMC 1979). These sediment deposits are found primarily in low-lying areas and depressions (Grigg 1988). Thus, the total area used for extrapolating coral density is 3.6 km^2, or 80% of 4.5 km^2 (WPRFMC 1979). The preliminary results of a recent resurvey of the Makupuu bed show that the bed may actually be as much as 15% larger then previously thought (Grigg 1998, pers. comm.).

- Also in the MHI is a bed off Kaena Point, Oahu.

- In the NWHI, a very small bed of deepwater precious corals have been found on WesPac bed, between Nihoa and Necker Islands and east of French Frigate Shoals. This bed is not large enough to sustain commercial harvests. However, large areas of potential habitat exist in the NWHI on seamounts and banks near 400 m depth. Based on the abundance of potential habitat it is thought that stocks of precious corals may be more abundant in the northwestern end of the island chain.

- A small precious coral bed has also been discovered at Brooks Banks, located near Cross Seamount southwest of the island of Hawaii. This bed is no large enough to sustain commercial harvests

- Precious corals have also been discovered at the 180 Fathom Bank, north of Kue Island, in EEZ waters surrounding Palmyra Island, a US possession in the western Pacific. The extent of this bed is not known. While little is known about the distribution and abundance of precious corals in the western Pacific region, it is almost certain that undiscovered beds of precious corals exist in the EEZ waters of the region covered by the Council.

Description	**Lat. N**	**Long. W.**	**Area in km^2**
Off Keahole Point, Hawaii	19°46.0'	156°06.0'	0.24
Off Makapuu, Oahu	21°18.0'	157°35.5'	4.2
Off Kaena Point, Oahu	21°35.4'	158°22.9'	0.24
WesPac Bed, between Nihoa and Necker Islands	23°18'	162°35'	0.8
Brooks Banks	24°06.0'	166°48'	1.6
180 Fathom Bank, north of Kue Island	28°50.2'	178°53.4'	0.8

Table 2: Location of known precious coral beds. Source: WPRFMC 1979

3.2 Systematics of the Deepwater Coral Species

Precious corals have a global distribution (Grigg 1993). The richest beds are found on seamounts in the western North Pacific Ocean and the western Mediterranean Sea. Precious corals are found principally in three orders of the class Anthozoa: Gorgonacea, Antipatharia, and Zoanthiae (Grigg 1984). In the western Pacific region, pink coral (*Corallium secundum*), gold coral (*Gerardia sp*. and *Parazoanthus sp*.), black coral (*Antipathes* sp.) and bamboo coral (*Lepidistis olapa*) are the primary species/genera of commercial importance. Of these, the most valuable precious corals are species of the genus *Corallium*, the pink and red corals (Grigg 1984). Pink coral (*Corallium secundum*) and Midway deep-sea coral (*Corallium* sp. nov) are two of the principal species of commercial importance in the Hawaiian and Emperor Seamount chain's (Grigg 1984). *C. secundum*, is found in the Hawaiian archipelago from Milwaukee Banks in the Emperor Seamounts (36°N) to the Island of Hawaii (18°N); *Corallium* sp nov. is found between 28°–36°N, from Midway to the Emperor Seamounts (Grigg 1984). In addition to the pink corals, the bamboo corals, *Lepidistis olapa* and *Acanella* sp., are commercially important precious corals in the western Pacific region (Grigg 1984). Pink coral and bamboo coral are found in the order Gorgonacea in the subclass Octocorallia of the class Anthozoa, in the Phylum Coelenterata (Grigg, 1984). The final two major groups of commercially important precious corals, gold coral and black coral, are found in separate orders, Zoanthidea and Antipatharia, in the subclass Hexacorallia in the class Anthozoa and the phylum Coelenterata. The gold coral, *Gerardia* sp., is endemic to the Hawaiian and Emperor Seamount chain (Grigg 1984). It inhabits depths ranging from 300–400 m (Grigg 1974, 1984). In Hawaii, gold coral, *Gerardii* sp., grows in association with

Acanella as a parasitic overgrowth (Brown 1976, Grigg 1984). Gold coral is, therefore, only found growing in areas that were previously inhabited by colonies of *Acanella* (Grigg 1993).

Grigg (1984) classifies black corals in the order *Antipatharia*. Grigg says there are 200 known species of black coral that occur in the oceans of the world, and of this total, only about 10 species are of commercial importance, almost all of which are found in the genus *Antipathes*.

Many species of gorgonian corals are known to occur within the habitat of pink, gold and bamboo corals in the Hawaiian Islands. At least 37 species of precious corals in the order Gorgonacea have been identified from the Makapuu bed (Grigg and Bayer 1976). In addition, 14 species of black coral (order Antipatharia) have been reported to occur in Hawaiian waters (Grigg and Opresko 1977, Oishi 1990).

3.3 Biology and Life History

Precious corals may be divided into two groups of species based on the depths that they inhabit, the deepwater species and the shallow water species. In the EEZ waters of the western Pacific region, precious corals are found in two principal depth zones: 350–450 m and 1,000–1,500 m. In the Hawaiian Islands, these two zones comprise 1,700 nm^2 and 5,900 nm^2 of potential habitat, respectively, and range from 18^{o} N to 35^{o} S.

The deepwater precious coral species include pink coral (*Corallium secundum*), gold coral (*Gerardia sp*., and *Parazoanthus sp*.) and bamboo coral (*Lepidistis olapa*). As previously discussed, the most valuable precious corals are in the genus *Corallium* (Grigg 1984). There are seven varieties of pink and red precious corals in the western Pacific region, six of which are recognized as distinct species of *Corallium* (Grigg 1981). As mentioned, the two species of *Corallium* of commercial importance in the EEZ around the Hawaiian Islands are *C. secundum* (pink coral) and *Corallium* sp. Nov. (Midway deep-sea). The Midway deep-sea coral (*Corallium* sp. Nov), a previously undescribed species of *Corallium*, was discovered in 1980–1981 by Japanese vessels fishing for precious corals on the Emperor Seamounts northwest of Midway Island. The discovery of this rich, unexploited deepwater precious coral species resource underscores the potential of the coral fishery in the NWHI.

The second group of species is found in shallow water between 30 and 100 m (Grigg 1993). The shallow water fishery is comprised of three species of black coral, *Antipathes dichotoma*, *A. grandis* and *A. ulex,* which have historically been harvested in Hawaii (Oishi 1990). In Hawaii, *A. dichotoma* accounts for around 90% of the commercial harvest of black coral (Oishi 1990). *A. grandis* accounts for 9% and *A. ulex* 1% of the total black corals harvested. In Hawaii, roughly 85% of all black coral harvested are taken from within state waters. The State of Hawaii and the Coucnil manage black corals jointly. Within state waters (0–3 nmi), black corals are managed by the State of Hawaii (Grigg 1993).

Species and Common Name	Depth Range (m)
Corallium secundum Angle skin coral	350–475
Corallium sp nov. Midway deepsea coral	1,000–1,500
Gerardia sp. Hawaiian gold coral	300–400
Lepidisis olapa bamboo coral	350–400
Antipathes dichotoma, black coral	30–100
Antipathes grandis, pine black coral	45–100
Antipathes ulex, fern black coral	40–100
Antipathes anguina, wire black coral	20–60

Table 3: Depth zonation of all species of precious coral in the Western Pacific. (Source: Grigg 1993)

While different species of precious corals inhabit distinct depth zones, their habitat requirements are strikingly similar. Grigg (1984) notes that these corals are non-reef building and inhabit depth zones below the euphotic zone. In an earlier study, Grigg (1974) determined that precious corals are found in deep water on solid substrate in areas that are swept relatively clean by moderate to strong bottom currents (>25 cm/sec). Strong currents help prevent the accumulation of sediments, which would smother young coral colonies and prevent settlement of new larvae. Grigg (1984) notes that, in Hawaii, large stands of *Corralium* are only found in areas where sediments almost never accumulate. He also notes that 1971–75, surveys of all potential sites for precious corals in the MHI conducted using a manned submersible show that most shelf areas in the MHI near 400 m are periodically covered with a thin layer of silt and sand. Grigg (1988) concludes that the concurrence of oceanographic features (strong currents, hard substrate, low sediments) necessary to create suitable precious coral habitat are rare in the MHI.

The habitat sustaining precious corals is generally in pristine condition. There are no known areas that have sustained damage due to resource exploitation, notwithstanding the alleged heavy foreign fishing for corals in the Hancock Seamounts area. Although unlikely, if future development projects are planned in the proximity of precious coral beds, care should be taken to prevent damage to the beds. Projects of particular concern would be those that suspend sediments or modify water-movement patterns.

There is a correlation between the location and abundance of *Corallium* beds and the Kuroshio Current in the western Pacific region (Grigg 1984). This relationship further illustrates the importance of suitable current regimes in determining suitable precious coral habitat. Currents also play an important ecological role in transporting food to and carrying wastes away from corals.

There has been very little research conducted concerning the food habits of precious corals. Precious corals are filter feeders (Grigg 1984, 1993). The sparse research available suggests that particulate organic matter and microzooplankton are important in the diets of pink and bamboo coral (Grigg 1970). Many species of pink coral (*Corallium*), gold coral (*Gerardia*) and black coral (*Antipathes*) form fan shaped colonies (Grigg 1984, 1993). This type of morphological adaption maximizes the total area of water that is filtered by the polyps (Grigg 1984, 1993). Bamboo coral (*Lepidisis olapa*), unlike other species of precious corals, is unbranched (Grigg 1984). Long coils that trail in the prevailing currents maximize the total amount of seawater that is filtered by the polyps (Grigg 1984). While clearly, the presence of strong currents is a vital factor determining habitat suitability for precious coral colonies, their role to date is not fully understood.

Precious corals are known to grow on a variety of bottom substrate types. Precious coral yields, however, tend to be higher in areas of shell sandstone, limestone and basaltic or metamorphic rock with a limestone veneer.

Light is one of the most important determining factors of the upper depth limit of many species of precious corals (Grigg 1984). The larvae of two species of black coral, *Antipathes grandis* and *A. dichotoma*, are negatively phototaxic**.**

Grigg (1984) states that temperature does not appear to be a significant factor in delimiting suitable habitat for precious corals. In the Pacific Ocean, species of *Corallium* are found in temperature ranges of 8^{o} to 20^{o}C, he observes. Temperature may determine the lower depth limits of some species of precious coral, including two species of black corals in the MHI, he suggests. In the MHI, the lower depth range of two species of black corals (*Antipathes dichotoma* and *A. grandis*) coincides with the top of the thermocline (about 100 m), Grigg observes.

In pink coral (*Corallium secundum*), the sexes are separate (Grigg 1993). Based on the best available data, it is believed that *C. secundum* becomes sexually mature at a height of approximately 12 cm (13 years) (Grigg 1976). Pink coral reproduce annually, with spawning occurring during the summer, during the months of June and July. Coral polyps produce eggs and sperm. Fertilization of the oocytes is completed externally in the water column (Grigg 1976, 1993). The resulting larvae, called planulae, drift with the prevailing currents until finding a suitable site for settlement.

Pink, bamboo and gold corals all have planktonic larval stages and sessile adult stages. Larvae settle on solid substrate where they form colonial branching colonies. Grigg (1993) notes that the length of the larval stage of all deepwater species of precious corals is not known. Clean swept areas exposed to strong currents provide important sites for settlement of the larvae, Grigg adds. The larvae of several species of black coral (*Antipathes*) are negatively photoactic, he notes. They are most abundant in dimly lit areas, such as beneath overhangs in waters deeper than 30 m, he observes. In an earlier study, Grigg (1976) found that "within their depth ranges, both species are highly aggregated and are most frequently found under vertical dropoffs. Such features are commonly associated with terraces and undercut notches relict of ancient sea level still stands. Such features are common off Kauai and Maui in the MHI. Both species are particularly abundant off of Maui and Kauai, suggesting that their abundance is related to suitable habitat." Off of Oahu, many submarine terraces that otherwise would be suitable habitat for black corals are covered with sediments, Grigg (1976) adds.

Grigg (1993) observes that precious corals have low recruitment and mortality. They are slow growing and long lived, believed to reach the age of 75 years and older, he notes. Common causes of mortality include smothering by sediments and toppling of colonies due to erosion of the substrate, he concludes. (Another cause is worms boring into the colony, weakening it and causing it to collapse**.**)

A variety of invertebrates and fish are known to utilize the same habitat as precious corals. These species of fish include onaga (*Etelis coruscans*), kahala (*Seriola dumerallii*) and the shrimp (*Heterocarpus ensifer*). These species do not seem to depend on the coral for shelter or food.

Densities of pink, gold and bamboo coral have been determined for an unexploited section of the Makapuu bed (Grigg, 1976). As noted in the FMP for precious corals, the average density of pink coral in the Makapuu bed is 0.022 colonies/m^2. This figure was extrapolated to the entire bed (3.6 million m^2), giving an estimated standing crop of 79,200 colonies. At the 95% confidence limit, the standing crop is 47,500 to 111,700 colonies. The standing crop of colonies was converted to biomass ($3N_iW_i$), resulting in an estimate of 43,500 kg of pink coral in the Makapuu bed.

In addition to coral densities, Grigg (1976) determined the age-frequency distribution of pink coral colonies in Makapuu bed. He applied annual growth rates to the size frequency to calculate the age structure of pink coral at Makapuu Bed (Table 4).

Age Group (years)	**Number of Colonies**
0–10	44
10–20	73
20–30	22
30–40	12
40–50	7
50–60	0

Table 4: Age-Frequency Distribution of *Corallium secundum* (Source: Grigg 1973)

Estimates of density were also made for bamboo (*Lepidisis olapa*) and gold coral (*Gerardia* sp.) for Makapuu bed. The distributions of both these species are patchy. As noted in the FMP, the area where they occur comprises only half of that occupied by pink coral (1.8 km^2). Estimates of the unexploited abundance of bamboo and gold coral were 18,000 and 5,400 colonies, respectively. Estimates of density for the unexploited bamboo coral and gold coral in the Makapuu bed are 0.01 colonies/m^2 and 0.003 colonies/m^2. Using a rough estimate for the mean weights of gold and bamboo coral colonies (2.2 kg and 0.6 kg), a standing crop of about 11,880 kg of gold coral and 10,800 kg for bamboo for Makapuu bed was obtained.

Growth rates for several species of precious corals found in the western Pacific region have been calculated.

Grigg (1976) determines that the height of pink coral (*C. secundum*) colonies increases about 0.9 cm/yr up to about 30 years of age. As noted in the FMP for precious corals, the height of the largest colonies of *Corallium secundum* at Makapuu bed rarely exceed 60 cm. Colonies of gold coral are known to grow up to 250 cm tall while bamboo corals may reach 300 cm. The natural mortality rate of pink coral at Makapuu bed is believed to be 0.066, equivalent to an annual survival rate of about 93%.

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4 CRUSTACEAN SPECIES

4.1 Habitat

Adult spiny lobsters are typically found on rocky substrate in well-protected areas, in crevices and under rocks (Pitcher 1993, FAO 1991). Unlike many other species of *Panulirus*, the juveniles and adults of *P. marginatus* are not found in separate habitat apart from one another (MacDonald and Stimson 1980, Pitcher 1993, Parrish and Polovina 1994). Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters (MacDonald and Stimson 1980, Parrish and Polovina 1994). Juvenile and adult *P. marginatus* do utilize shelter differently from one another (MacDonald and Stimson 1980). Similarly, juvenile and adult *P. pencillatus* also share the same habitat (Pitcher 1993).

In the NWHI, *P. marginatus* is found seaward of the reefs and within the lagoons and atolls of the islands (WPRFMC 1983). Uchida (1986) reports that *P. penicillatus* rarely occur in the commercial catches of the NWHI lobster fishery. In the NWHI, *P. pencillatus* is found inhabiting shallow waters (<18 m) (Uchida and Tagami 1984).

In the NWHI, the relative proportion of slipper lobsters to spiny lobsters varies between banks; several banks produce relatively higher catch rates of slipper lobster than total spiny lobster (Uchida 1986; *Clarke et al. 1987, WPRFMC 1986). The slipper lobster is taken in deeper waters than the spiny lobster (Clarke et al., 1987, WPRFMC 1986). Uchida (1986) reports that the highest catch rates for slipper lobster in the NWHI occur between the depths of 20–55 m.

Pitcher (1993) observes that, in the southwestern Pacific, spiny lobsters are typically found in association with coral reefs. Coral reefs provide shelter as well as a diverse and abundant supply of food items, he notes. Pitcher also states that in this region, *P. pencillatus* inhabits the rocky shelters in the windward surf zones of oceanic reefs, an observation also noted by Kanciruk (1980). Other species of *Panulirus* show more general patterns of habitat utilization, Pitcher continues. At night, *P. penicillatus* moves on to reef flat to forage, Pitcher continues. Spiny lobsters are nocturnal predators (FAO 1991).

4.2 Morphology

Spiny lobsters are non-clawed, decapod crustaceans with slender walking legs of roughly equal size (Uchida 1986, FAO 1991). Spiny lobster have a large spiny carapace with two horns and antennae projecting forward of their eyes and a large abdomen terminating in a flexible tailfan (FAO 1991).

Uchida (1986) provides a detailed description of the morphology of *S. squammosus* and *S. haanii*. He notes that the two species are very similar in appearance and are easily confused (Uchida 1986). The appearance of the slipper lobster is notably different than that of the spiny lobster.

4.3 Reproduction

Spiny lobsters (*Panulirus* sp.) are dioecious (Uchida 1986). Generally, the different species of the genus *Panulirus* have the same reproductive behavior and life cycle (Pitcher 1993). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986). In *Panulirus* sp., the fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female's oviduct and are then fertilized and attach to the setae of the female's pleopod (WPRFMC 1983, Pitcher 1993). At this point the female lobster is ovigerous, or "berried" (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30–40 days (MacDonald 1986, Uchida 1986). Spiny lobsters are very fecund (WPRFMC 1983). The release of the phyllosoma larvae appears to be timed to coincide with the full moon and dawn in some species (Pitcher 1993). In *Scyllarides* sp. fertilization is internal (Uchida 1986b).

4.4 Larval Stage

Very little is known about the planktonic phase of the phyllosoma larvae of *Panulirus marginatus* (Uchida et al. 1980). After hatching, the "leaf-like" larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar morphological stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1986, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. The puelurus stage lasts 6 months or less (WPRFMC 1983). Spiny lobster pueruli are free-swimming and actively return to shallow, nearshore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). Johnston (1973) reports that the phyllosoma phase of some species of the genera *Scyllarides* is somewhat shorter. MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. MacDonald (1986) found puerulus settlement occurred primarily at the new moon and first quarter lunar phase in Hawaii. The settlement of puerulus is higher in the central portion of the Hawaiian Island chain than what, and it is higher in the NWHI than around the MHI (MacDonald 1986).

There is a lack of published data pertaining to the preferred depth distribution of phyllosoma larvae in Hawaii. However, the depth distribution of phyllosoma larvae of other species of *Panulirus* common in the Indo-Pacific region has been documented. Phillips and Sastry (1980) reports that the newly hatched larvae of the western rock lobster (*P. cygnus*) is typically found within 60 m of the surface. Later stages of the phyllosoma larvae are found at depths between 80–120 m. *P. cygnus* undergoes a diurnal vertical migration, ascending to the surface at night, descending to lower depths during the day, the authors add. Research has shown that early phyllosoma larvae display a photopositive reaction to dim light, the authors add. In the Gulf of Mexico, the depth of the thermocline, Phillips and Sastry note restricts the depth to which Panulirus larvae descend.

MacDonald (1986) states that after settlement the pueluri molt and transform into post-pueruli, a transitional phase between the pelagic phyllosama phase and the juvenile stage. Yoshimura and Yamakawa (1988) note that very little is known about the habitat requirements of Palinurid pueruli after settlement occurs. However, Pitcher (1993) states that the post-pueruli of *Panulirus penicillatus* has been observed inhabiting the same "high-energy reef-front habitat" as adults of the species. Studying the benthic ecology and habitat utilization of newly settled pueruli and juveniles of the Japanese spiny lobster (*P. japonicus*), Yoshimura and Yamakawa (1988) conclude that microhabitats, such as small holes in rocks and boulders and algae, provide important habitat for the newly settled pueruli and juvenile lobsters. The Japanese spiny lobster is found inhabiting shallow waters at depths of 1–15 m on rocky bottom (FAO 1991).

The oceanographic and physiographic features that result in the retention of lobster larvae within the Hawaiian archipelago are not understood (WPRFMC 1983). Johnston (1968) suggests that fine-scale oceanographic features, such as eddies and currents, serve to retain phyllosoma larvae within the Hawaiian Island chain. In the NWHI, puerulus settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type (MacDonald 1986). The relatively long pelagic larval phase for palinurids results in very wide dispersal of spiny lobster larvae; palinurid larvae are transported up to 2,000 miles by prevailing ocean currents (Johnston 1973, MacDonald 1986).

4.5 Life Histories and Habitat Descriptions for Crustacean Species

4.5.1 Habitat Description for Hawaiian Spiny Lobster (Panulirus marginatus)

<u>Management Plan and Area</u>: American Samoa, Guam, MHI, NWHI, Northern Mariana Islands, Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Midway Island, Howland and Baker Islands and Wake Islands.

The Hawaiian spiny lobster, within the Council's jurisdiction are managed under the FMP for the Crustaceans of the Western Pacific Region

<u>General Description and Life History</u>

The Hawaiian spiny lobster (*Panuliris marginatus*) is endemic to the Hawaiian Islands and Johnston Atoll (Brock 1973, FAO 1991). The relative abundance of *P. marginatus* at Johnston Atoll is very low (Brock 1973). The spiny lobster is distributed throughout the entire NWHI, from Kure Atoll to Nihoa (Uchida 1986a). *P. marginatus* is the principal species landed in the NWHI spiny lobster fishery (WPRFMC.1983).

The reported depth distribution of this species in the NWHI is 5–100 fm (WPRFMC 1983). While this species is found down to depths of 100 fm it usually inhabits shallower waters

(FAO 1991). Uchida and Tagami (1984) report that *P. marginatus* is most abundant in waters of 90 m or less. Moffitt (1998, pers. comm.) states that spiny lobster are found in greatest abundance between the depths of 10–50 fm. At Maro Reef, in the NWHI, large adult spiny lobsters have been captured at depths as shallow as 10 feet (Moffitt 1998, pers comm.).

Uchida and Tagami (1984) note that within the NWHI there is a dramatic shift between depth and relative abundance. They report that in the vicinity of the northern most islands and banks relative abundance of spiny lobsters was highest at depths of 19–54 m and that at the lower end of the chain the highest abundance of spiny lobsters were observed between 55–73 m. North of Maro Reef the highest relative abundance of spiny lobsters is found at shallower depths, they continue. They suggest that this variability may be due to differences in the temperature regime in the NWHI.

P. marginatus is typically found on rocky substrate in well-protected areas such as crevices and under rocks (FAO 1991). During the day, spiny lobsters are found in dens or crevices in the company of one or more other lobsters (WPRFMC 1983). MacDonald and Stimson (1980), studying the population biology of spiny lobsters at Kure Atoll in the NWHI, found that solitary lobsters inhabited 57% of the dens examined. More than one lobster, with adult and juvenile lobsters of both sexes often found sharing the same dens, occupied the remaining 43%. However, the authors note, adult and juvenile spiny lobsters exhibit distinctly different den occupancy patterns, with juveniles (less than 6 cm in carapace length) typically in multiple occupancy dens with other lobsters. Adult and juvenile spiny lobsters are not segregated by geographic area or habitat type at Kure Atoll, MacDonald and Stimson observe. They found that juvenile spiny lobsters do not utilize separate nursery habitats apart from the adult lobsters. The larval spiny lobster puerulus recruits directly to the adult habitat (Parrish and Polovina 1994). This is in contrast to the juveniles of other species of spiny lobsters that tend to reside in shallow water and migrate to deeper, offshore waters as they mature (MacDonald and Stimson 1980).

There are limited data available concerning growth rates, reproductive potentials and natural mortality rates at the various life history stages (WPRFMC 1983). The relationship between egg production, larval settlement, and stock recruitment are poorly understood (WPRFMC 1983).

Eggs

The Hawaiian spiny lobster (*P. marginatus*) is dioecious (Uchida 1986a). The male spiny lobster deposits a spermatophore or sperm packet on the female's abdomen (WPRFMC 1983, Uchida 1986a). In *P. marginatus*, fertilization of the eggs occurs externally (Uchida 1986a). The female lobster scratches and breaks the mass, releasing the spermatozoa (WPRFMC 1983). Simultaneously, ova are released for the female's oviduct, where they are then fertilized and attach to the setae of the female's pleopod (WPRFMC 1983). At this point the female lobster is ovigerous, or "berried" (WPRFMC 1983). The fertilized eggs hatch into phyllosoma larvae after 30–40 days (MacDonald 1986, Uchida 1986a).

The spawning season for *P. marginatus* varies throughout the Hawaiian Island chain (Uchida 1986a). In the northwestern end of the NWHI spawning occurs primarily during the early summer months (Uchida et al. 1980, Uchida, 1986a). MacDonald and Stimson (1980) found ovigerous females at Kure Atoll between the months of May to September. Uchida et al (1980) found the peak abundance of ovigerous female lobsters at Nihoa, French Frigate Shoals between late summer and early winter. It is believed that reproduction is nearly continuous in the warmer waters south of Maro Reef in the NWHI (WPRFMC 1983). Around the island of Oahu spawning occurs year-round (Uchida 1986a). In the MHI, peak-spawning activity occurs between the months of May and August with a minimal amount of activity from November to January (Uchida 1986a). Egg-bearing females are found year-round in the MHI (WPRFMC 1983).

Spiny lobsters are very fecund (WPRFMC 1983). Honda (1980) found that fecundity increased with size. Most female spiny lobsters reach sexually maturity at 2 years of age (WPRFMC 1983). Estimating size at maturity for male and female spiny lobsters at Necker Island and Oahu, Prescott (19 *) concludes the Necker Island females reach sexual maturity at 60.7 mm, males at 59.2 mm, while Oahu females reach sexual maturity at 58.6 mm, males at 63.6 mm. At Necker Island the smallest mated lobster observed was 48.3 mm; it is not conclusive that the ovaries of females are mature at this size (Uchida and Tagami 1984). Growth rates for male spiny lobsters at Necker Island have been calculated as follows: 3.7 cm CL at 1 year, 5.7 cm at 2 years, 7.3 cm at 3 years, 8.5 cm at 4 years, 9.4 cm at 5 years and 10.1 cm in 6 years (Uchida 1986a). Due to insufficient data the growth of females has not been calculated (Uchida 1986a).

<u>Larvae</u>

After hatching, the larvae (or phyllosoma) enter a planktonic phase (WPRFMC 1983). The duration of this planktonic phase varies depending on the species and geographic region (WPRFMC 1983). Very little is known about the planktonic phase of the phyllosoma larvae of *P. marginatus* (Uchida et al.1980). The planktonic larval stage may last from 6 months to 1 year from the time of the hatching of the eggs (WPRFMC 1983, MacDonald 1986). There are 11 dissimilar stages of development that the phyllosoma larvae pass through before they transform into the postlarval puelurus phase (Johnson 1968, MacDonald 1986).

The pelagic phyllosoma stage of development is followed by the puerulus stage. Spiny lobster pueruli are free-swimming and actively migrate into shallow, near-shore waters in preparation for settlement (WPRFMC 1983, MacDonald 1986). The puelurus stage lasts 6 months or less (WPRFMC 1983). MacDonald and Stimson (1980) found pelagic, puerulus larvae settlement to occur at approximately 1 cm in length. After settlement the pueluri molt and transform into postpueruli, a transitional phase between the pelagic phyllosama phase and the juvenile stage (MacDonald 1986)**.**

It is believed, that because of the endemic nature of *P. marginatus* in the Hawaiian archipelago, the resident population is the source of larval recruits (Uchida et al. 1983). Shaklee (1962) found no genetic variation within the various spiny lobster populations at the different islands and banks in the NWHI chain. These data suggest that a single stock of spiny lobster exists in the NWHI (WPRFMC 1983). Recruitment of puerulus lobster larvae occurred at Kure Atoll beginning in the spring and lasting to October; no recruitment occurred from October to March (MacDonald and Stimson 1980). The distribution of lobster larvae in the waters surrounding the banks and islands of the NWHI is patchy (Parrish and Polovina 1994). Settlement of palinurid larvae tends to be higher in the middle of the Hawaiian Island chain and higher in the NWHI than in the MHI (MacDonald, 1986).

There is evidence that the recruitment of puelerus lobster larvae is tied to the lunar phase with maximum recruitment occurring during the new moon and first quarter phases (MacDonald and Stimson 1980).

Juvenile

Parrish and Polovina (1994) found that banks with summits deeper than 30 m had consistently lower catches of spiny lobster; six of eight banks surveyed with summits at depths greater then 30 m did not provide commercial quantities of spiny lobster. They suggest a depth threshold may prevent the successful settlement and/or survival of pueruli of the spiny lobster in commercial quantities at these banks.

Parrish and Polovina (1994) studied the production rates of three banks in the NWHI; two commercially productive banks, Maro Reef and Necker Island, and one commercially unproductive bank, Lisianski. In this study the percent coverage of the different substrate types were measured and classified into four habitat types. The intermediate relief habitat (5–30 cm) was found to support the highest abundance of juvenile lobsters. Based on the results of their analysis, Parrish and Polovina conclude that the intermediate relief habitat provides optimal habitat for juvenile spiny lobster. This intermediate relief habitat rarely exceeded 10 cm in height and was comprised of macroalgaes including *Dictopterus* sp., *Sargassum* sp. and *Padina* sp. Parrish and Polovina determined that a much greater proportion of intermediate substrate exists at the two productive banks studied, Maro Reef and Necker Island, than at the unproductive bank, Lisianski Island. They conclude that the amount of suitable habitat may be a factor limiting the total abundance of adult lobster production. The intermediate relief habitat provides suitable habitat for the settlement, survival and growth of *P. marginatus* pueruli and post pueruli. It does not provide enough structural relief to support a community of predatory reef fish, Parrish and Polovina note. Furthermore, they add, the lack of structural relief provides little shelter or protection for fish that forage on juvenile lobster from large piscovores such as sharks and jacks.

Parrish and Polovina (1994) describe the substrate of Necker Island and Maro Reef as predominantly comprised of intermediate relief algal communities. However, prolonged changes in water temperature could greatly modify the algal abundance, they note. The effects of such changes might include increased predation, reduced recruitment and reduced availability of food, they conclude.

Annual exploratory trapping survey at Maro Reef in the NWHI has been conducted by NMFS since 1994. Haight (1998) explains that the survey was designed to identify juvenile spiny lobster habitat and determine abundance. Preliminary results of this survey indicate that the northwestern portion of Maro Reef supports higher concentrations of juvenile *P. marginatus* than are found at other sample stations within the reef. The northwest portion of the reef extends outward from the lagoon and as a result is exposed to greater wave action and currents than other areas of Maro Reef, Haight observes. The benthic habitat at the northwestern site (site 1) is distinctly different from that of other sites sampled within Maro Reef, he continues. Of particular note was the predominance of live coral colonies of *Acropora* and *Pocillopora* corals, he observes. However, colonies of *Acropora* sp. coral were not found at any of the stations sampled within the reef and are rarely found outside the reef (F. Parrish, unpub. data. in Haight 1998). Three other sites—comprised of coral heads interspersed with barren sand patches and coral rubble—were sampled during the survey, and the majority of spiny lobsters found at them were adults (Haight 1998). The specific ecological and physical mechanisms that are responsible for higher abundance of juvenile spiny lobster at the northwestern portion of Maro Reef need further study.

MacDonald and Stimson (1980) found juvenile spiny lobsters to exhibit a restricted home range, while adult spiny lobsters displayed a much wider home. Uchida and Tagami (1984) observed that 90 percent of recaptured adult spiny lobsters showed movement of 5 nmi or less, while MacDonald and Stimson (1980) found spiny lobsters had a dispersal rate that rarely exceeded several hundred m.

<u>Adult</u>

Spiny lobsters are distributed throughout the NWHI, from Nihoa to Kure Atoll (WPRFMC 1983). The distribution of adult spiny lobsters is uneven throughout the NWHI chain. Research conducted prior to advent of commercial exploitation of spiny lobsters found the greatest abundance of lobsters at Necker and Maro Reef in the NWHI (Uchida et al. 1980, WPRFMC 1983). Surprisingly, the benthic habitat of Maro Reef differs markedly from bottom conditions found at Necker Island (Uchida et al 1980, WPRFMC 1983). The substrate at Necker Island is largely composed of coral interspersed with sandy areas and sandstone outcroppings. The bottom at Maro Reef is primarily composed of coral rubble and sand, lacking the type of habitat features normally thought to be lobster habitat (WPRFMC 1983).

Uchida et al (1980) found significant differences in the average sizes among spiny lobsters populations at the various banks and islands they sampled. MacDonald and Stimson (1980) found there to be a seasonal variation in the size distribution of the spiny lobster population at Kure Atoll in the NWHI. Small lobsters were more abundant in the months of June to September while larger lobsters were found to be more abundant in January. These researchers found males to be more abundant than females throughout the year. Male spiny lobsters were also found to comprise the majority of individuals in the larger-sized class.

Spiny lobsters are nocturnal predators (FAO 1991). Spiny lobsters are regarded as omnivorous, opportunistic scavengers (Pitcher 1993). Food items reported from the diets of *Panulirus* sp. include echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass (Pitcher 1993).

Habitat Description for Hawaiian Spiny Lobster (Panulirus marginatus)

	Egg	Larvae	Juvenile	Adult
Duration	30–40 days.	Planktonic Phyllosoma stage (6–12 months), free-swimming pueruli stage (up to 6 months).	Not known	Not known
Diet	N/A	No information available	No information available	Diet of *Panulirus* sp. includes echinoderms, crustaceans, molluscs (primarily gastropods) algae and seagrass
Distribution	Release of phyllosoma larvae appears to be timed to coincide with the full moon and dawn (Pitcher 1993). In NWHI spawning takes place during summer months, in MHI spawning takes place year round.	In Hawaii, puerulus settlement occurrs primarily at the new moon and first quarter lunar phase (MacDonald 1986)	Juvenile *P. marginatus* recruit directly to adult habitat; they do not utilize separate shallow water nursery habitat apart from the adults as do many Palinurid lobsters.	
Location	female spiny lobster broods the eggs until they hatch	Puerulus larvae seem to have a low rate of settlement success and survival if summit of bank is deeper than 30 m.	Banks with summits deeper than 30 m support lower abundance of juvenile lobsters. The NW portion of Maro supports higher concentrations of juvenile lobsters.	NWHI, MHI, Johnston Atoll
Water Column	N/A	Pelagic - Palinurid larvae are transported great distances by the prevailing water currents, up to 2,000 miles	Benthic	Benthic
Bottom Type	N/A	N/A	Areas of intermediate relief habitat (5–30 cm) seems to provide optimal habitat for juveniles	Adults are typically found on rocky substrates in well protected areas, in crevices and under rocks.
Oceanic Features	female spiny lobster may move to areas of strong currents to release newly hatched larvae into the oceanic environment.	In the NWHI, settlement appears to be linked to the north and southward shifts of the North Pacific Central Water (NPCW) type.	No information available	No information available

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4.5.2 Habitat Description for Kona Crab (*Ranina ranina*)

Management Plan and Area: American Samoa, Guam, Main Hawaiian Islands (MHI), Northwestern Hawaiian Islands (NWHI), Commonwealth of the Northern Mariana Islands (NMI), Johnston Atoll, Kingman Reef, Palmyra Atoll, Jarvis Island, Howland and Baker Islands and Wake Islands.

Very little is known about the life history of *Ranina ranina*. The kona crab is found in the northwestern Hawaiian Islands (NWHI) from Kure Atoll to Nihoa at depths of 24 to 115 m (Uchida, 1986; Edmonson, 1946). *R. ranina* is also found in the main Hawaiian Islands (MHI).

It is believed that female kona crabs obtain sexual maturity somewhere between 54.3 and 63 mm CL. Uchida (1986) reports that 60% of male kona crabs ≥60 mm were sexually mature.

Kona crabs are dioecious and display sexual dimorphism. The males tend to grow to a larger size (Uchida, 1986). The sex ratio of males to females has been found to be skewed in favor of males (Fielding and Haley, 1976; Onizuka, 1972).

This species spawns at least twice during the spawning season (Uchida, 1986). The female kona crab usually spawns a second time approximately nine days after the first bacth of eggs hatch. Fertilization of the eggs occurs externally. The fertilized eggs adhere to the females numerous seatae (Uchida, 1986). In the MHI, ovigerous females have been found to occur only from May to September (Uchida, 1986; Fielding and Haley, 1976). There are insufficient data available to define the exact spawning season in the NWHI (Uchida, 1986).

A small, directed fishery for kona crabs exists in the MHI. There is no directed fishery for kona crabs in the NWHI however it is taken incidentally in the spiny lobster fishery. The principal gear used in the fishery is the kona crab net. *R. ranaina* is also taken in lobster traps. In the MHI from 1961 to 1979 the average total landings for kona crab averaged 13,519 kg.

Egg and larval distribution

Kona crab eggs are spherical and orange. They hatch at approximately 29 days after fertilization (Uchida, 1986). About 5 days prior to hatching the eggs change from an orange to brown color at the onset of the eyed stage (Uchida, 1986).

Larvae

Little is known about the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later (Uchida, 1986).

Juvenile distribution

There is no information available concerning the distribution or habitat utilization patterns of juvenile kona crabs.

Adult distribution

Adult kona crabs are found inhabiting sandy bottom habitat at depths between 24 to 115 m. Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in waits for prey or food particles (Uchida, 1986).

The Council has designated EFH for the juvenile and adult life stages of *Ranina ranina* as the shoreline to a depth of 100 m. EFH for this species larval stage is designated as the water column from the shoreline to the outer limit of the EEZ down to 150 m.

Habitat Description for Kona Crab (*Ranina ranina*)

	Egg	Larvae	Juvenile	Adult
Duration	Approximately 29 days after fertilization	Little is known about the duration of the plankton larval stage of kona crabs. The first molt occurs at 7-8 after hatching, the second molt about seven days later.	Not known	No inforamtion available
Diet	N/A	Not known	Not known	Kona crabs are opportunistic carnivores that feed throughout the day. It buries itself in the sand where it lies in waits for prey or food particles
Distribution: General and Seasonal	Fertilization of the eggs occurs externally. The fertilized eggs adhere to the females numerous seatae.	Little is known about the plankton larval stage of kona crabs	There is no information available concerning the distribution or habitat utilization patterns of juvenile kona crabs	Adult kona crabs are found inhabiting sandy bottom habitat at depths between 24 to 115 m.
Water Column	Demersal	Pelagic?	Demersal	Demersal
Bottom Type	N/A	N/A	N/A	Sandy bottom
Oceanic Features	N/A	Larvae are subject to advection by prevailing currents.	N/A	N/A

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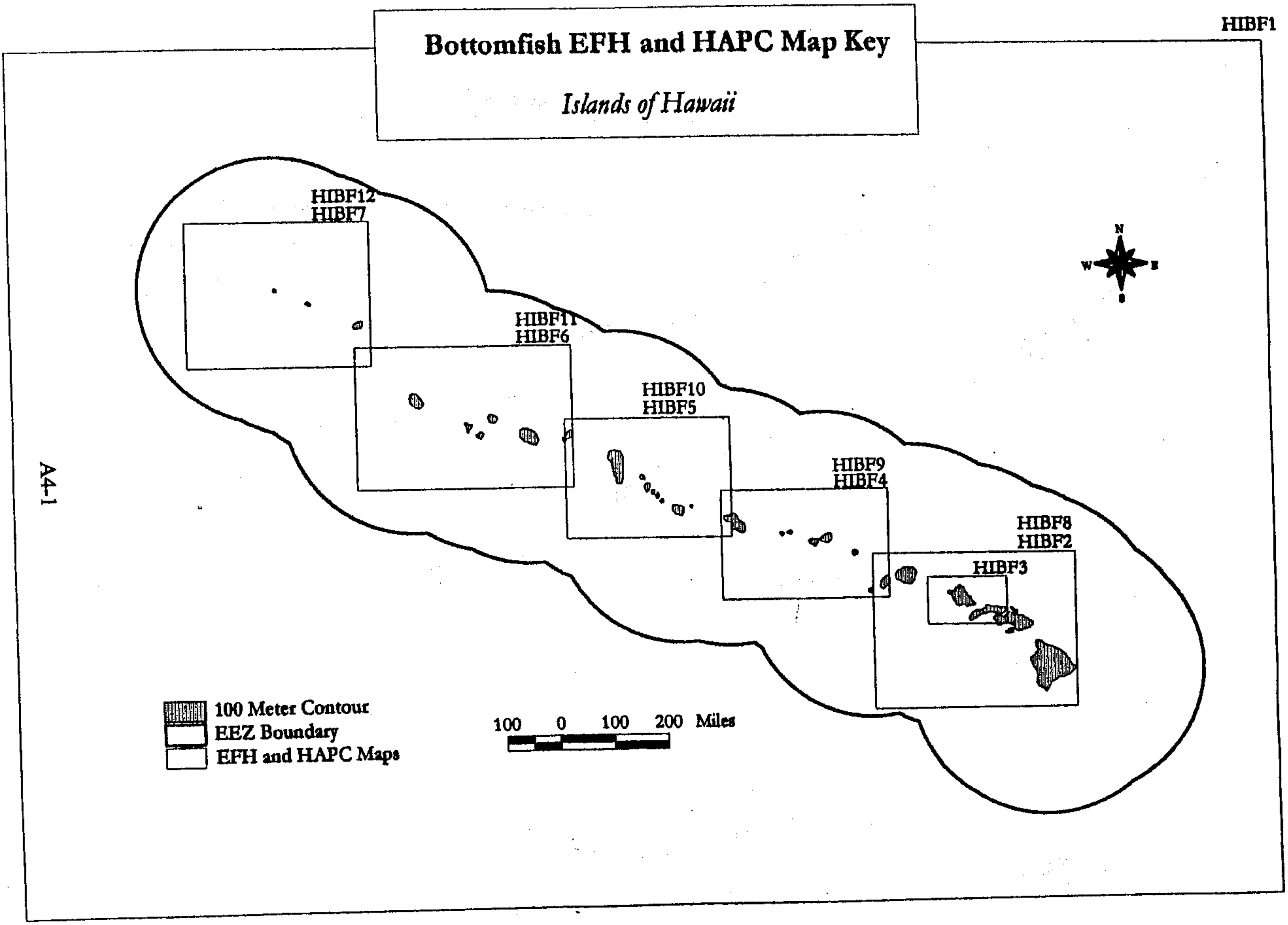
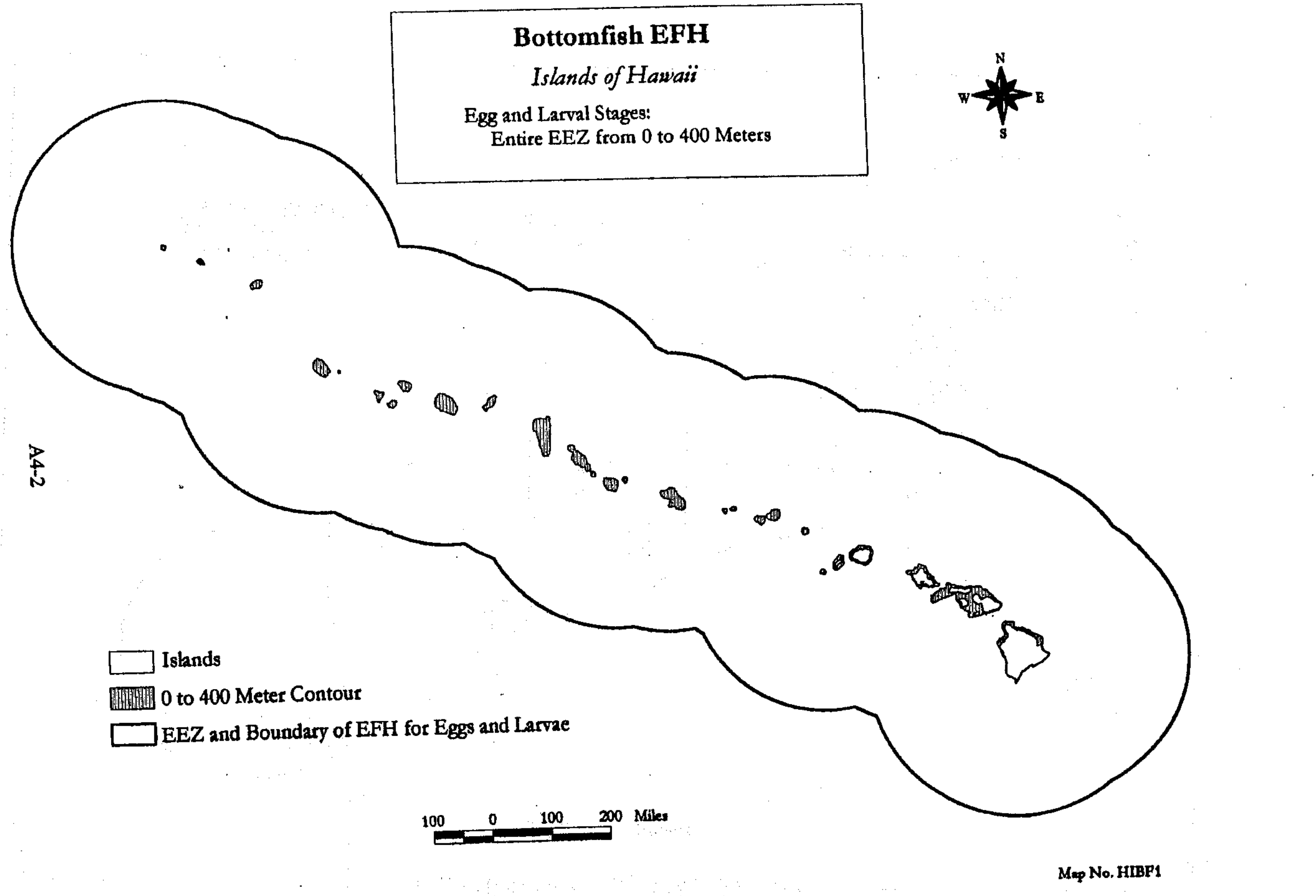
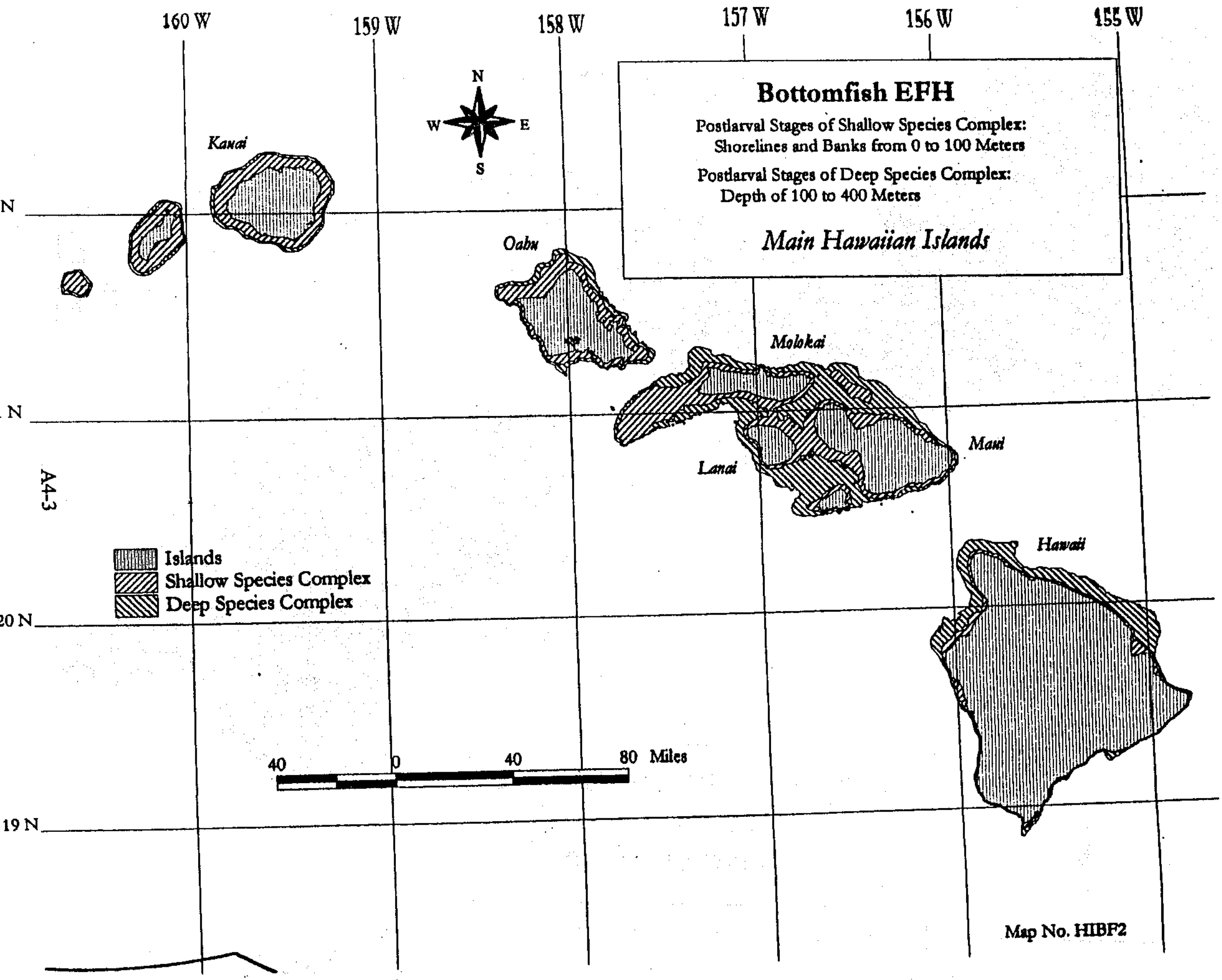
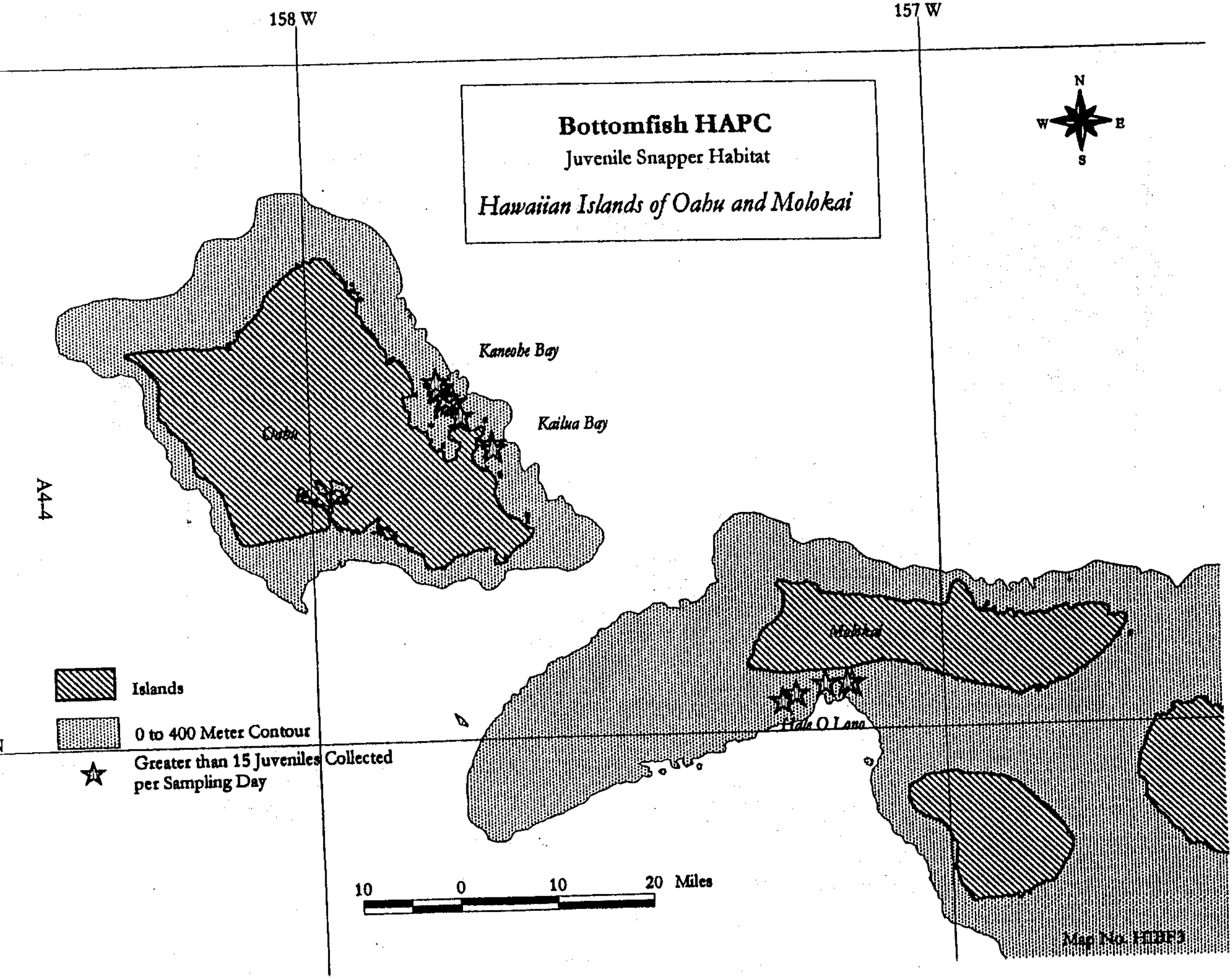
Appendix 4
Essential Fish Habitat and Habitat Areas of Particular Concern for the Hawaiian Islands, American Samoa, Guam and the Northern Mariana Islands


HIBF1
Bottomfish EFH and HAPC Map Key
Islands of Hawaii
HIBF12
HIBF7
HIBF11
HIBF6
HIBF10
HIBF5
HIBF9
HIBF4
HIBF8
HIBF2
HIBF3
N
W
E
S
100 Meter Contour
EEZ Boundary
EFH and HAPC Maps
100 0 100 200 Miles

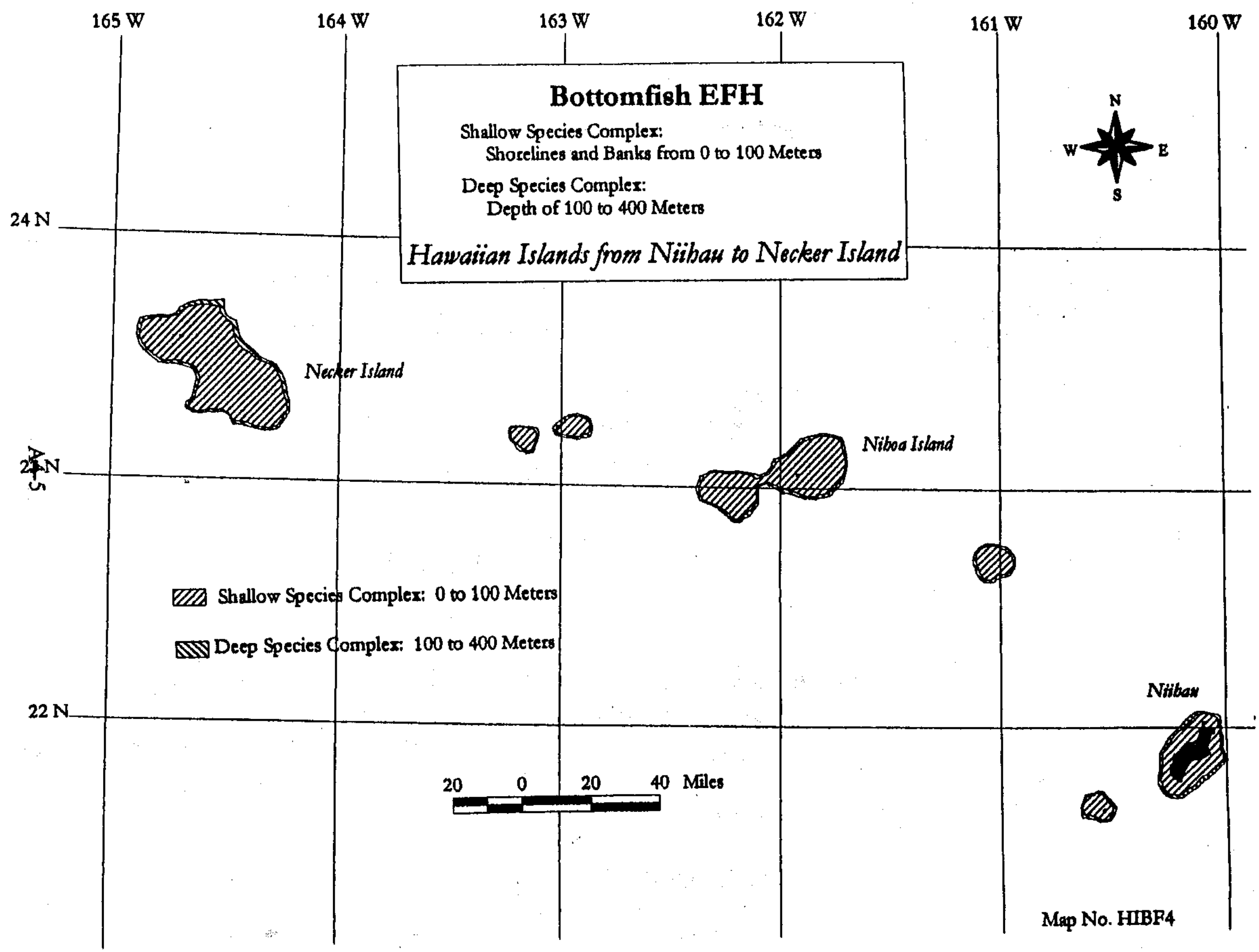


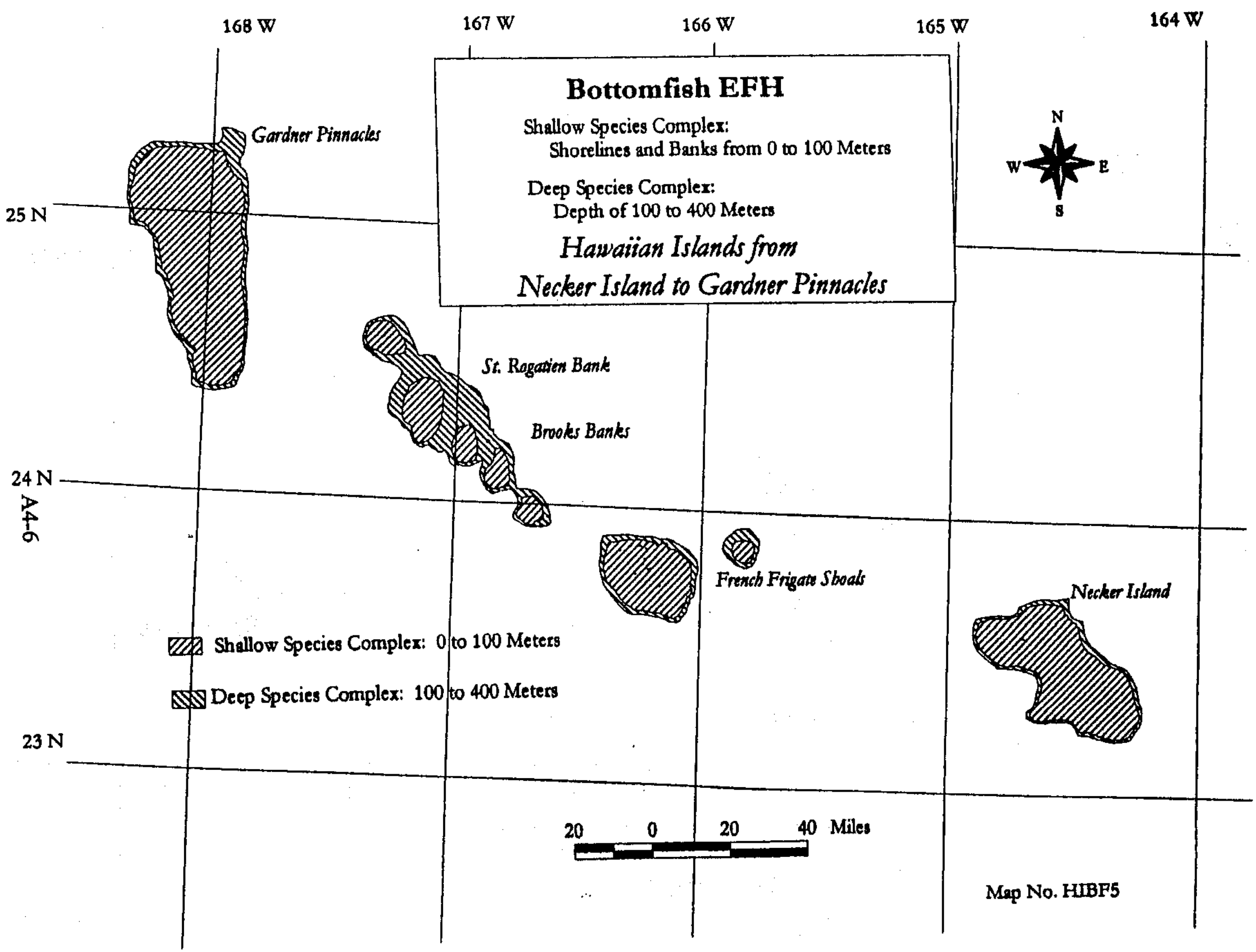
Bottomfish EFH
Islands of Hawaii
Egg and Larval Stages:
Entire EEZ from 0 to 400 Meters
N
W
E
S
Islands
0 to 400 Meter Contour
EEZ and Boundary of EFH for Eggs and Larvae
100
0
100
200
Miles
Map No. HIBF1


Bottomfish EFH
Postlarval Stages of Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex:
Depth of 100 to 400 Meters
Main Hawaiian Islands
160 W
159 W
158 W
157 W
156 W
155 W
20 N
19 N
N
W
E
S
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Islands
Shallow Species Complex
Deep Species Complex
40
0
40
80
Miles
Map No. HIBF2

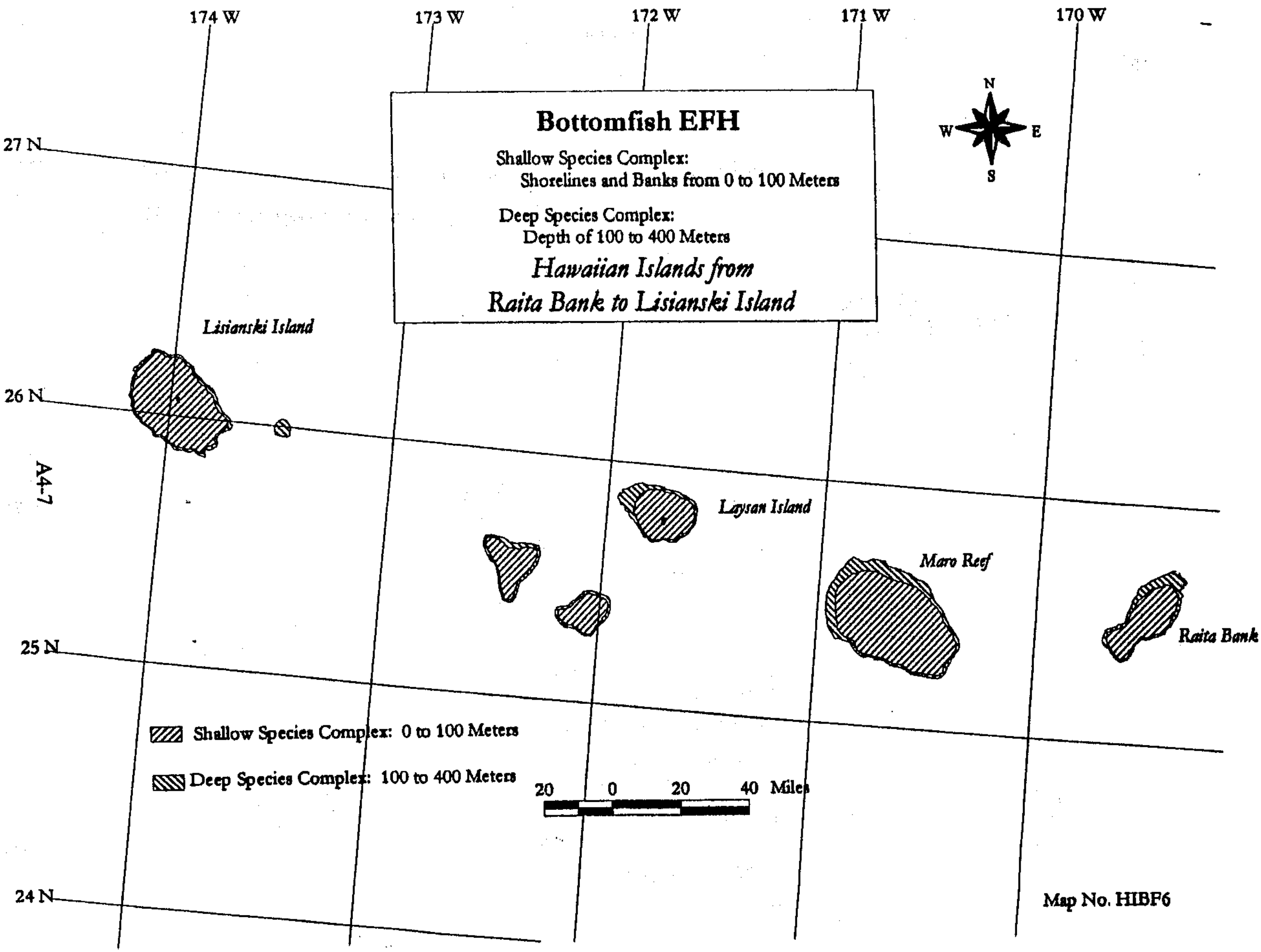


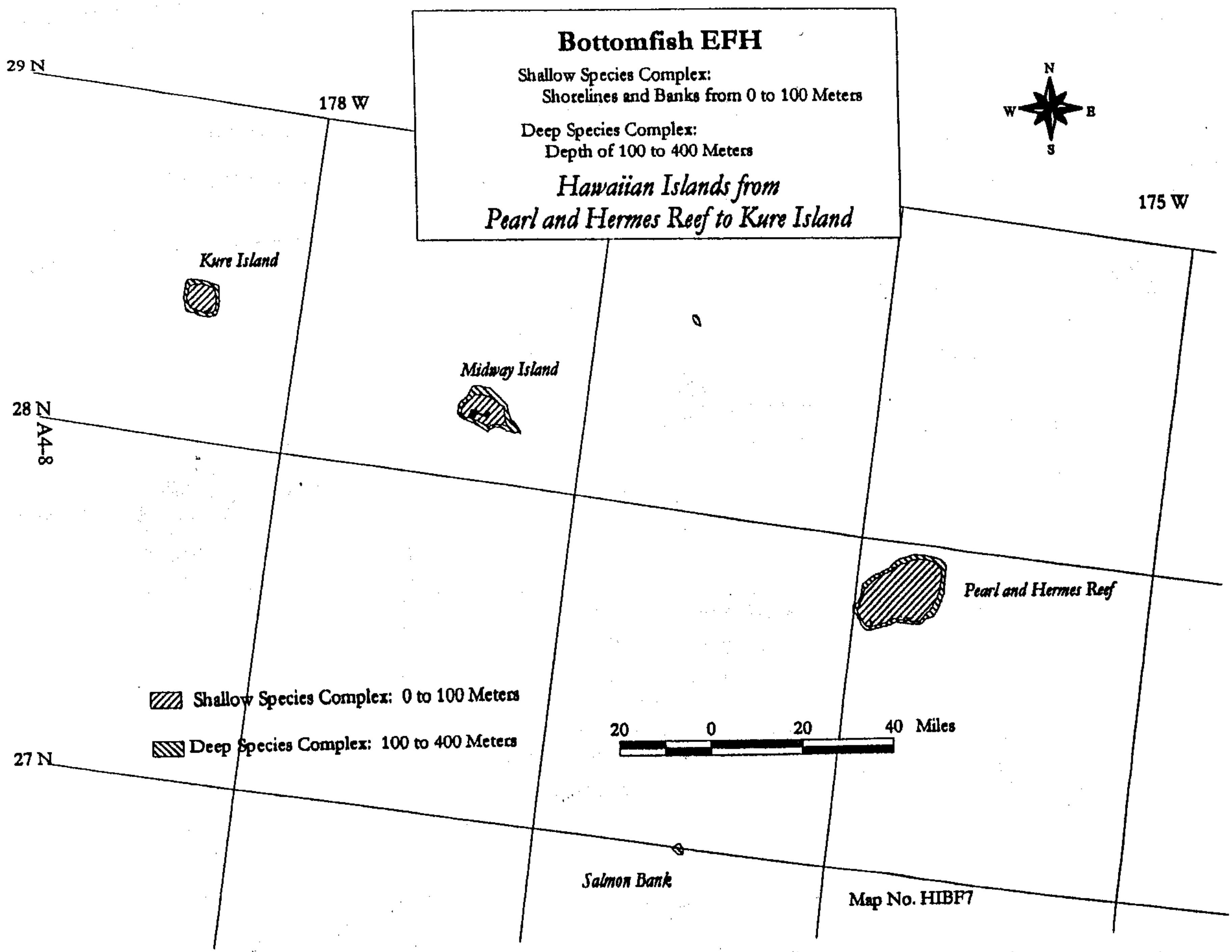
158 W
157 W
Bottomfish HAPC
Juvenile Snapper Habitat
Hawaiian Islands of Oahu and Molokai
N
W
E
S
Kaneohe Bay
Kailua Bay
Oahu
Molokai
Hale O Lono
Islands
0 to 400 Meter Contour
Greater than 15 Juveniles Collected per Sampling Day
10
0
10
20
Miles
Map No. HIBF3

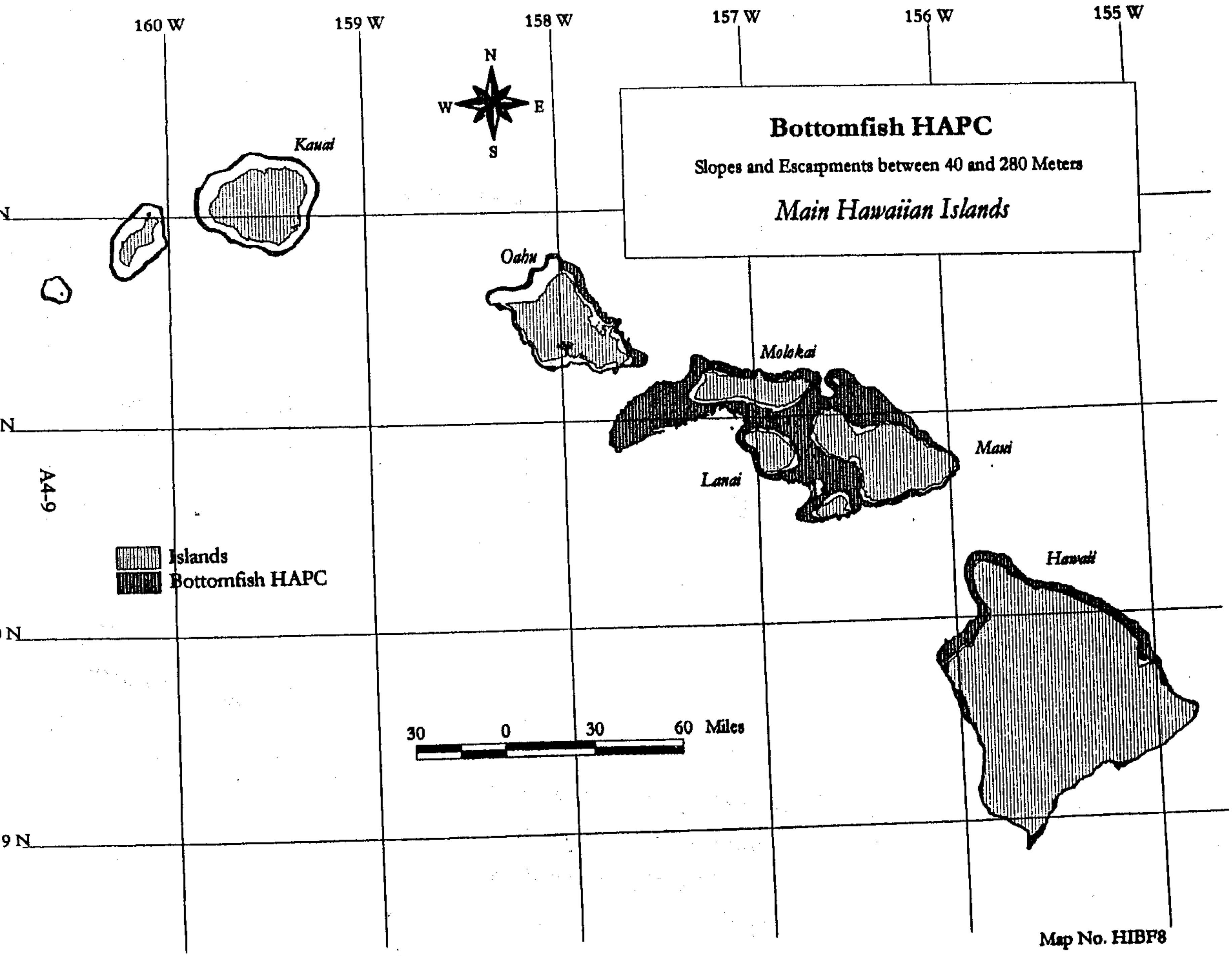

165 W
164 W
163 W
162 W
161 W
160 W
Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Hawaiian Islands from Niihau to Necker Island
N
W
E
S
24 N
Necker Island
Niboa Island
Shallow Species Complex: 0 to 100 Meters
Deep Species Complex: 100 to 400 Meters
22 N
Niihau
20 0 20 40 Miles
Map No. HIBF4



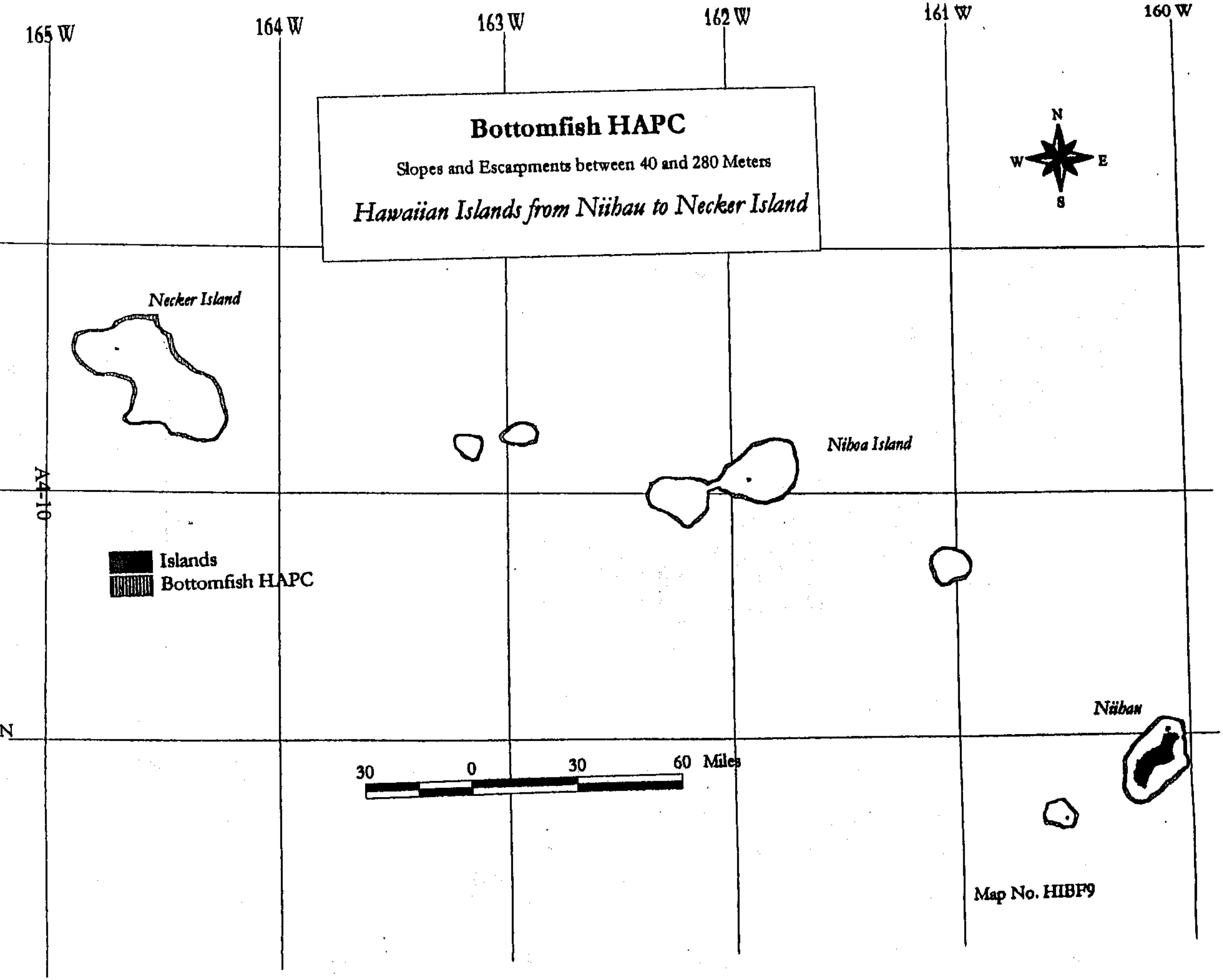
168 W
167 W
166 W
165 W
164 W
Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Hawaiian Islands from
Necker Island to Gardner Pinnacles
N
W
E
S
25 N
24 N
23 N
Gardner Pinnacles
St. Rogatien Bank
Brooks Banks
French Frigate Shoals
Necker Island
Shallow Species Complex: 0 to 100 Meters
Deep Species Complex: 100 to 400 Meters
20 0 20 40 Miles
Map No. HIBF5

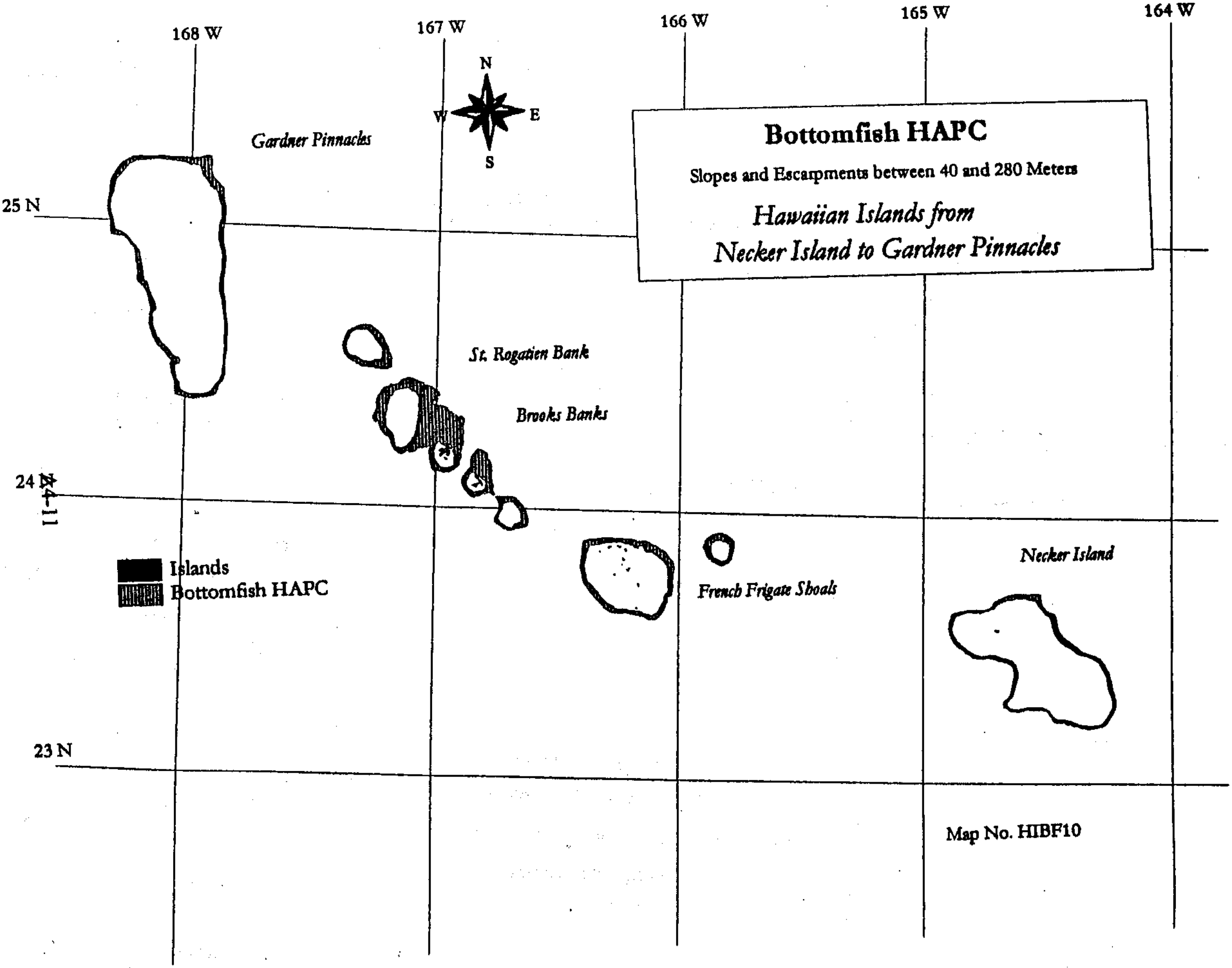

174 W
173 W
172 W
171 W
170 W
27 N
26 N
25 N
24 N
N
W
E
S
Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Hawaiian Islands from
Raita Bank to Lisianski Island
Lisianski Island
Laysan Island
Maro Reef
Raita Bank
Shallow Species Complex: 0 to 100 Meters
Deep Species Complex: 100 to 400 Meters
20 0 20 40 Miles
Map No. HIBF6

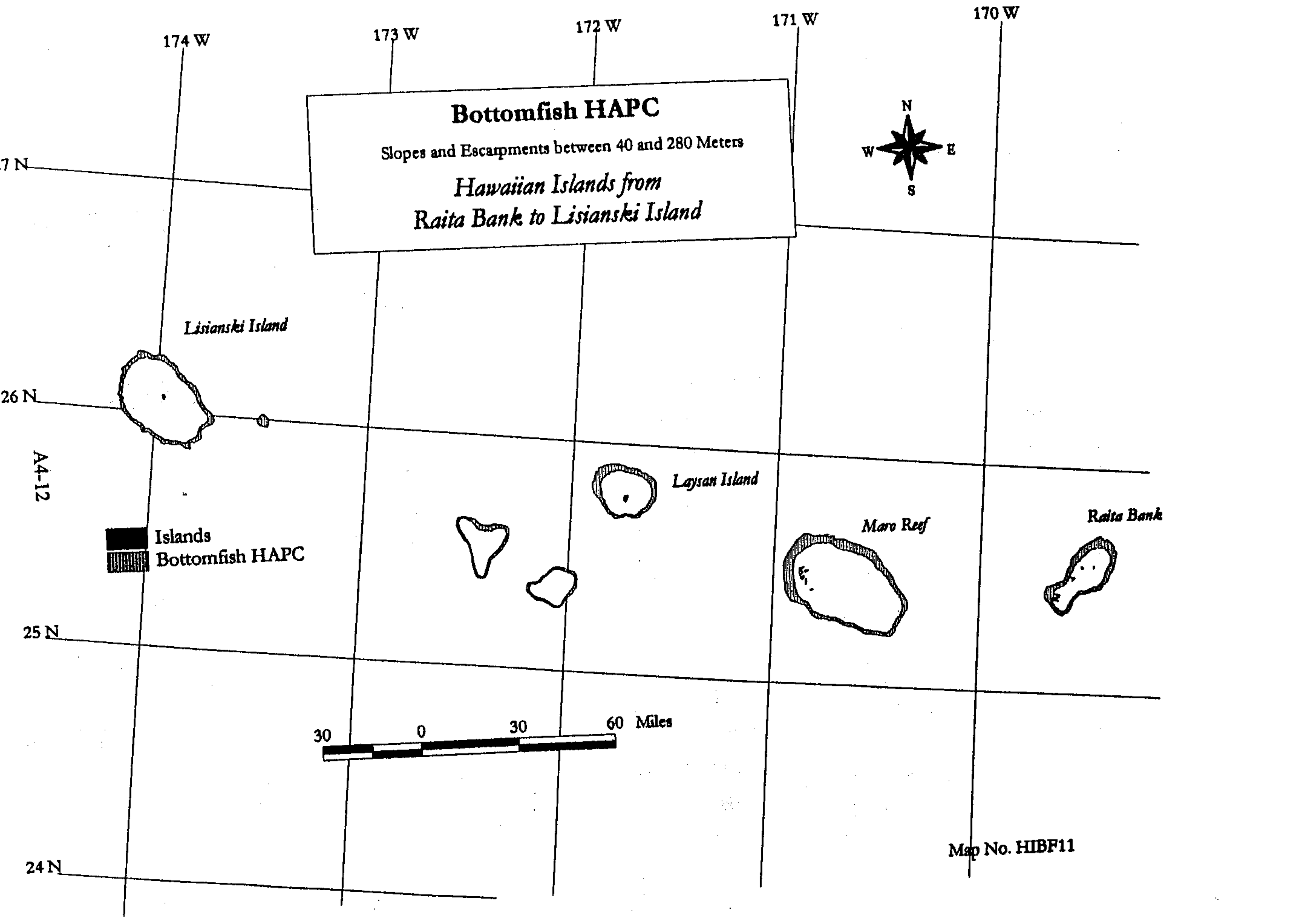

Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Hawaiian Islands from
Pearl and Hermes Reef to Kure Island
N
W
E
S
29 N
28 N
27 N
178 W
175 W
Kure Island
Midway Island
Pearl and Hermes Reef
Salmon Bank
Shallow Species Complex: 0 to 100 Meters
Deep Species Complex: 100 to 400 Meters
20 0 20 40 Miles
Map No. HIBF7

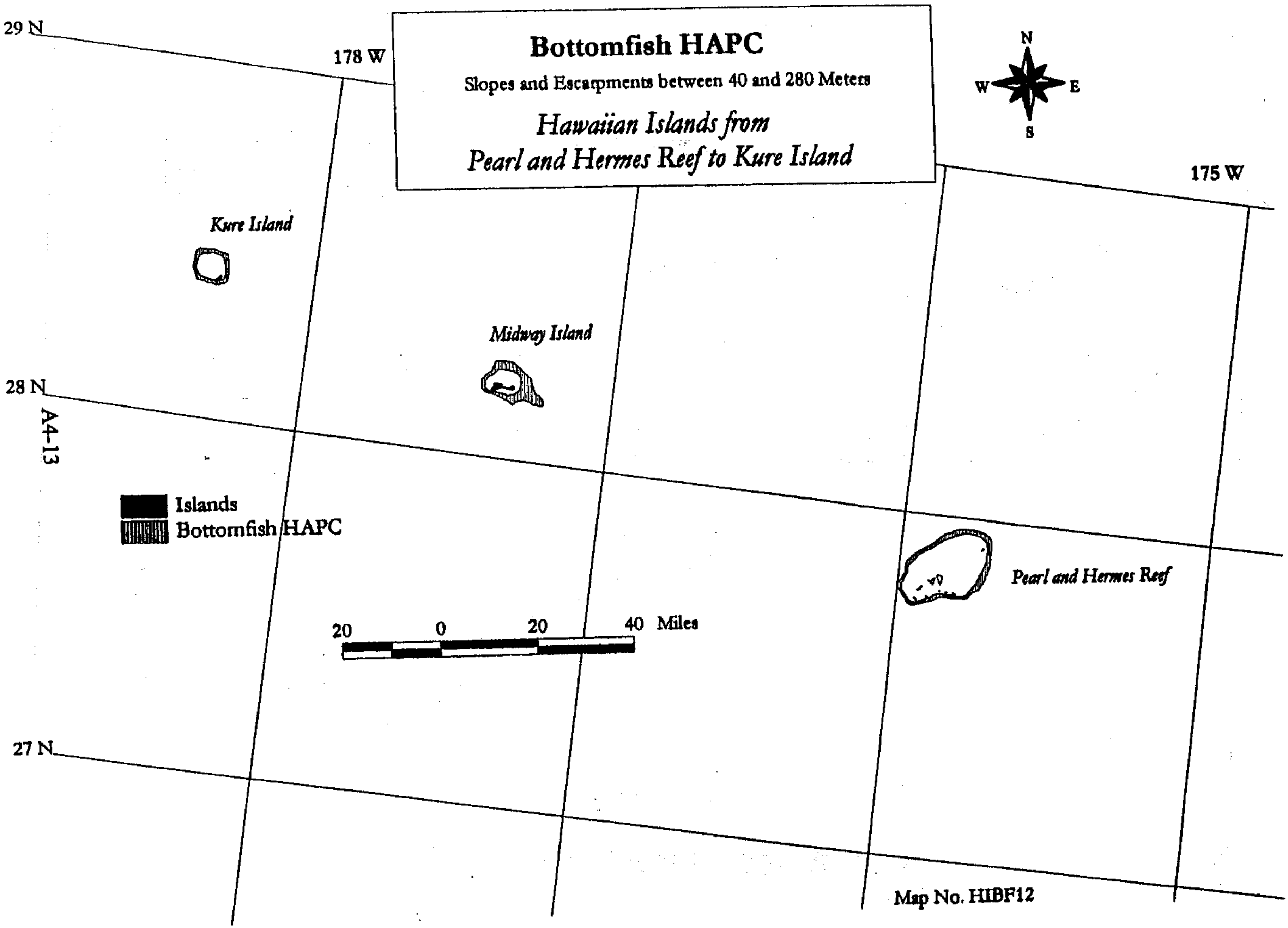


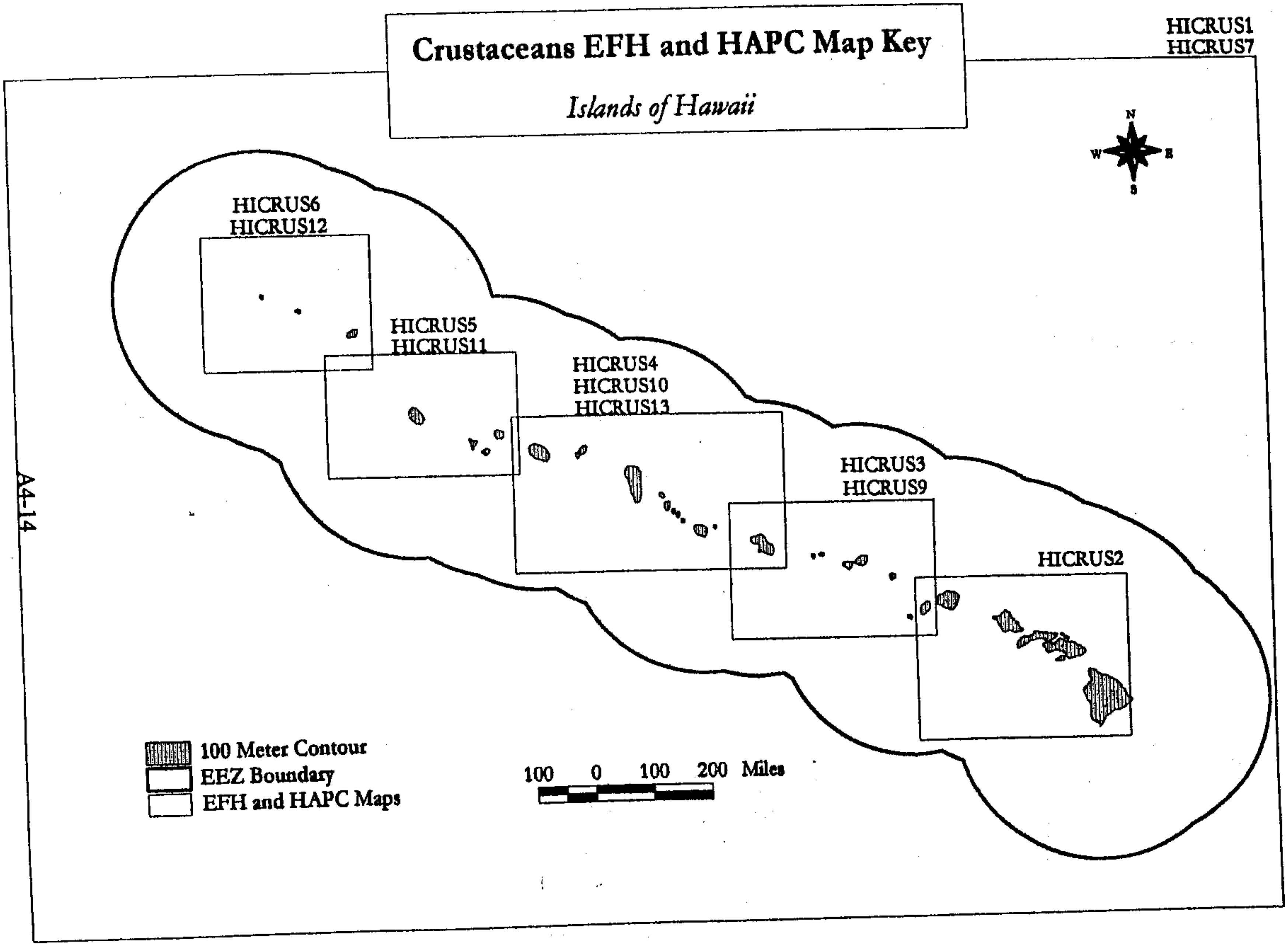
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Main Hawaiian Islands
160 W
159 W
158 W
157 W
156 W
155 W
N
W
E
S
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Islands
Bottomfish HAPC
30
0
30
60
Miles
Map No. HIBF8


165 W
164 W
163 W
162 W
161 W
160 W
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Hawaiian Islands from Niihau to Necker Island
N
W
E
S
Necker Island
Nihoa Island
Niihau
Islands
Bottomfish HAPC
30
0
30
60 Miles
Map No. HIBF9


Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Hawaiian Islands from
Necker Island to Gardner Pinnacles
168 W
167 W
166 W
165 W
164 W
25 N
24 N
23 N
N
W
E
S
Gardner Pinnacles
St. Rogatien Bank
Brooks Banks
French Frigate Shoals
Necker Island
Islands
Bottomfish HAPC
Map No. HIBF10


Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Hawaiian Islands from
Raita Bank to Lisianski Island
174 W
173 W
172 W
171 W
170 W
26 N
25 N
24 N
N
W
E
S
Lisianski Island
Laysan Island
Maro Reef
Raita Bank
Islands
Bottomfish HAPC
30
0
30
60
Miles
Map No. HIBF11

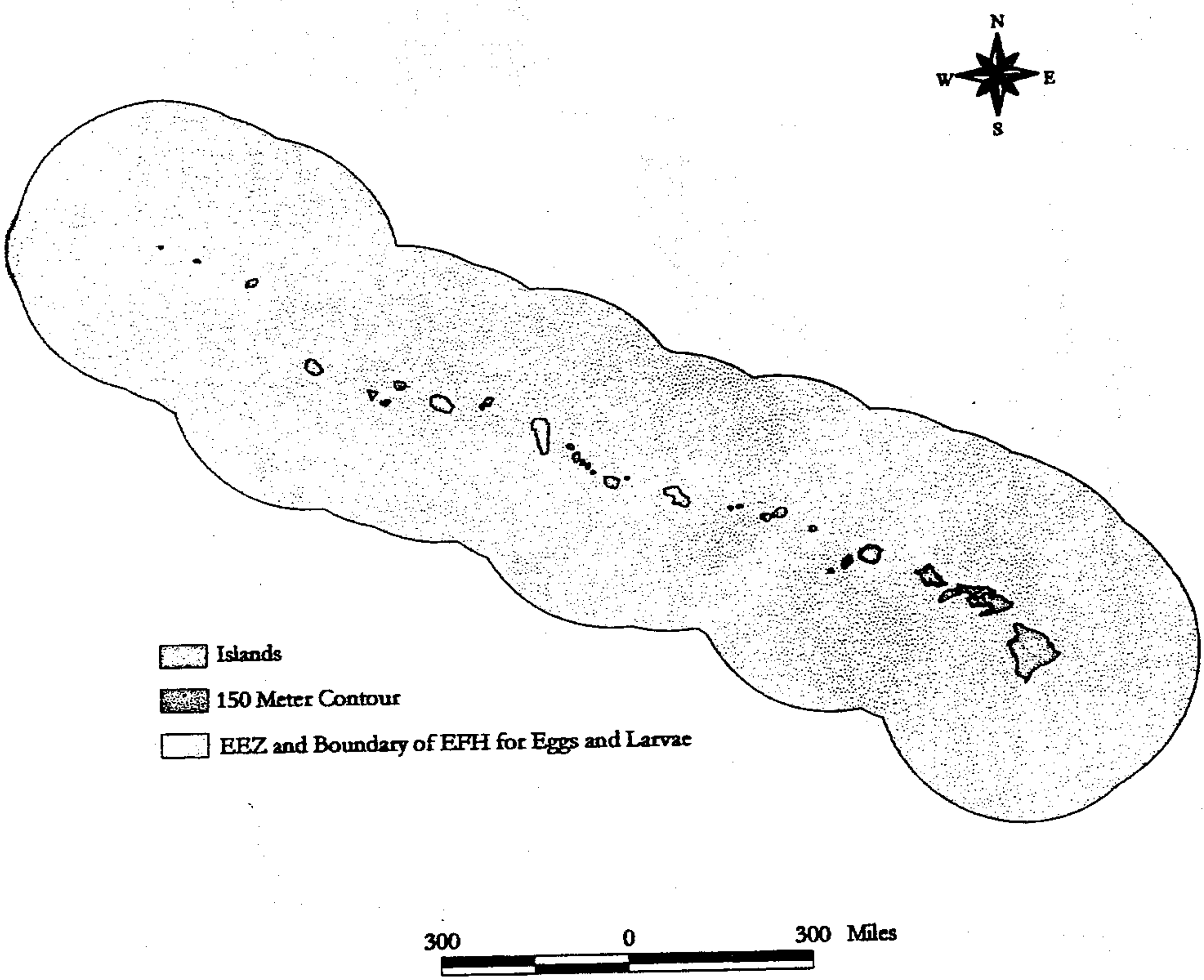

Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Hawaiian Islands from
Pearl and Hermes Reef to Kure Island
N
W
E
S
29 N
178 W
175 W
28 N
27 N
Kure Island
Midway Island
Pearl and Hermes Reef
Islands
Bottomfish HAPC
20
0
20
40
Miles
Map No. HIBF12


Crustaceans EFH and HAPC Map Key
Islands of Hawaii
HICRUS1
HICRUS7
N
W
E
S
HICRUS6
HICRUS12
HICRUS5
HICRUS11
HICRUS4
HICRUS10
HICRUS13
HICRUS3
HICRUS9
HICRUS2
100 Meter Contour
EEZ Boundary
EFH and HAPC Maps
100 0 100 200 Miles

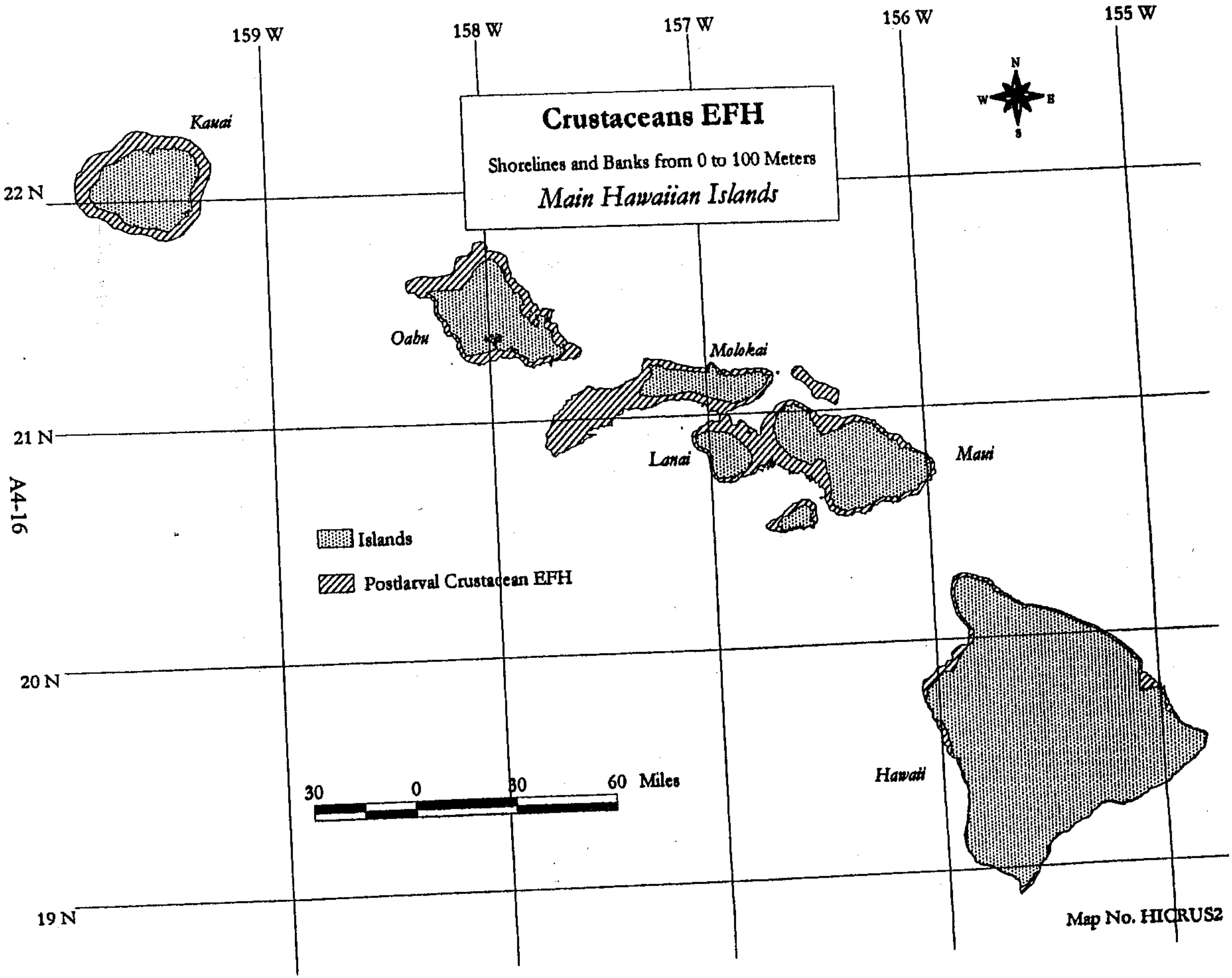
Crustaceans EFH

Islands of Hawaii

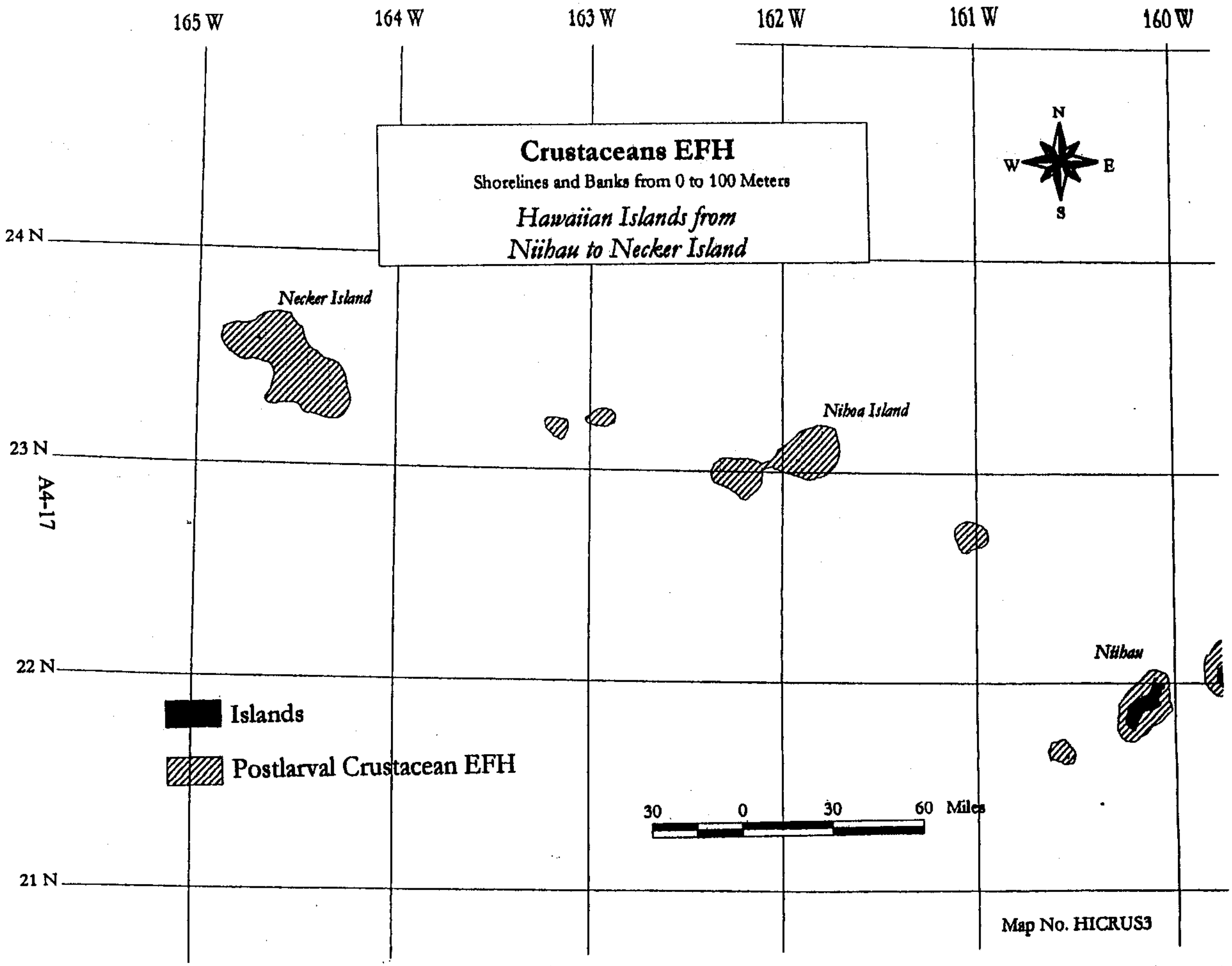
Eggs and Larvae:
Entire EEZ from 0 to 150 Meters

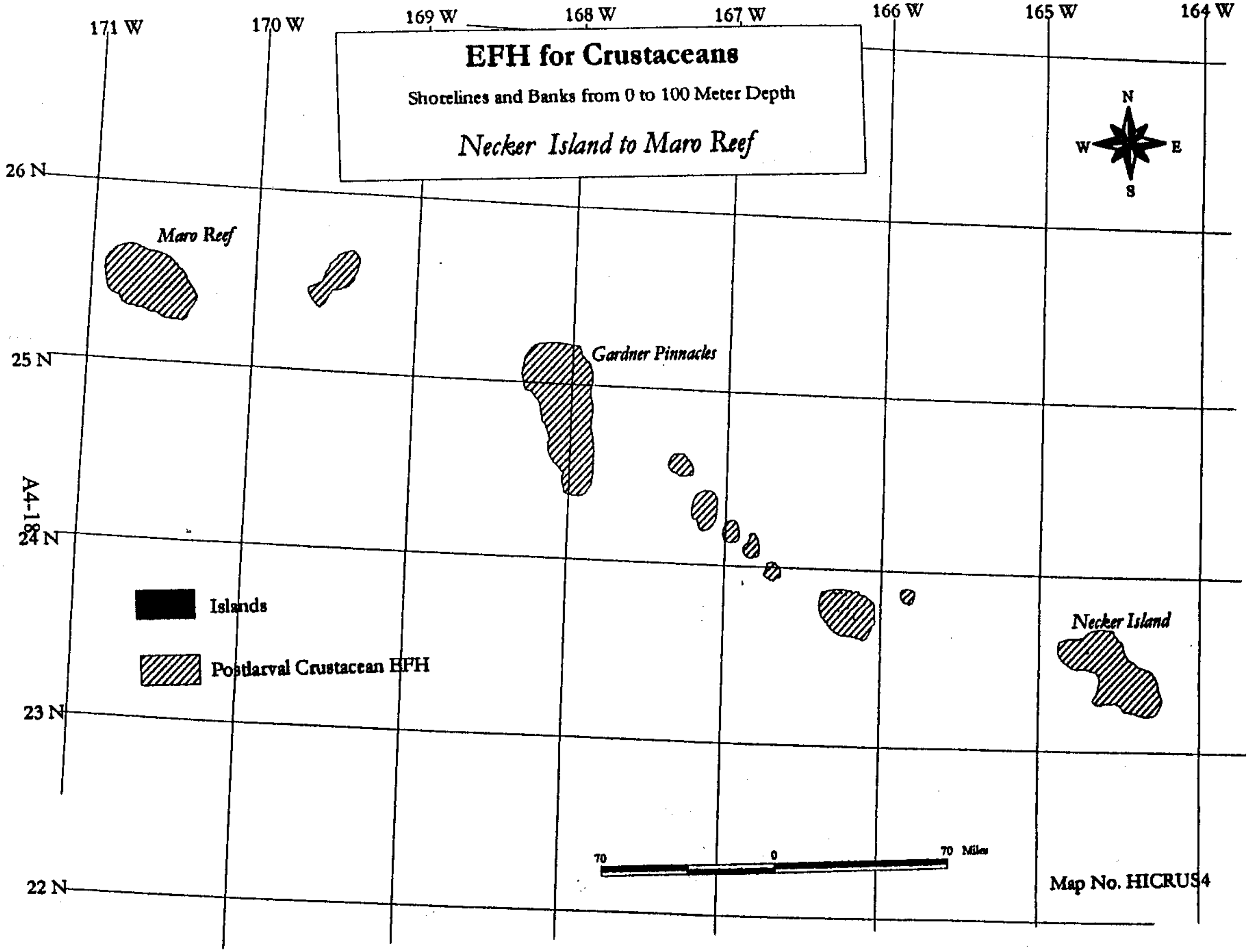


Map No. HICRUS1

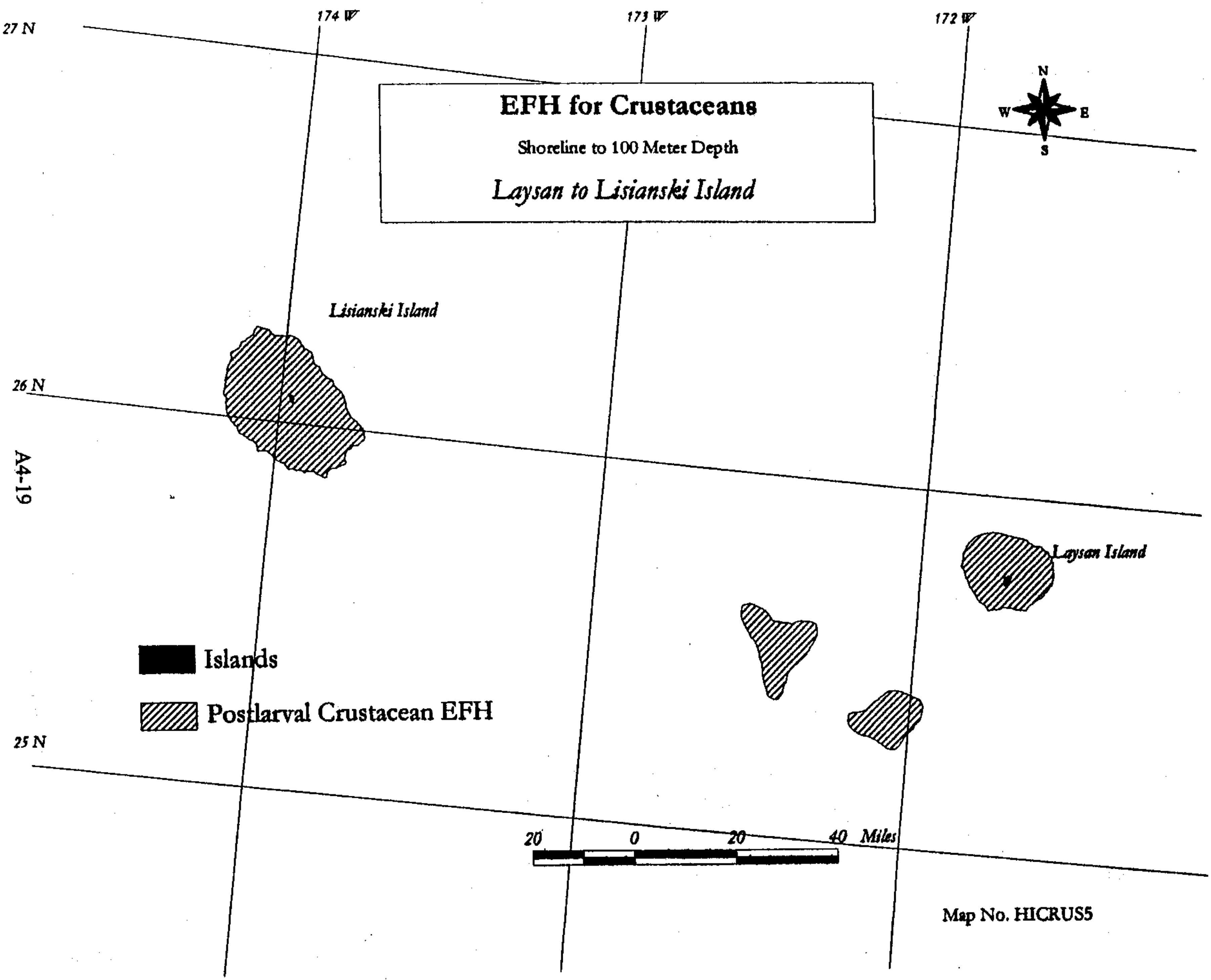


Crustaceans EFH
Shorelines and Banks from 0 to 100 Meters
Main Hawaiian Islands
159 W
158 W
157 W
156 W
155 W
22 N
21 N
20 N
19 N
N
W
E
S
Kauai
Oahu
Molokai
Lanai
Maui
Hawaii
Islands
Postlarval Crustacean EFH
30
0
30
60
Miles
Map No. HICRUS2

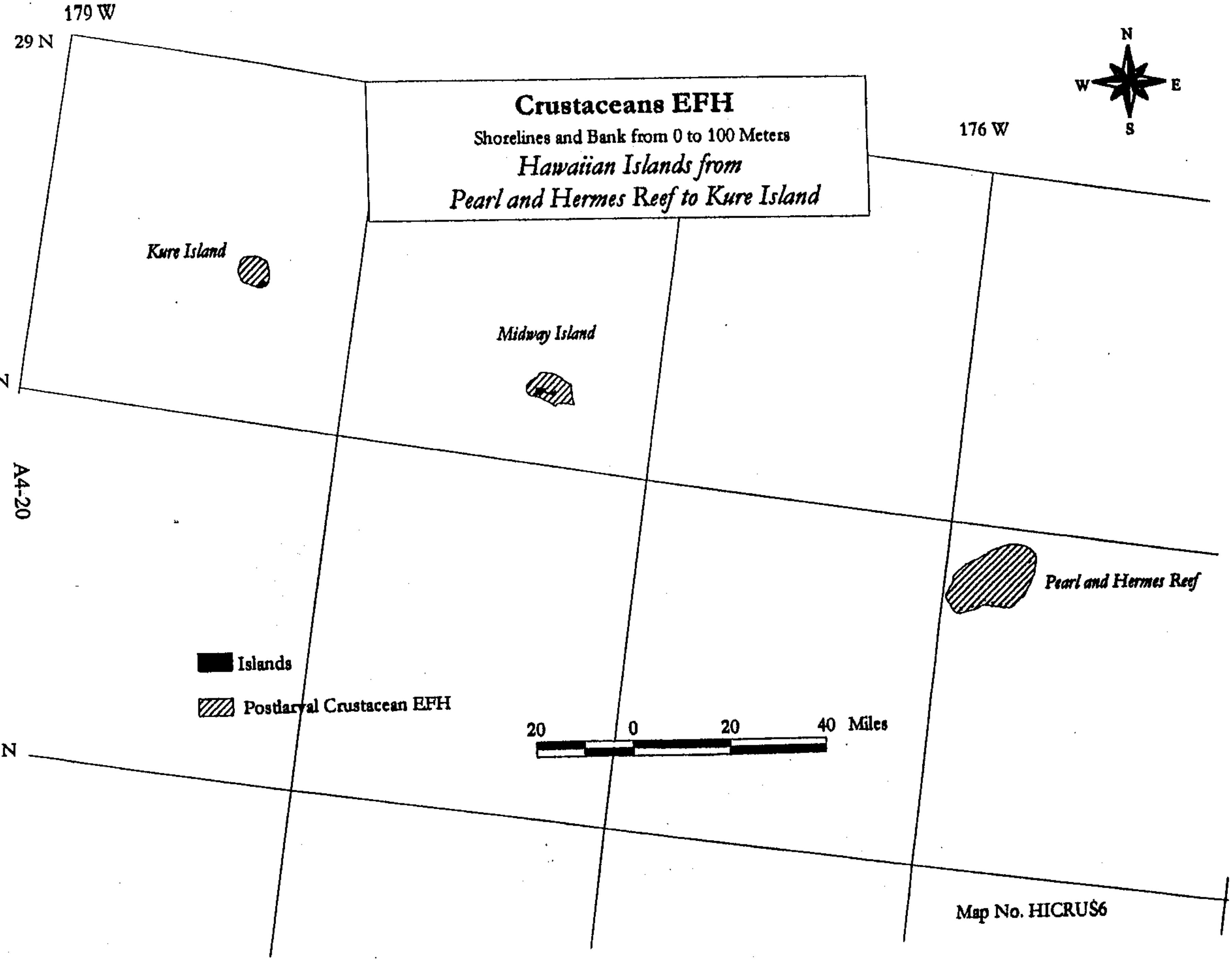

Crustaceans EFH
Shorelines and Banks from 0 to 100 Meters
Hawaiian Islands from
Niihau to Necker Island
165 W
164 W
163 W
162 W
161 W
160 W
24 N
23 N
22 N
21 N
N
W
E
S
Necker Island
Nihoa Island
Niihau
Islands
Postlarval Crustacean EFH
30
0
30
60
Miles
Map No. HICRUS3



EFH for Crustaceans
Shorelines and Banks from 0 to 100 Meter Depth
Necker Island to Maro Reef
171 W
170 W
169 W
168 W
167 W
166 W
165 W
164 W
26 N
25 N
24 N
23 N
22 N
N
W
E
S
Maro Reef
Gardner Pinnacles
Necker Island
Islands
Postlarval Crustacean EFH
70
0
70 Miles
Map No. HICRUS4



EFH for Crustaceans
Shoreline to 100 Meter Depth
Laysan to Lisianski Island
27 N
26 N
25 N
174 W
173 W
172 W
N
S
E
W
Lisianski Island
Laysan Island
Islands
Postlarval Crustacean EFH
20
0
20
40
Miles
Map No. HICRUS5

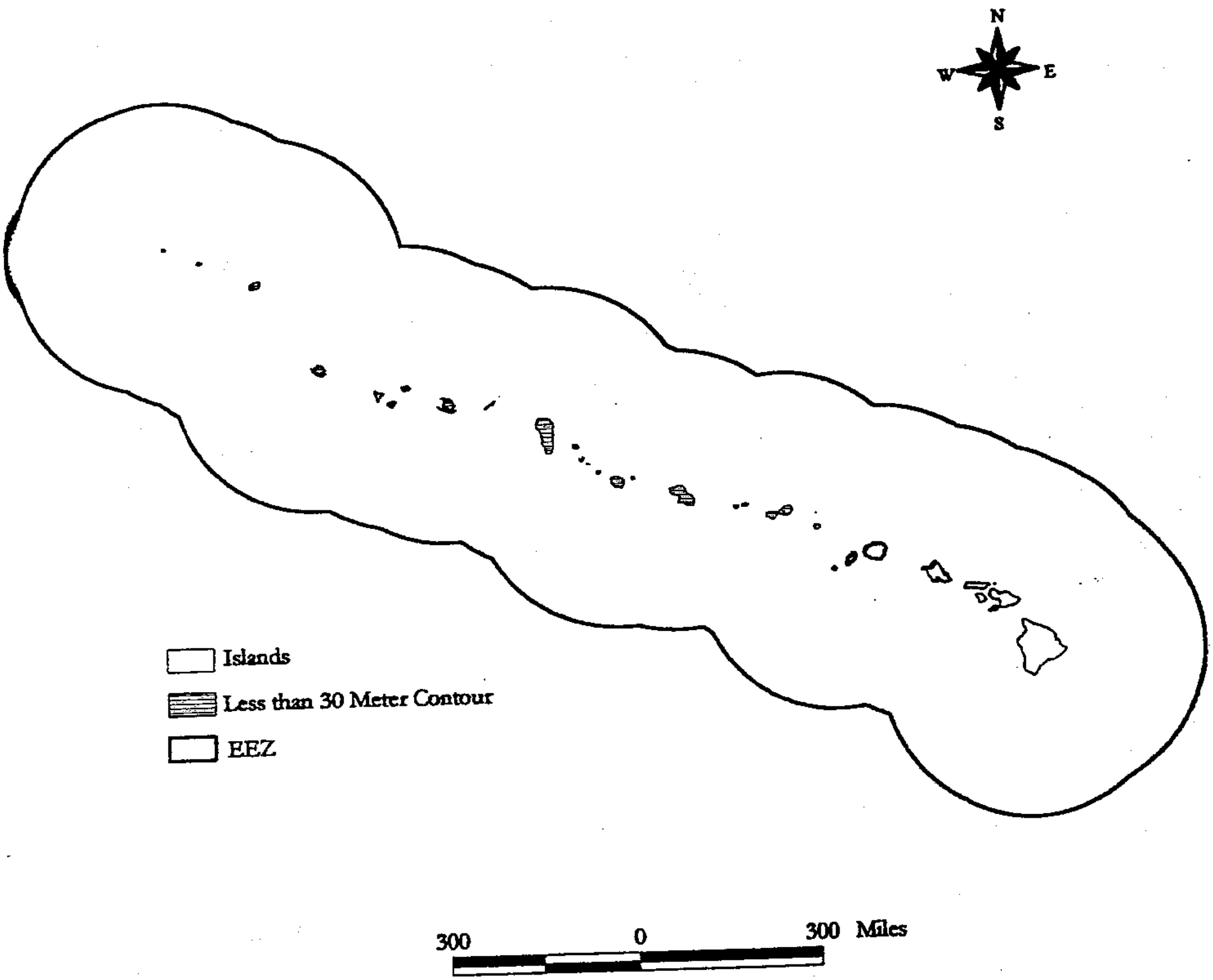


Crustaceans EFH
Shorelines and Bank from 0 to 100 Meters
Hawaiian Islands from
Pearl and Hermes Reef to Kure Island
179 W
176 W
29 N
28 N
27 N
N
W
E
S
Kure Island
Midway Island
Pearl and Hermes Reef
Islands
Postlarval Crustacean EFH
20
0
20
40
Miles
Map No. HICRUS6

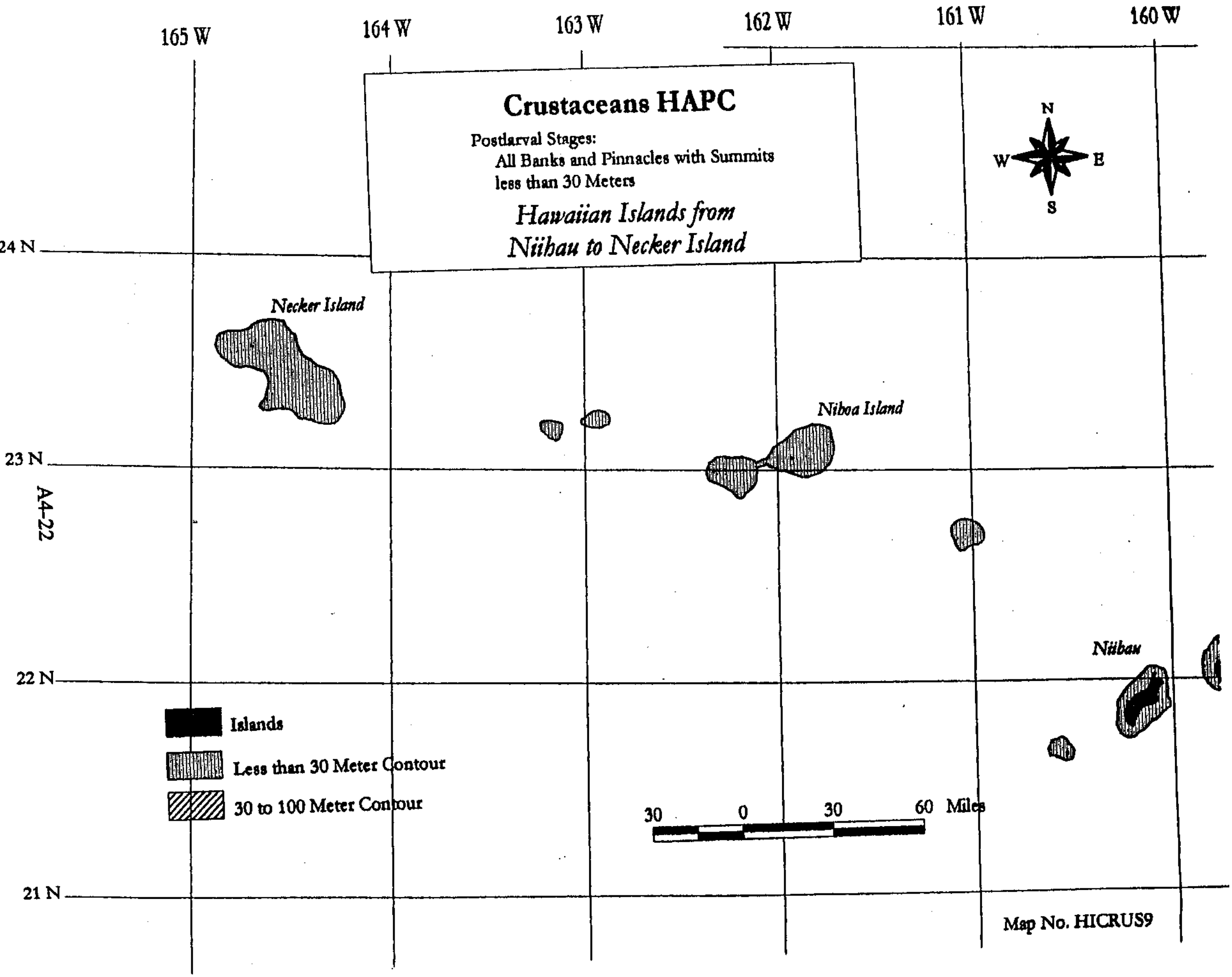
Crustaceans HAPC

Postlarval Stages:
All Banks and Pinnacles with Summits less than 30 Meters Deep

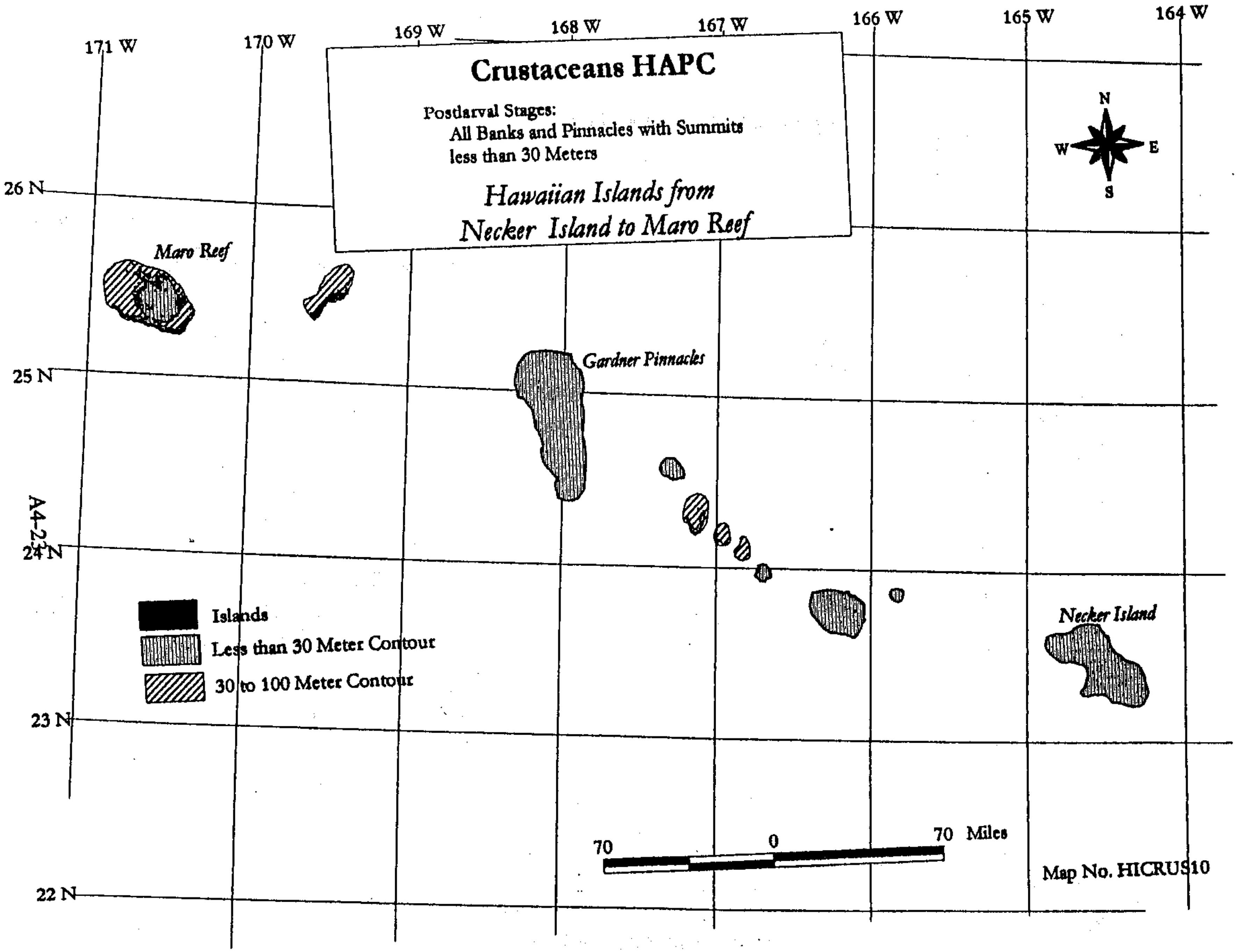
Islands of Hawaii



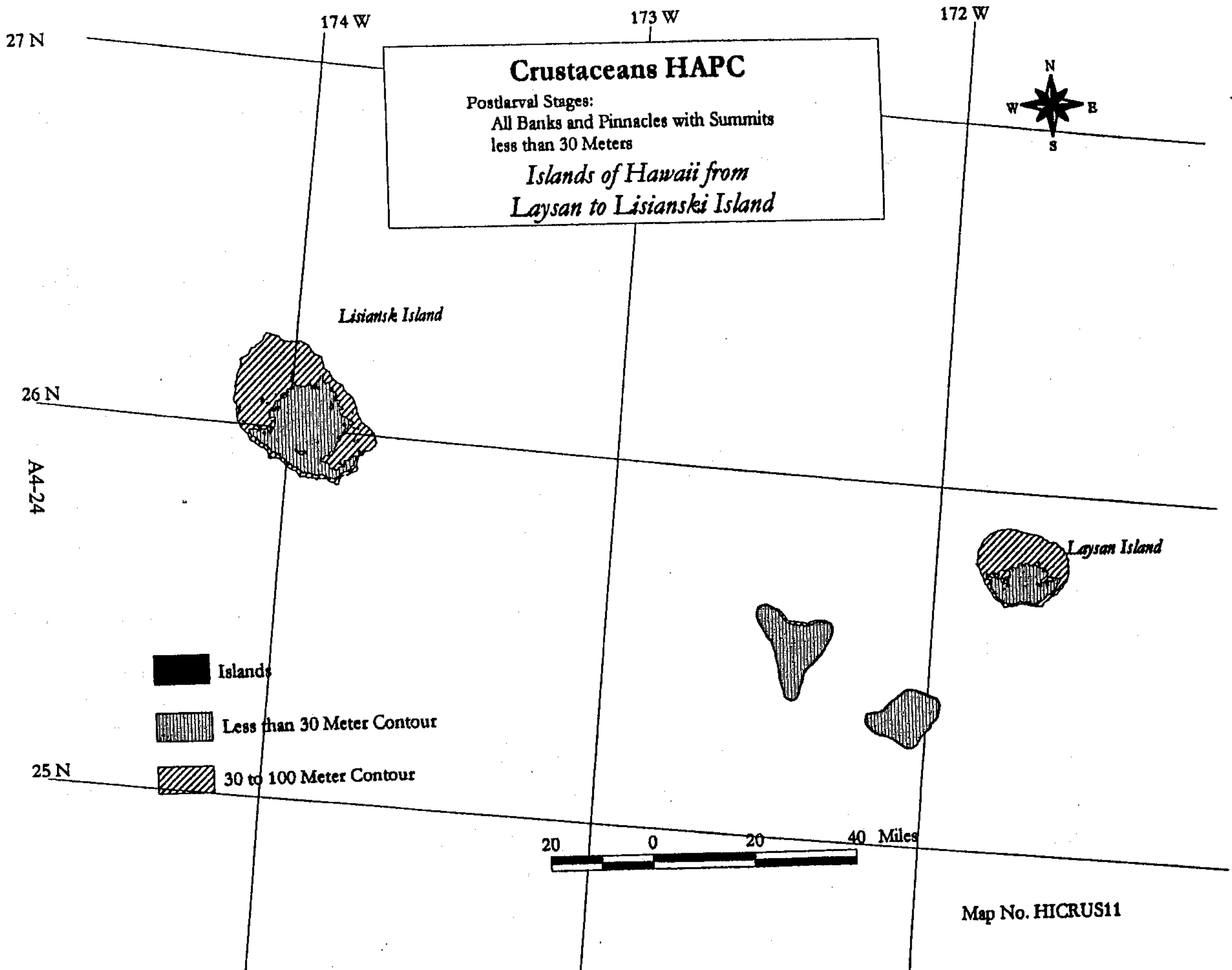
Map No. HICRUS7

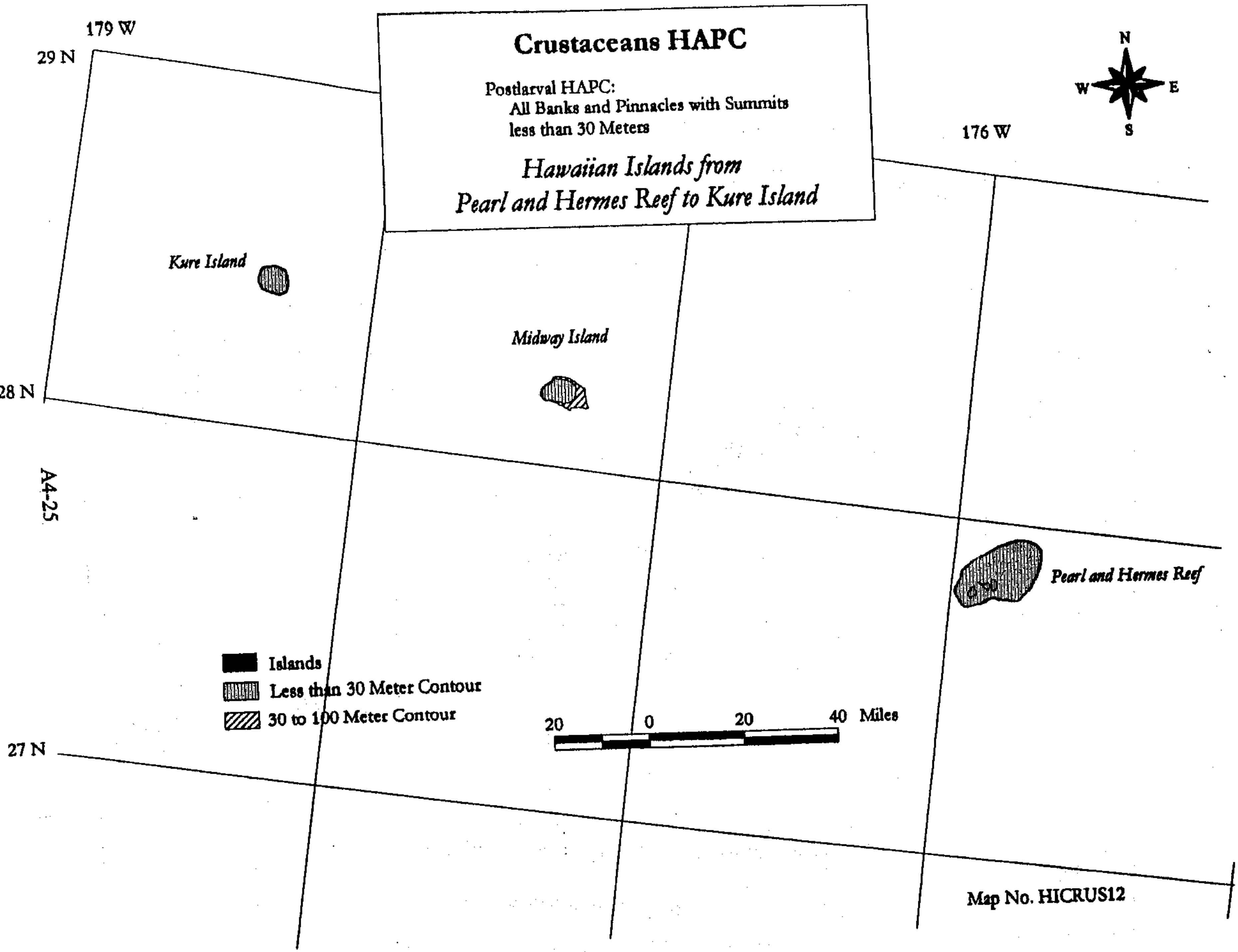


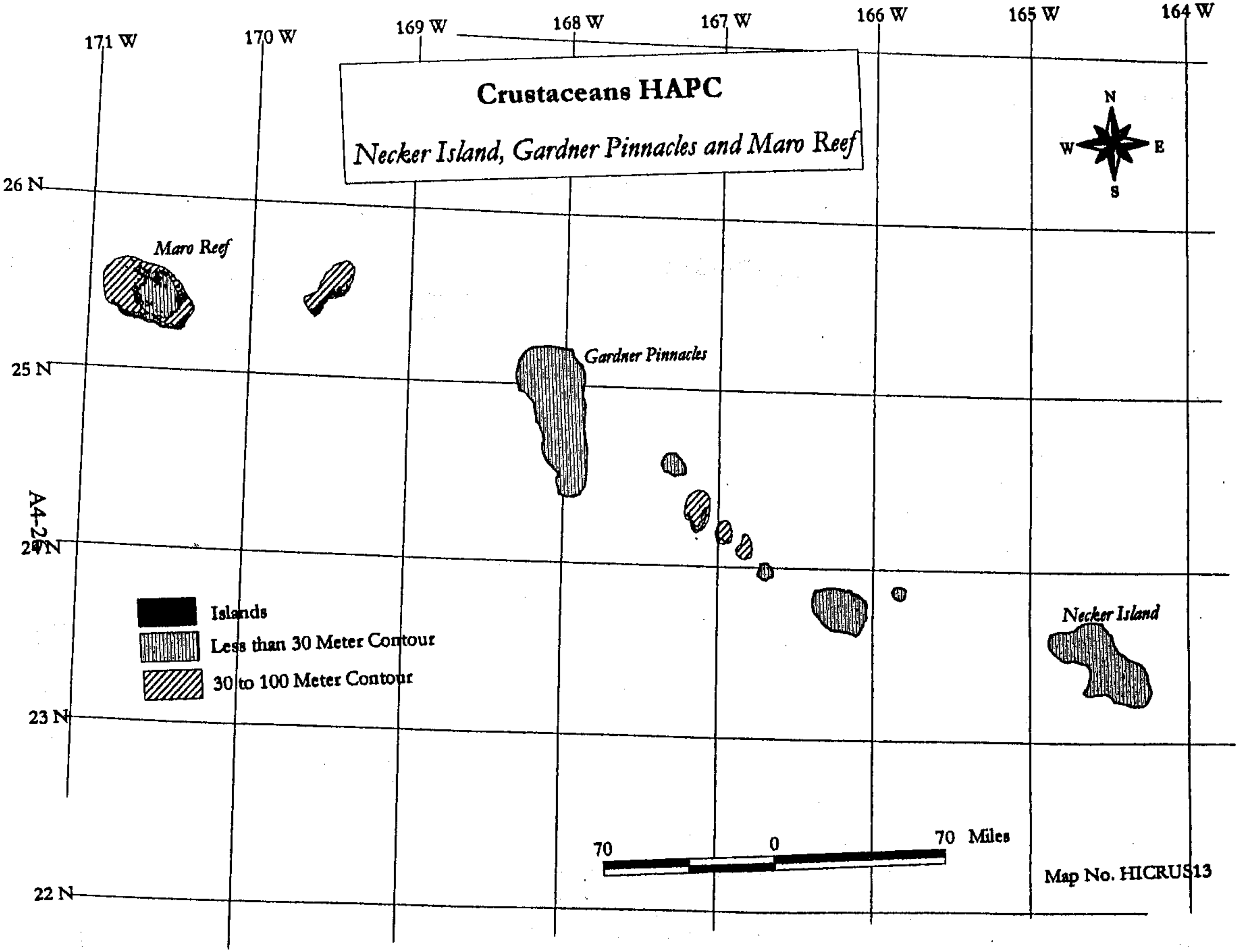
Crustaceans HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits less than 30 Meters
Hawaiian Islands from Niihau to Necker Island
165 W
164 W
163 W
162 W
161 W
160 W
24 N
23 N
22 N
21 N
N
W
E
S
Necker Island
Nihoa Island
Niihau
Islands
Less than 30 Meter Contour
30 to 100 Meter Contour
30
0
30
60
Miles
Map No. HICRUS9



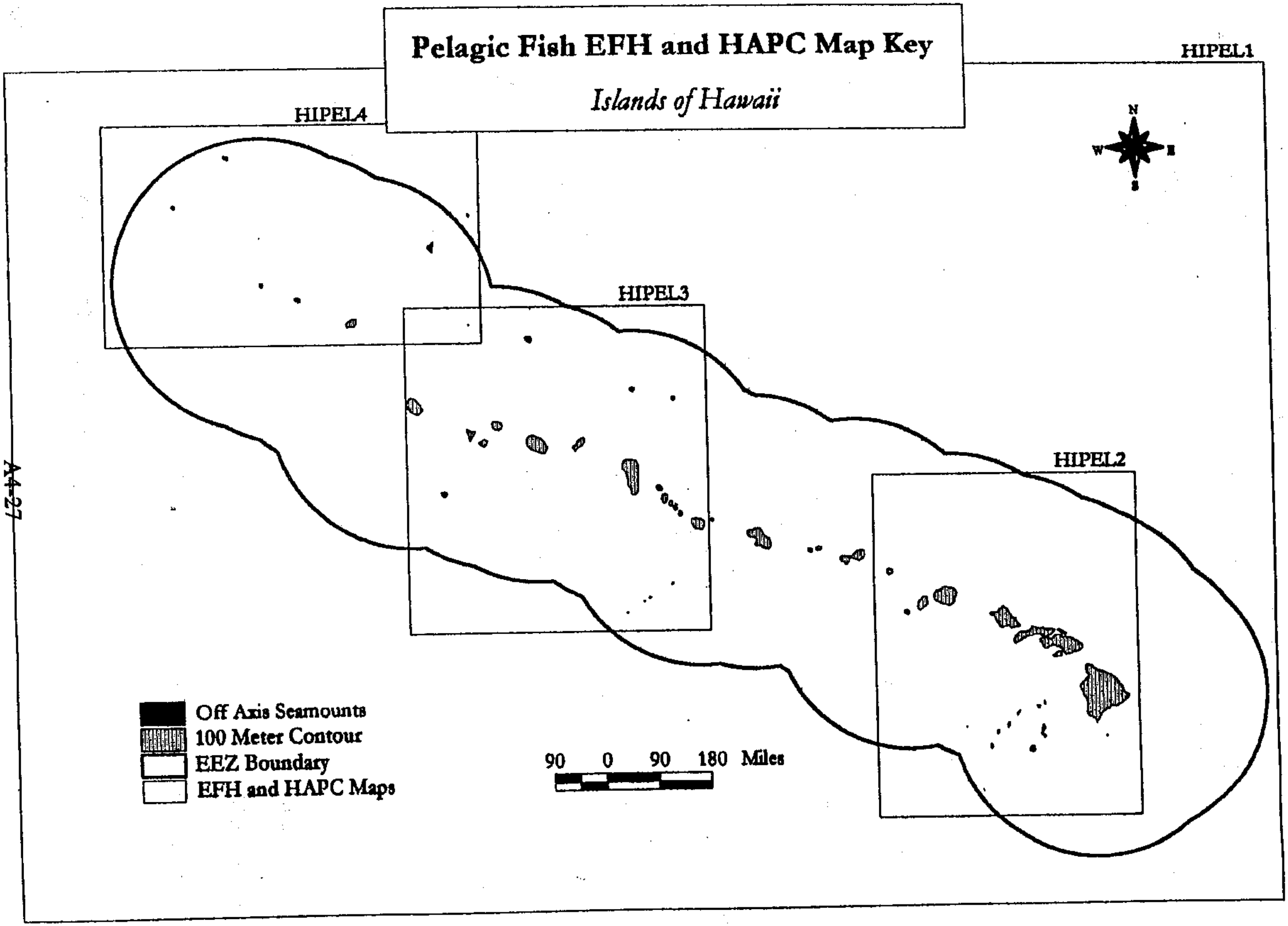
Crustaceans HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits less than 30 Meters
Hawaiian Islands from Necker Island to Maro Reef
171 W
170 W
169 W
168 W
167 W
166 W
165 W
164 W
26 N
25 N
24 N
23 N
22 N
N
S
E
W
Maro Reef
Gardner Pinnacles
Necker Island
Islands
Less than 30 Meter Contour
30 to 100 Meter Contour
70
0
70 Miles
Map No. HICRUS10


Crustaceans HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
less than 30 Meters
Islands of Hawaii from
Laysan to Lisianski Island
174 W
173 W
172 W
27 N
26 N
25 N
N
W
E
S
Lisiansk Island
Laysan Island
Islands
Less than 30 Meter Contour
30 to 100 Meter Contour
20
0
20
40
Miles
Map No. HICRUS11


Crustaceans HAPC
Postlarval HAPC:
All Banks and Pinnacles with Summits
less than 30 Meters
Hawaiian Islands from
Pearl and Hermes Reef to Kure Island
N
W
E
S
179 W
176 W
29 N
28 N
27 N
Kure Island
Midway Island
Pearl and Hermes Reef
Islands
Less than 30 Meter Contour
30 to 100 Meter Contour
20
0
20
40
Miles
Map No. HICRUS12



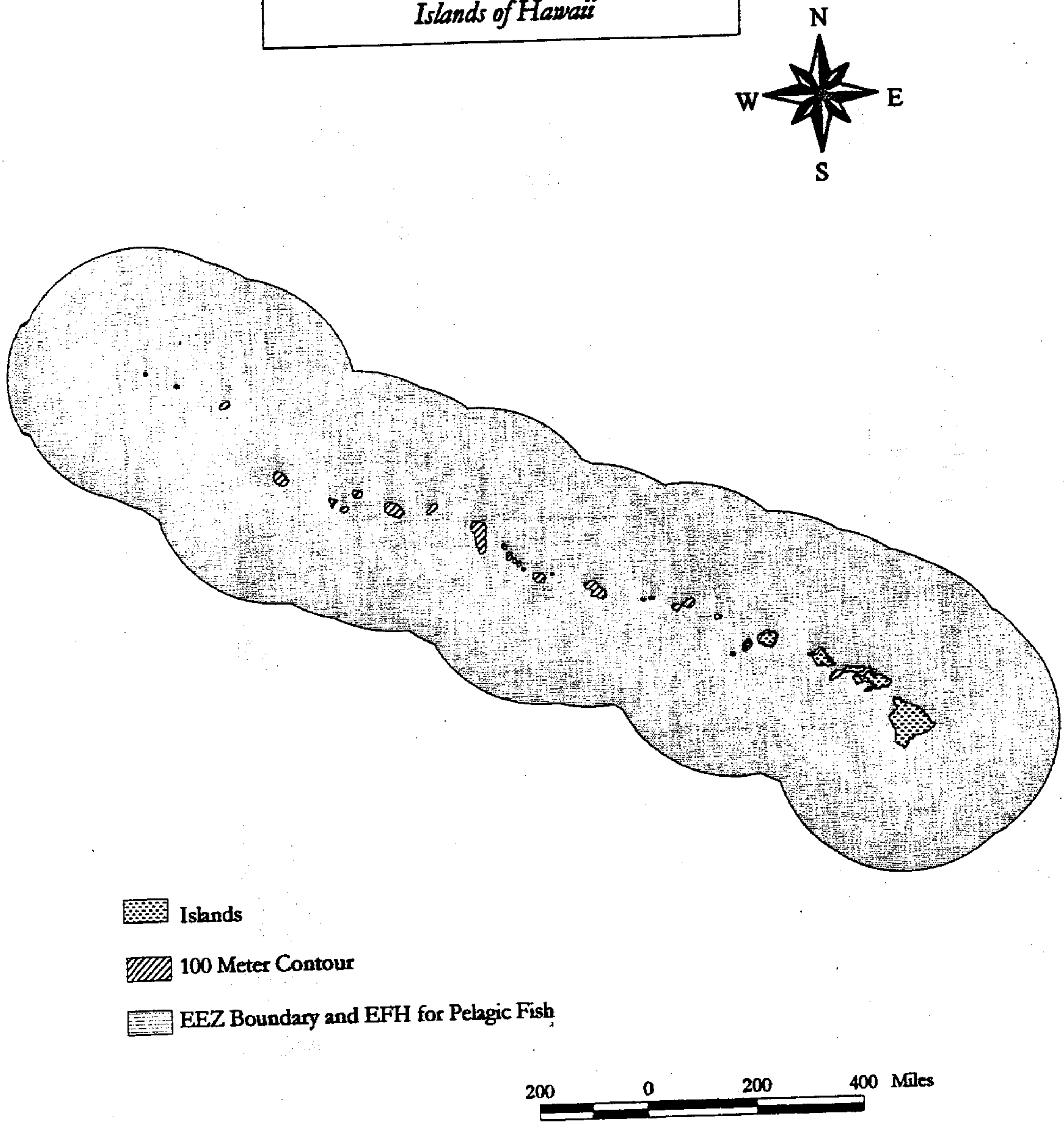
Crustaceans HAPC
Necker Island, Gardner Pinnacles and Maro Reef
171 W
170 W
169 W
168 W
167 W
166 W
165 W
164 W
26 N
25 N
24 N
23 N
22 N
N
E
S
W
Maro Reef
Gardner Pinnacles
Necker Island
Islands
Less than 30 Meter Contour
30 to 100 Meter Contour
70
0
70 Miles
Map No. HICRUS13


Pelagic Fish EFH and HAPC Map Key
Islands of Hawaii
HIPEL1
HIPEL2
HIPEL3
HIPEL4
N
W
E
S
Off Axis Seamounts
100 Meter Contour
EEZ Boundary
EFH and HAPC Maps
90 0 90 180 Miles

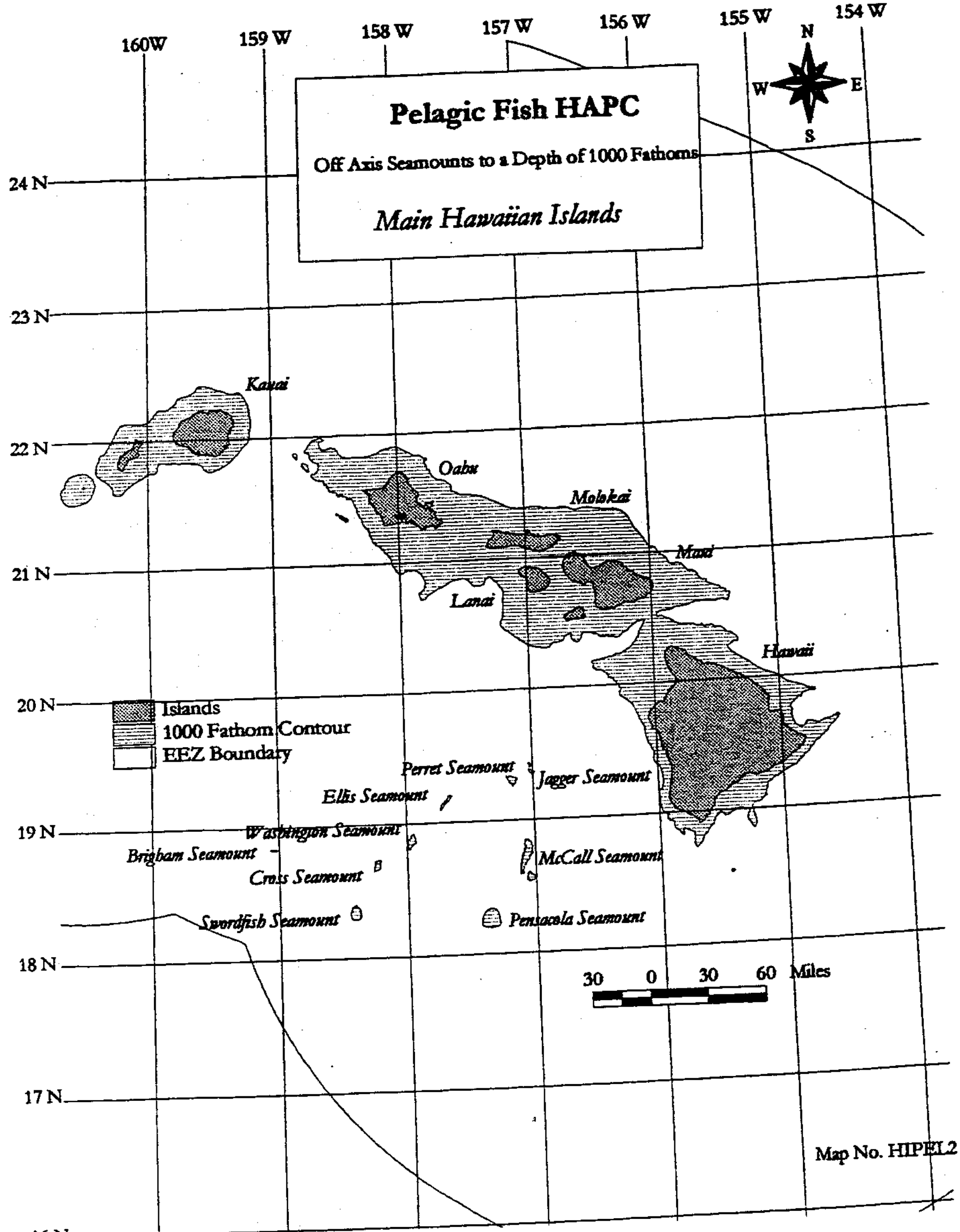
Pelagic Fish EFH

All Life History Stages:
Entire EEZ to a Depth of 1000 Meters

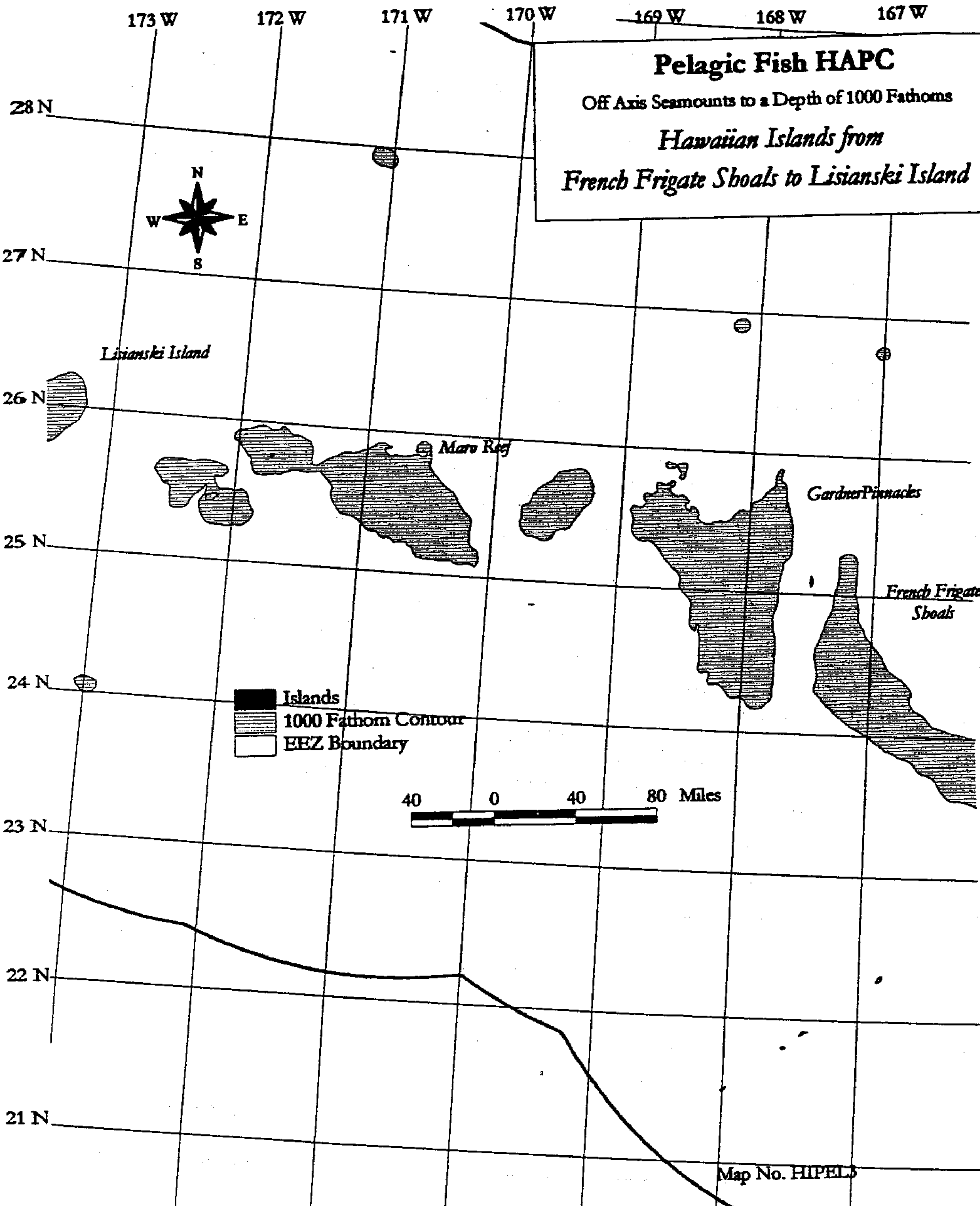
Islands of Hawaii



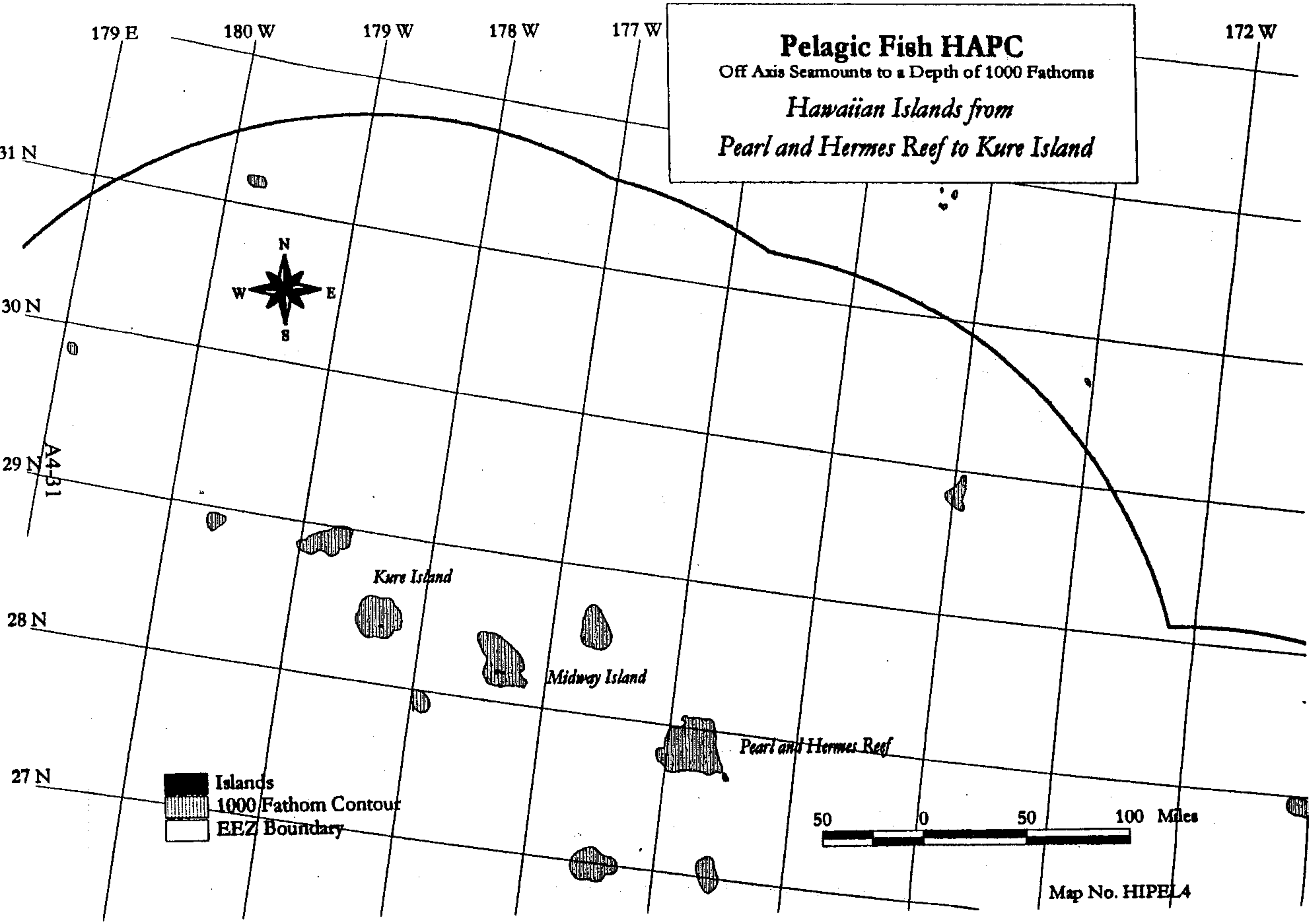
Map No. HIPEL1

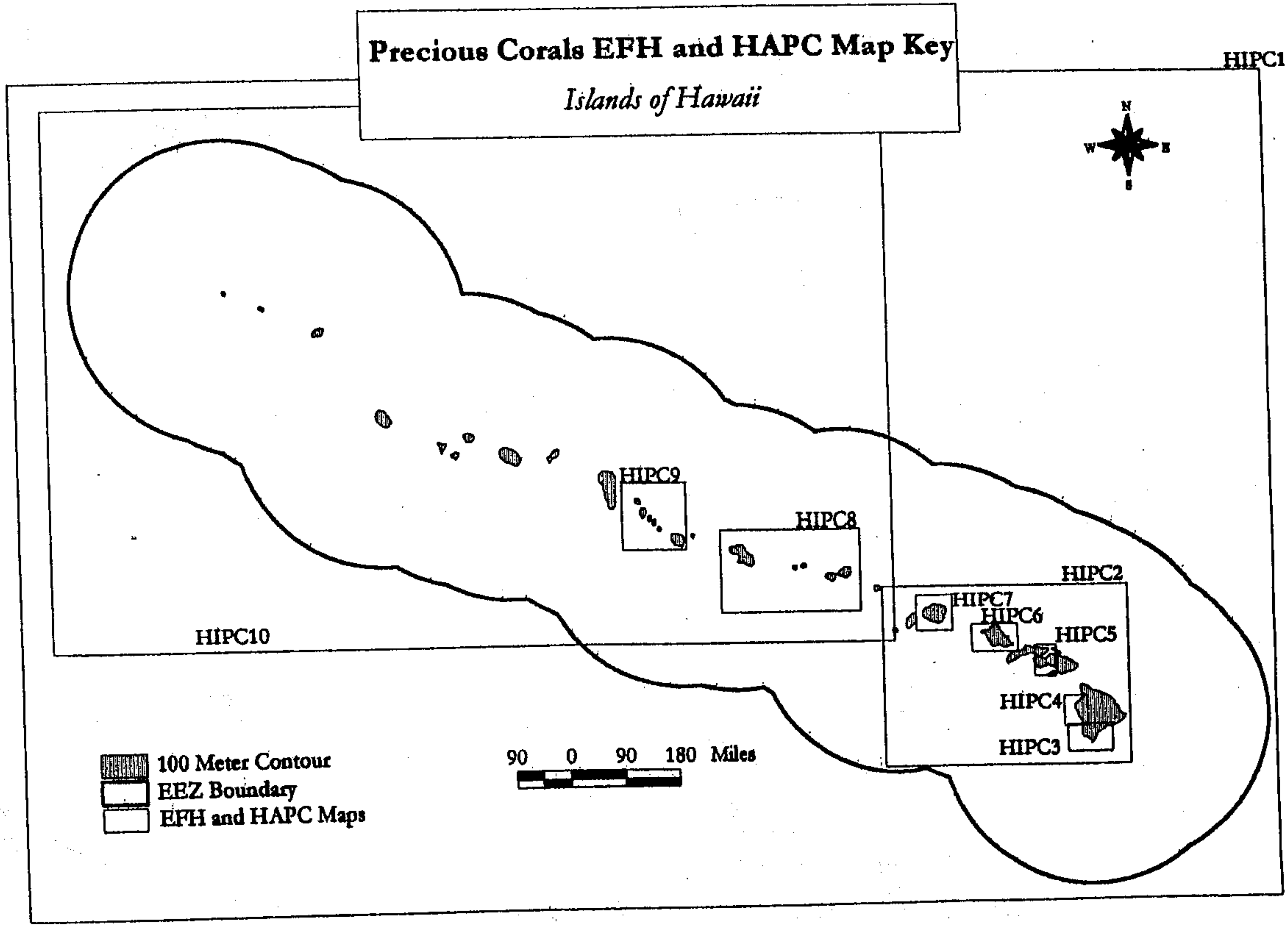


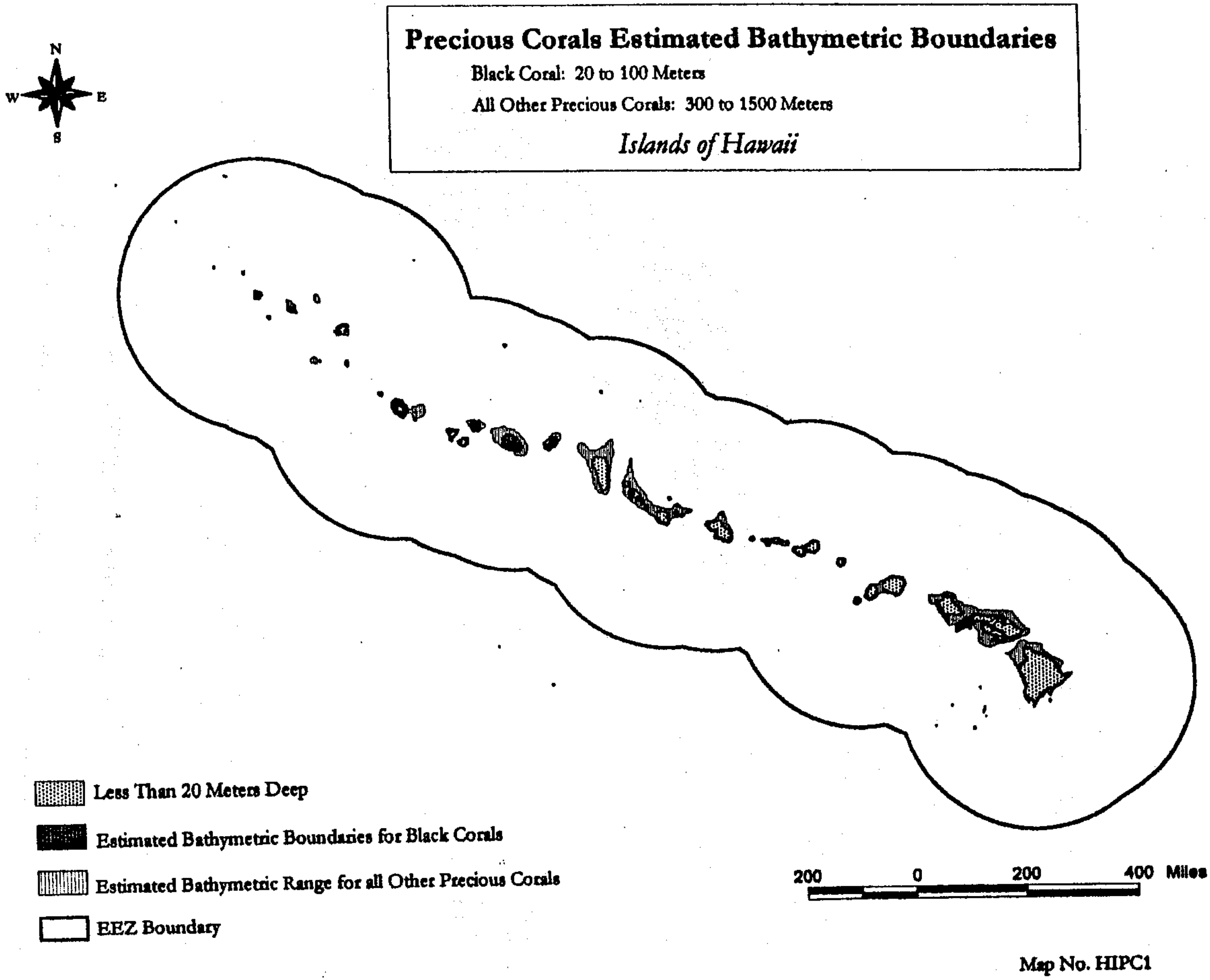
Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 1000 Fathoms
Main Hawaiian Islands
160W
159 W
158 W
157 W
156 W
155 W
154 W
N
W
E
S
24 N
23 N
22 N
21 N
20 N
19 N
18 N
17 N
16 N
Kauai
Oahu
Molokai
Maui
Lanai
Hawaii
Islands
1000 Fathom Contour
EEZ Boundary
Perret Seamount
Jagger Seamount
Ellis Seamount
Washington Seamount
Brigham Seamount
Cross Seamount
McCall Seamount
Swordfish Seamount
Pensacola Seamount
30 0 30 60 Miles
Map No. HIPEL2



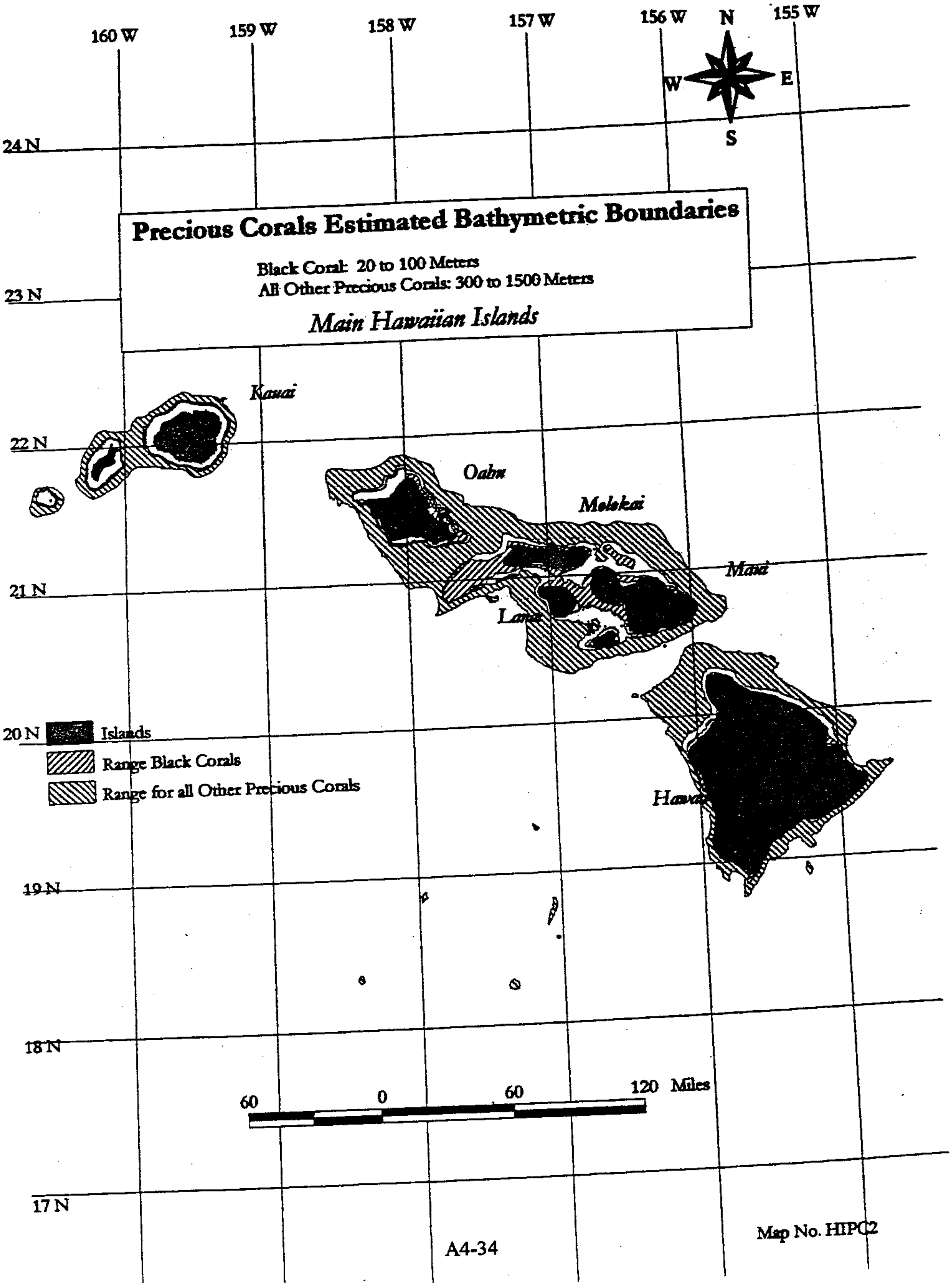
173 W
172 W
171 W
170 W
169 W
168 W
167 W
Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 1000 Fathoms
Hawaiian Islands from
French Frigate Shoals to Lisianski Island
28 N
27 N
26 N
25 N
24 N
23 N
22 N
21 N
N
W
E
S
Lisianski Island
Maro Reef
Gardner Pinnacles
French Frigate
Shoals
Islands
1000 Fathom Contour
EEZ Boundary
40
0
40
80
Miles
Map No. HIPEL3


Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 1000 Fathoms
Hawaiian Islands from
Pearl and Hermes Reef to Kure Island
179 E
180 W
179 W
178 W
177 W
172 W
31 N
30 N
29 N
28 N
27 N
N
S
E
W
Kure Island
Midway Island
Pearl and Hermes Reef
Islands
1000 Fathom Contour
EEZ Boundary
50
0
50
100 Miles
Map No. HIPEL4

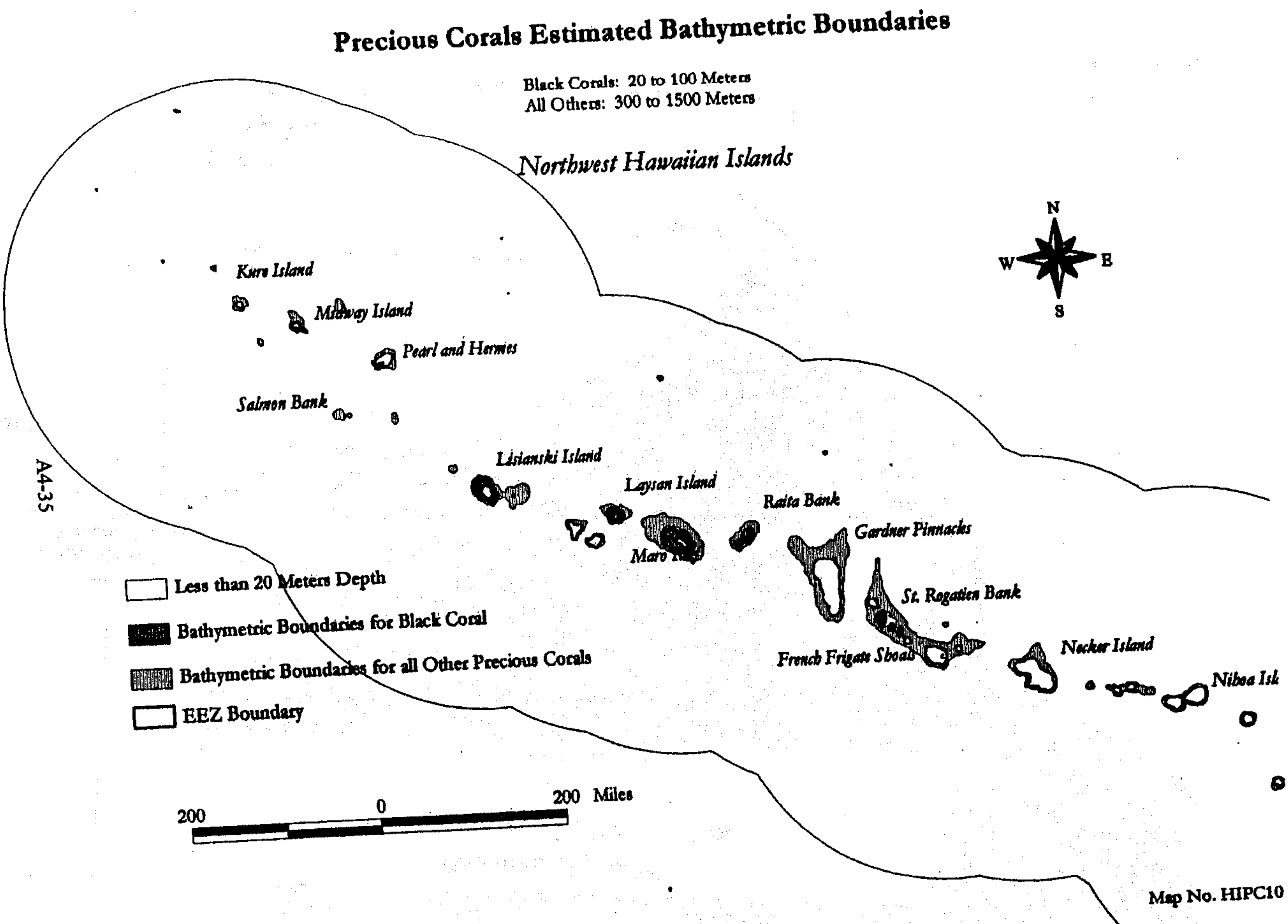

Precious Corals EFH and HAPC Map Key
Islands of Hawaii
HIPC1
N
W
E
S
HIPC9
HIPC8
HIPC2
HIPC7
HIPC6
HIPC5
HIPC4
HIPC3
HIPC10
100 Meter Contour
EEZ Boundary
EFH and HAPC Maps
90 0 90 180 Miles

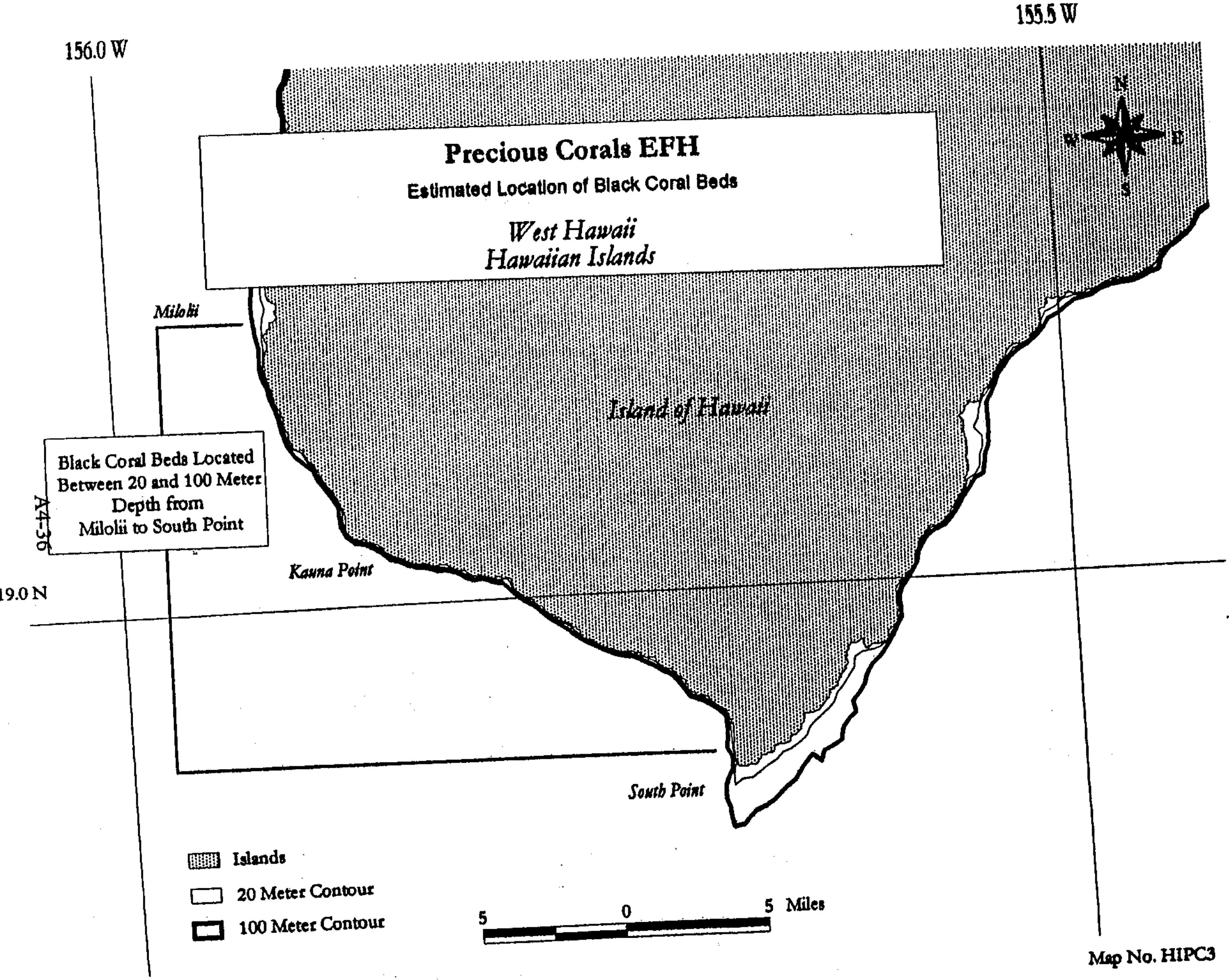


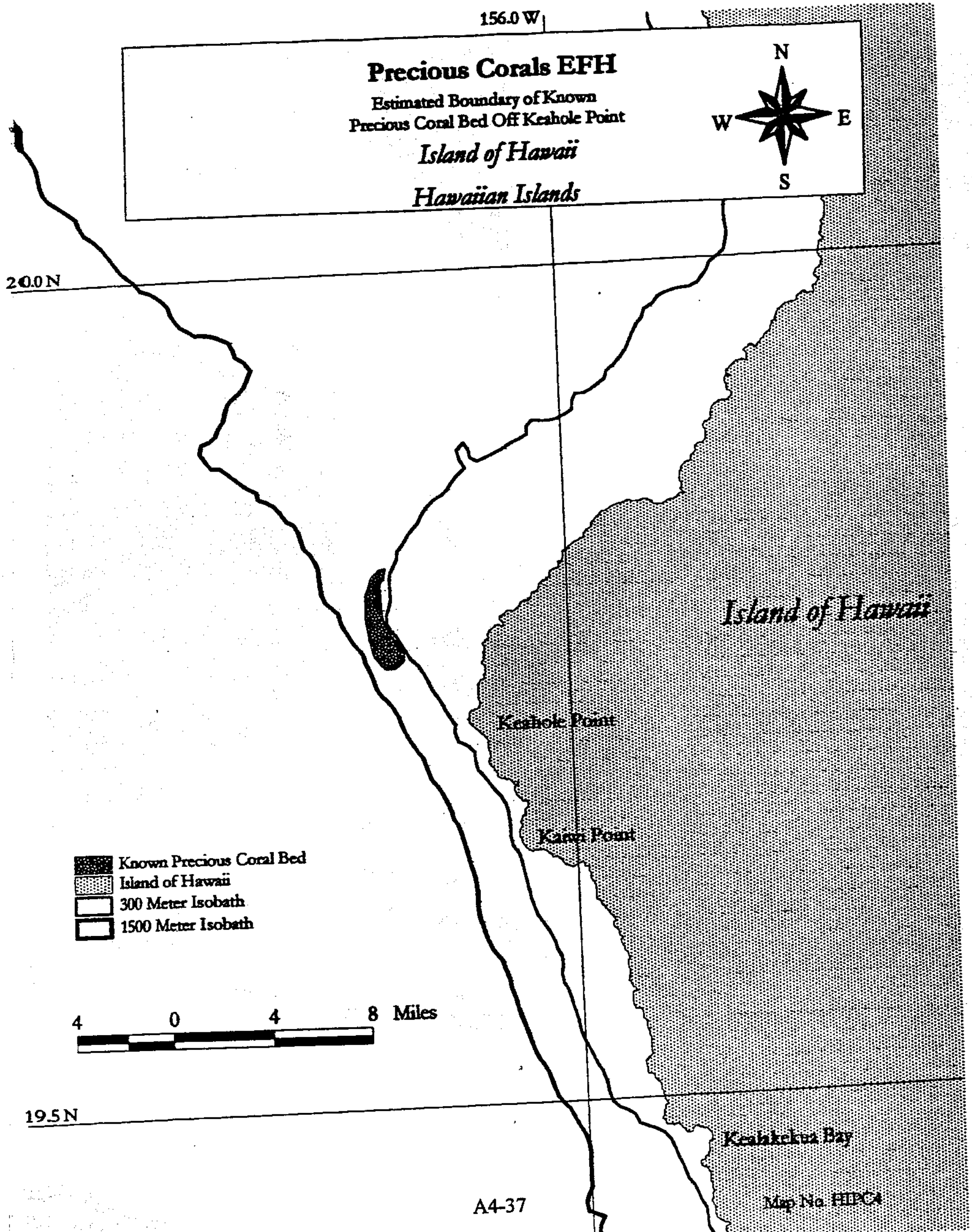
Precious Corals Estimated Bathymetric Boundaries
Black Coral: 20 to 100 Meters
All Other Precious Corals: 300 to 1500 Meters
Islands of Hawaii
N
W
E
S
Less Than 20 Meters Deep
Estimated Bathymetric Boundaries for Black Corals
Estimated Bathymetric Range for all Other Precious Corals
EEZ Boundary
200
0
200
400 Miles
Map No. HIPC1

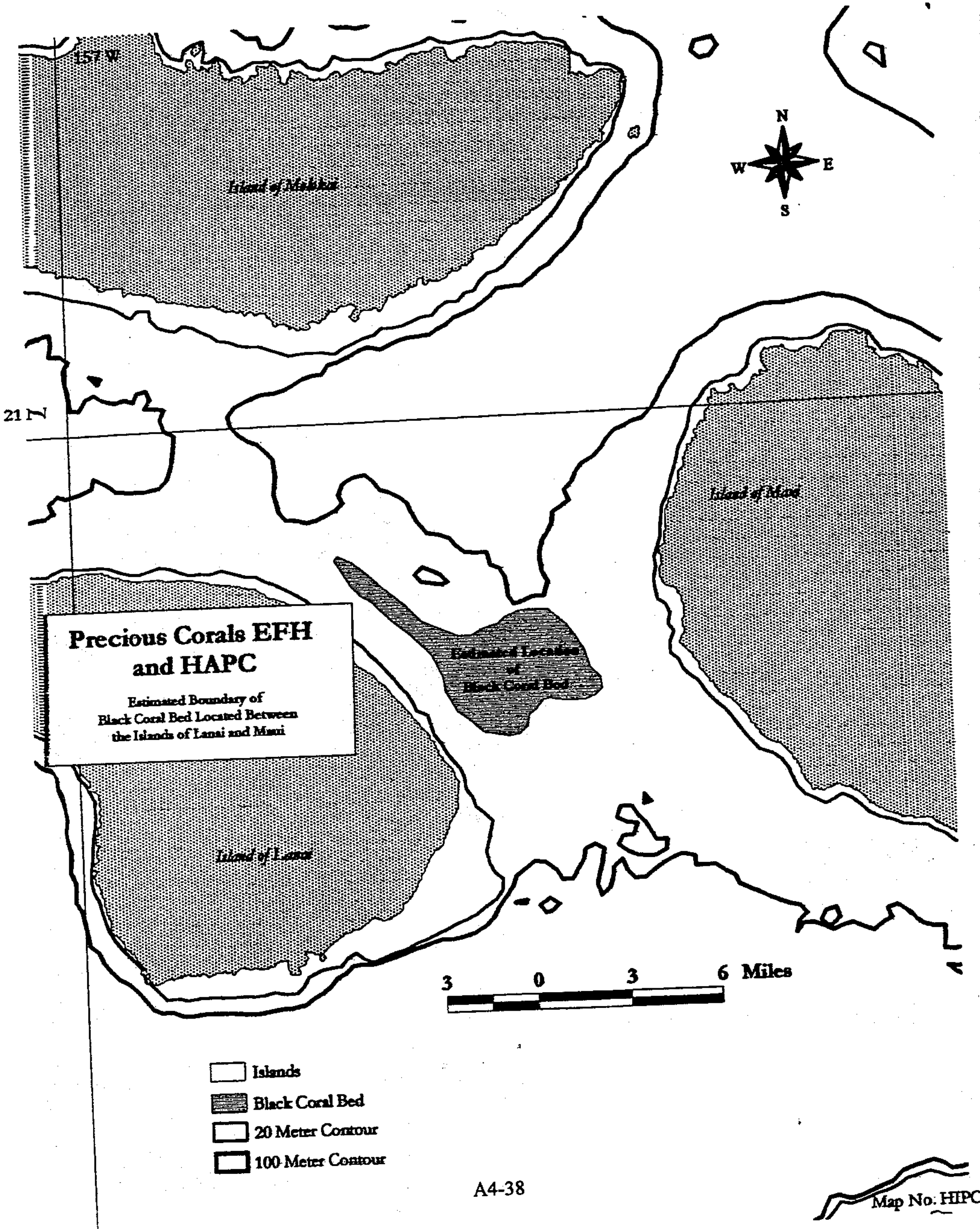

160 W
159 W
158 W
157 W
156 W
155 W
N
W
E
S
24 N
Precious Corals Estimated Bathymetric Boundaries
Black Coral: 20 to 100 Meters
All Other Precious Corals: 300 to 1500 Meters
Main Hawaiian Islands
23 N
Kauai
22 N
Oahu
Molokai
Maui
21 N
Lanai
20 N
Islands
Range Black Corals
Range for all Other Precious Corals
19 N
18 N
60
0
60
120 Miles
17 N

Map No. HIPC2

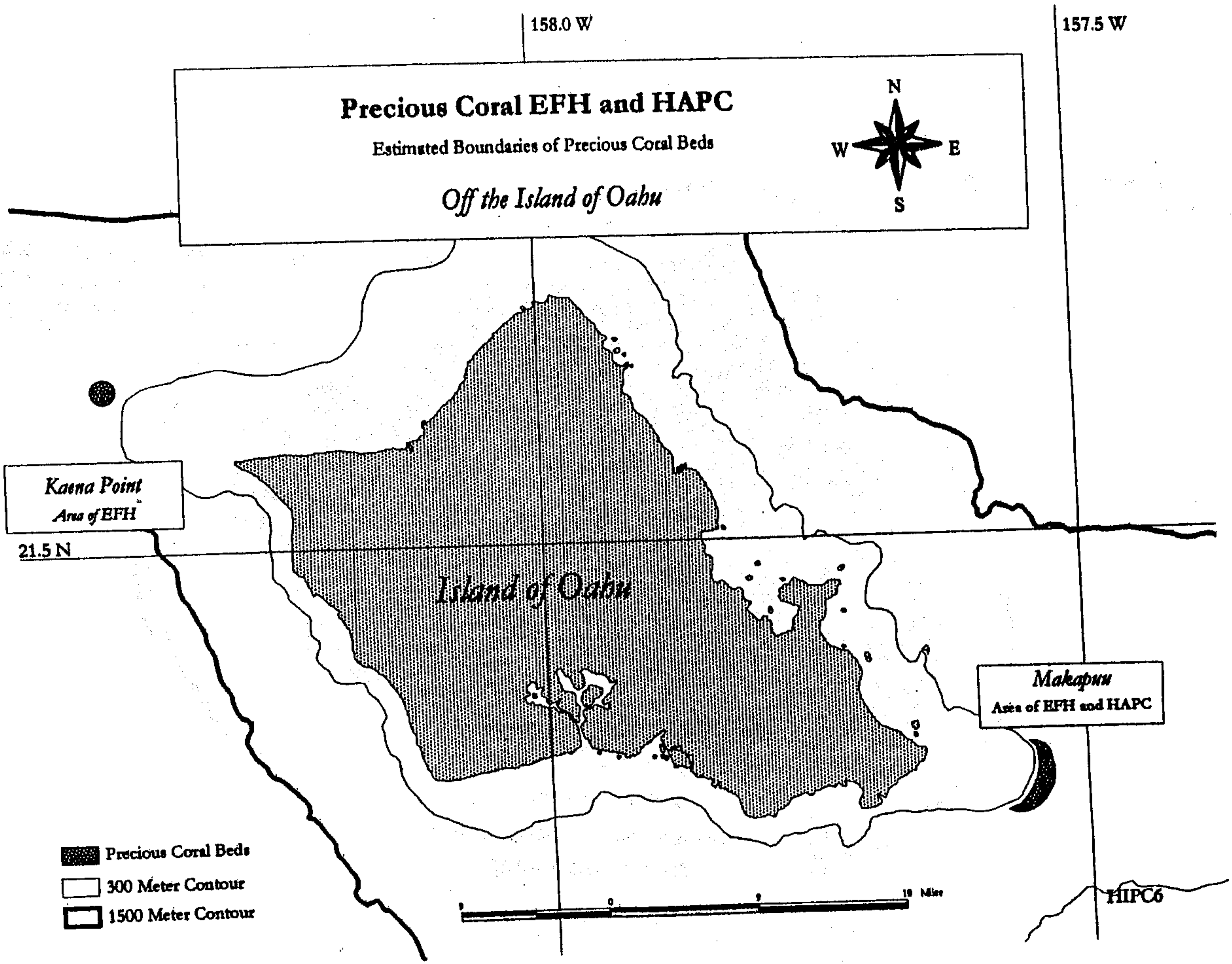

Precious Corals Estimated Bathymetric Boundaries
Black Corals: 20 to 100 Meters
All Others: 300 to 1500 Meters
Northwest Hawaiian Islands
N
W
E
S
Kure Island
Midway Island
Pearl and Hermes
Salmon Bank
Lisianski Island
Laysan Island
Raita Bank
Gardner Pinnacles
St. Rogatien Bank
French Frigate Shoals
Necker Island
Nihoa Isl.
Less than 20 Meters Depth
Bathymetric Boundaries for Black Coral
Bathymetric Boundaries for all Other Precious Corals
EEZ Boundary
200
0
200 Miles
Map No. HIPC10


156.0 W
155.5 W
Precious Corals EFH
Estimated Location of Black Coral Beds
West Hawaii
Hawaiian Islands
N
W
E
S
Milolii
Island of Hawaii
Black Coral Beds Located Between 20 and 100 Meter Depth from Milolii to South Point
Kauna Point
19.0 N
South Point
Islands
20 Meter Contour
100 Meter Contour
5
0
5 Miles
Map No. HIPC3

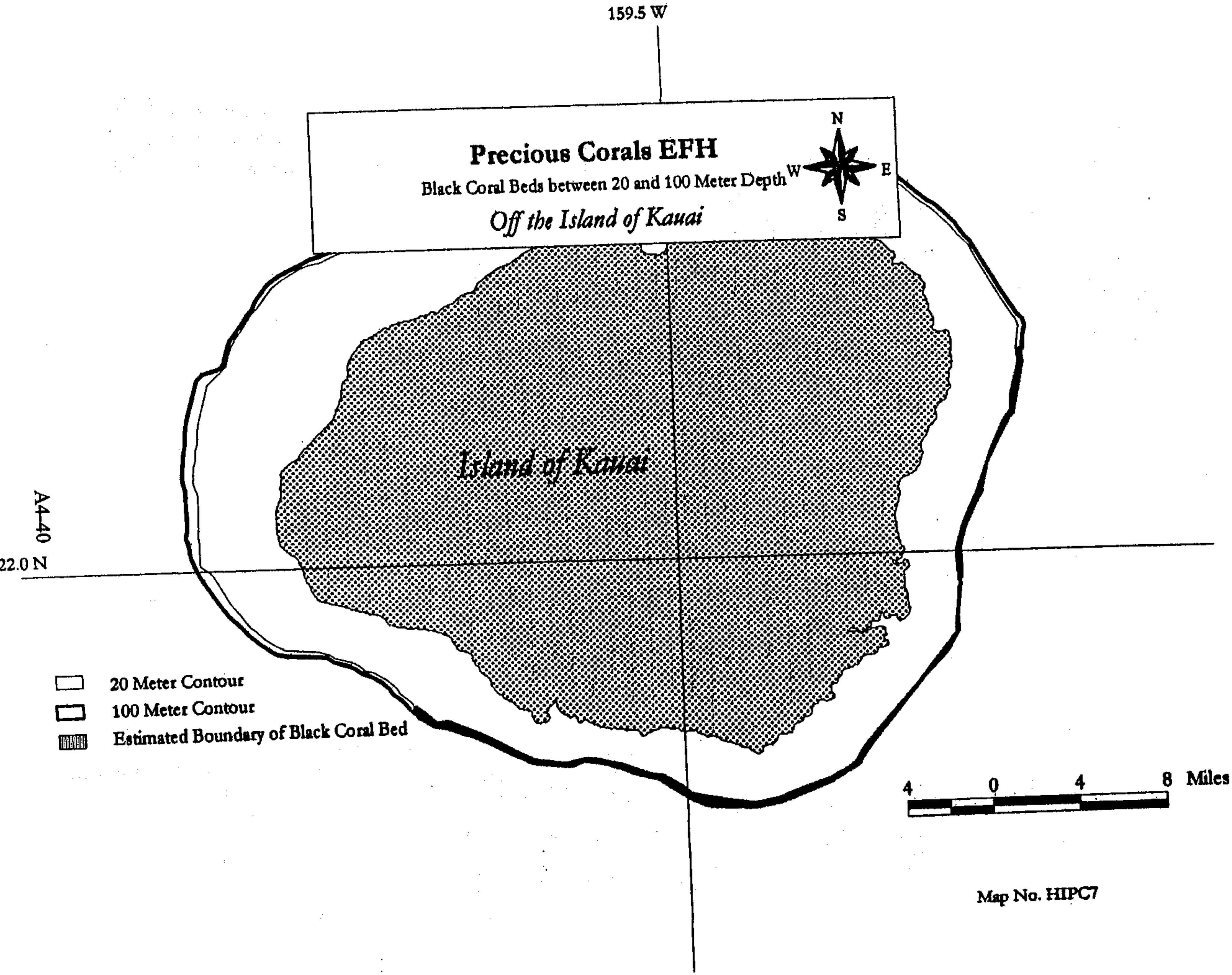

156.0 W
Precious Corals EFH
Estimated Boundary of Known
Precious Coral Bed Off Keahole Point
Island of Hawaii
Hawaiian Islands
N
W
E
S
20.0 N
Island of Hawaii
Keahole Point
Kaiwi Point
Known Precious Coral Bed
Island of Hawaii
300 Meter Isobath
1500 Meter Isobath
4
0
4
8
Miles
19.5 N
Kealakekua Bay
Map No. HIPC4

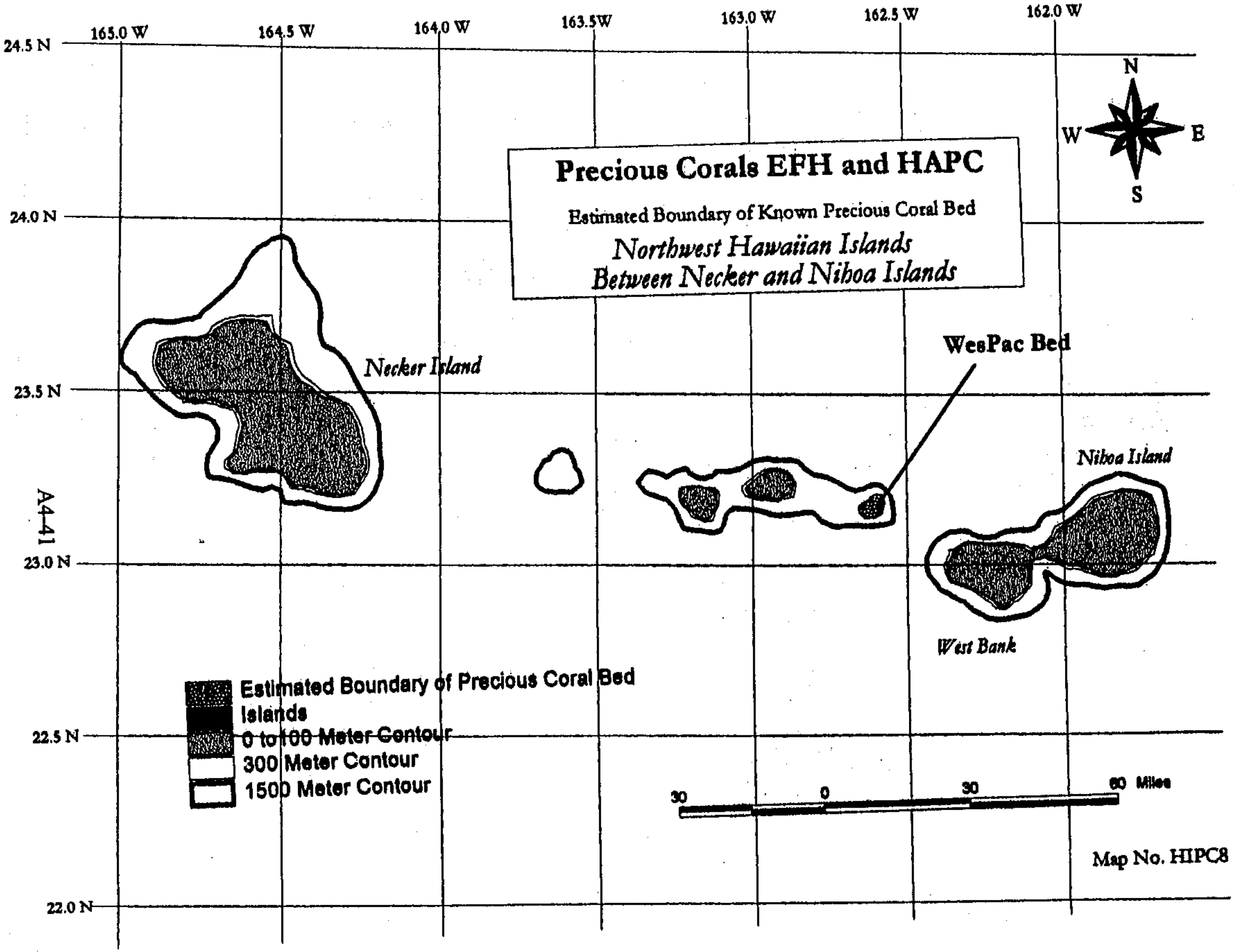


Precious Corals EFH and HAPC
Estimated Boundary of Black Coral Bed Located Between the Islands of Lanai and Maui
157 W
21 N
N
W
E
S
3 0 3 6 Miles
Islands
Black Coral Bed
20 Meter Contour
100 Meter Contour
Map No: HIPC

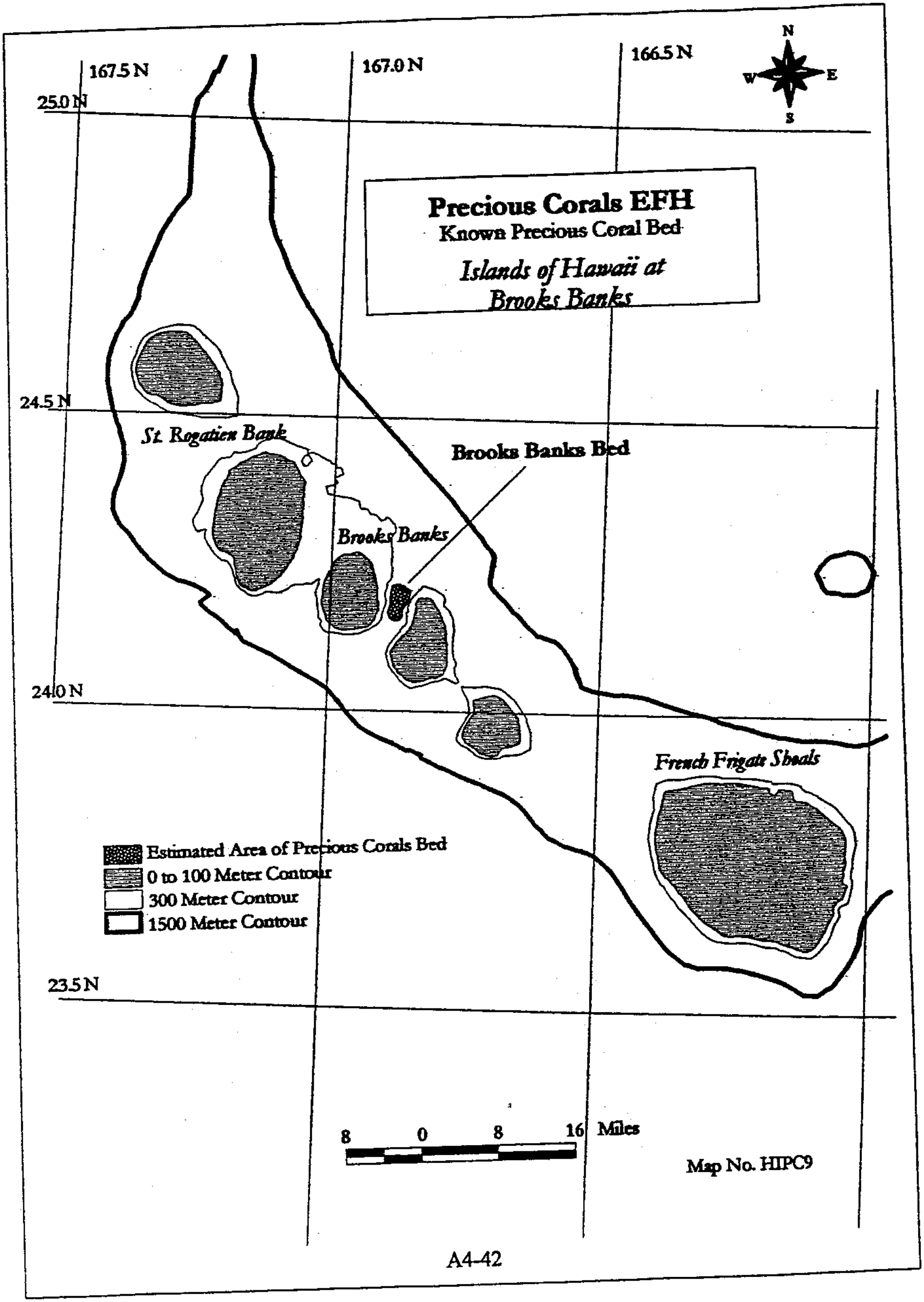


Precious Coral EFH and HAPC
Estimated Boundaries of Precious Coral Beds
Off the Island of Oahu
N
W
E
S
158.0 W
157.5 W
21.5 N
Kaena Point
Area of EFH
Island of Oahu
Makapuu
Area of EFH and HAPC
HIPC6
Precious Coral Beds
300 Meter Contour
1500 Meter Contour
0
10 Miles

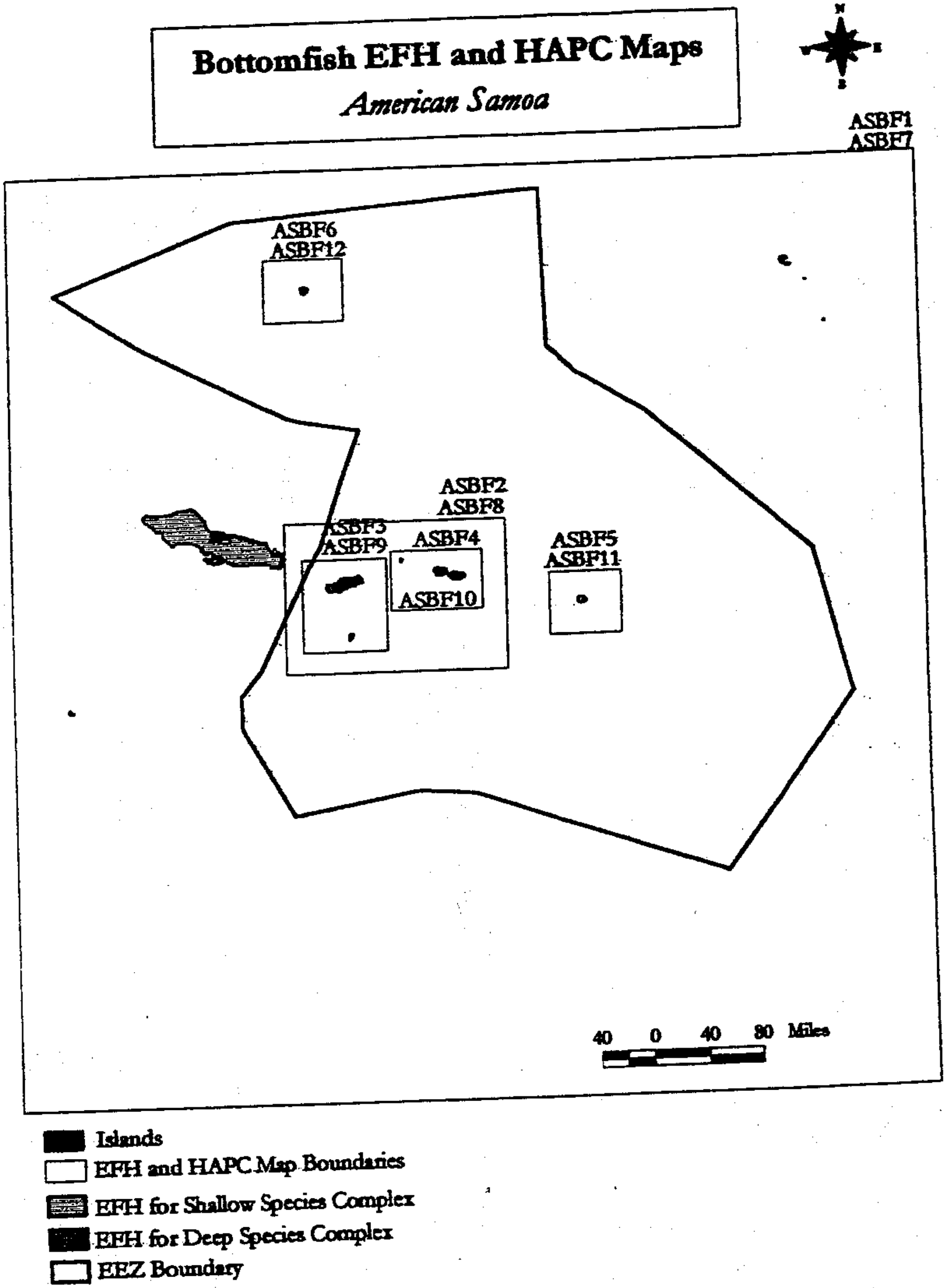

159.5 W
Precious Corals EFH
Black Coral Beds between 20 and 100 Meter Depth
Off the Island of Kauai
N
W
E
S
Island of Kauai
22.0 N
20 Meter Contour
100 Meter Contour
Estimated Boundary of Black Coral Bed
4 0 4 8 Miles
Map No. HIPC7

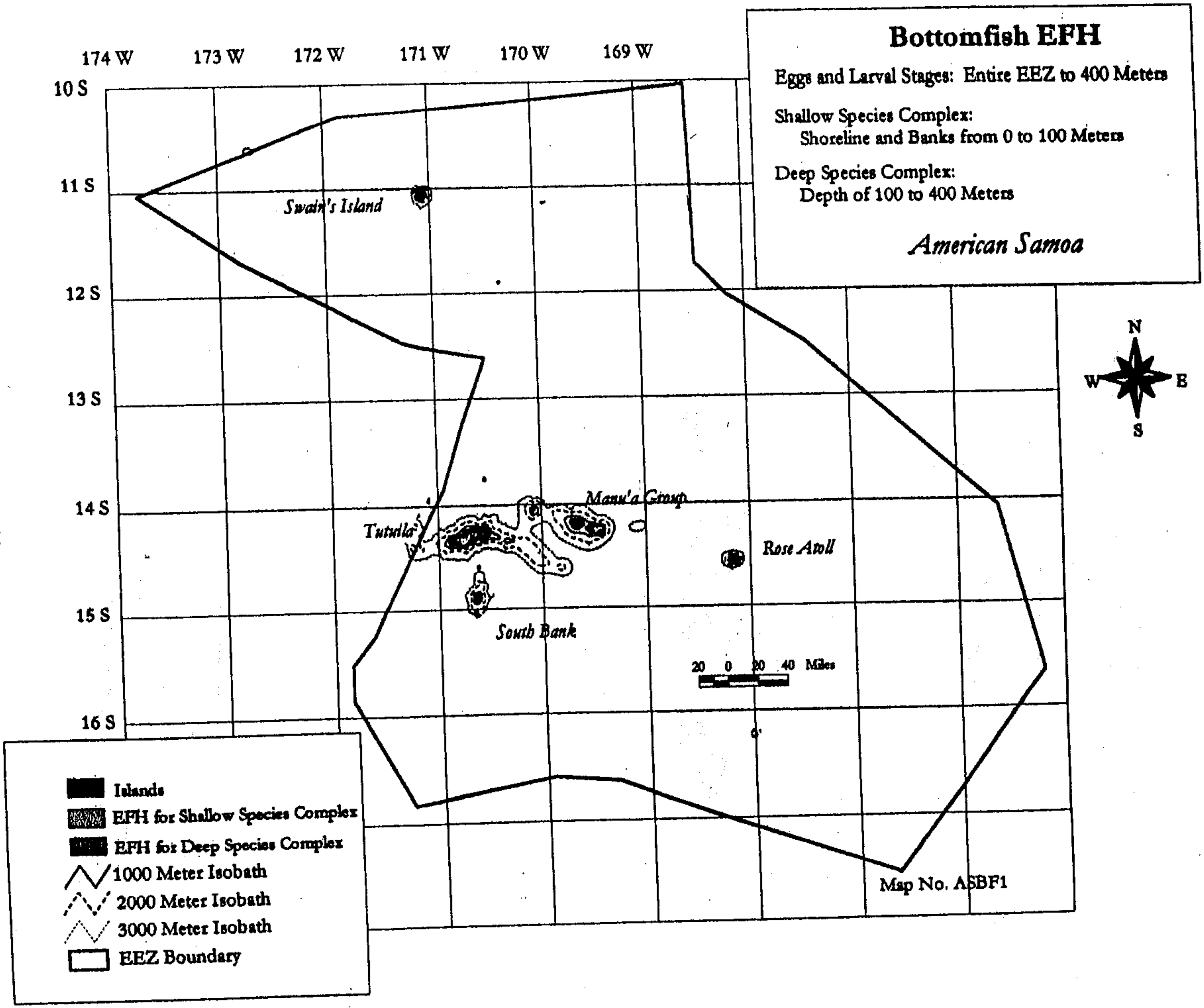


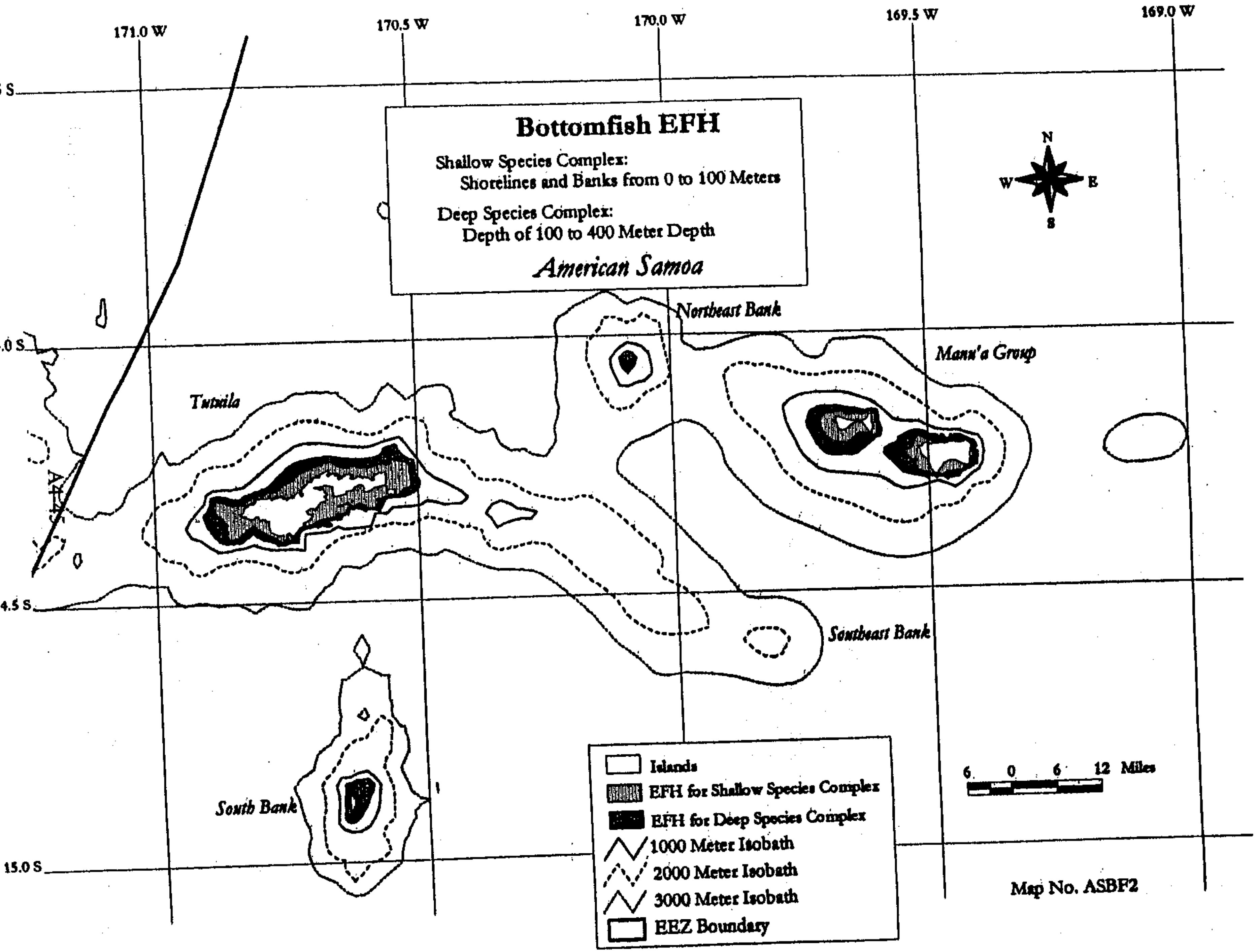
Precious Corals EFH and HAPC
Estimated Boundary of Known Precious Coral Bed
Northwest Hawaiian Islands
Between Necker and Niboa Islands
165.0 W
164.5 W
164.0 W
163.5W
163.0 W
162.5 W
162.0 W
24.5 N
24.0 N
23.5 N
23.0 N
22.5 N
22.0 N
N
W
E
S
Necker Island
WesPac Bed
Niboa Island
West Bank
Estimated Boundary of Precious Coral Bed
Islands
0 to 100 Meter Contour
300 Meter Contour
1500 Meter Contour
30
0
30
60 Miles
Map No. HIPC8



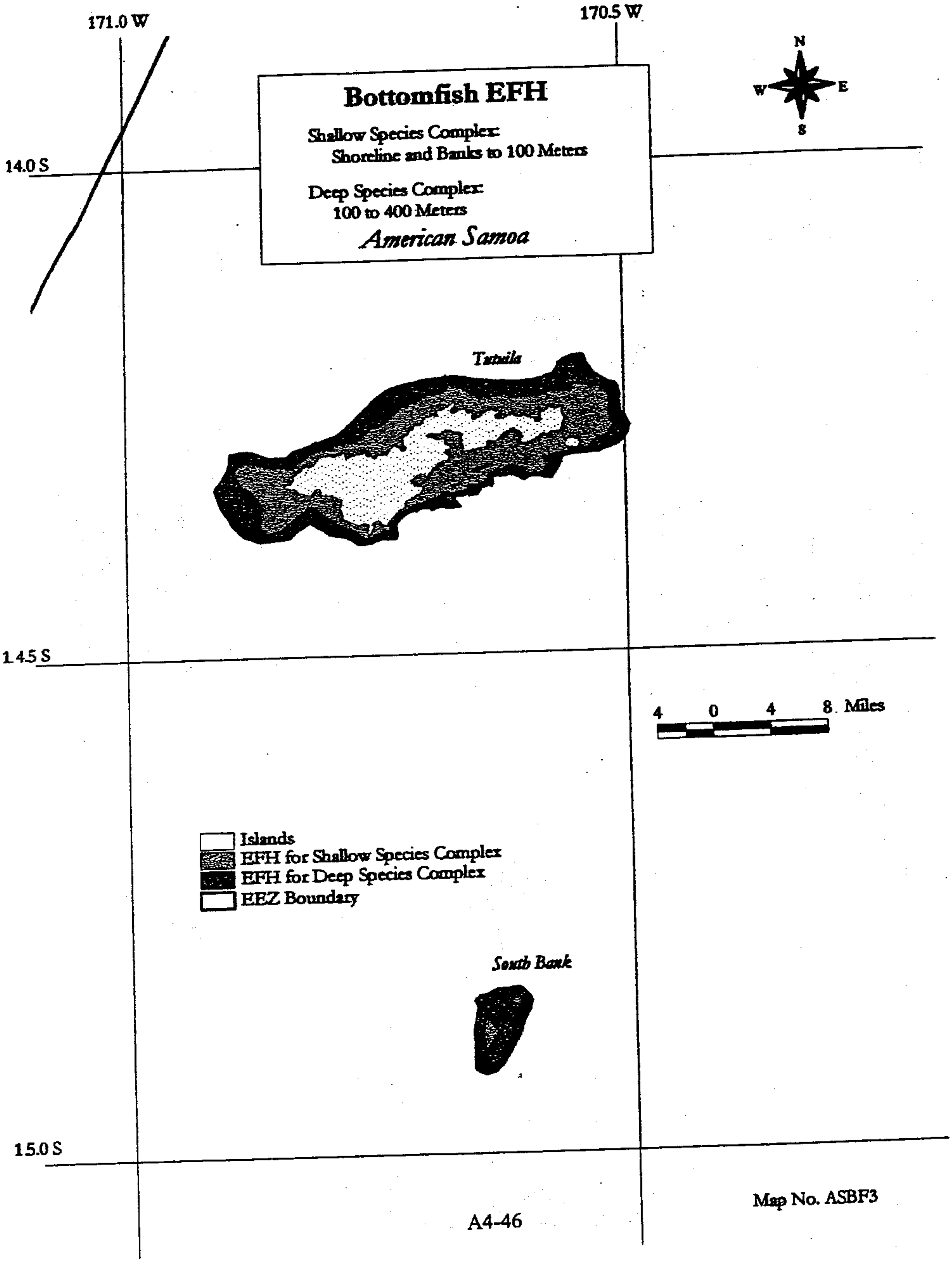
167.5 N
167.0 N
166.5 N
N
W
E
S
25.0 N
Precious Corals EFH
Known Precious Coral Bed
Islands of Hawaii at
Brooks Banks
24.5 N
St. Rogatien Bank
Brooks Banks Bed
Brooks Banks
24.0 N
French Frigate Shoals
Estimated Area of Precious Corals Bed
0 to 100 Meter Contour
300 Meter Contour
1500 Meter Contour
23.5 N
8
0
8
16
Miles
Map No. HIPC9


Bottomfish EFH and HAPC Maps
American Samoa
ASBF1
ASBF7
ASBF6
ASBF12
ASBF2
ASBF8
ASBF3
ASBF9
ASBF4
ASBF10
ASBF5
ASBF11
40 0 40 80 Miles
Islands
EFH and HAPC Map Boundaries
EFH for Shallow Species Complex
EFH for Deep Species Complex
EEZ Boundary


Bottomfish EFH
Eggs and Larval Stages: Entire EEZ to 400 Meters
Shallow Species Complex:
Shoreline and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
American Samoa
174 W
173 W
172 W
171 W
170 W
169 W
10 S
11 S
12 S
13 S
14 S
15 S
16 S
Swain's Island
Tutuila
Manu'a Group
Rose Atoll
South Bank
20 0 20 40 Miles
N
S
E
W
Islands
EFH for Shallow Species Complex
EFH for Deep Species Complex
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
EEZ Boundary
Map No. ASBF1

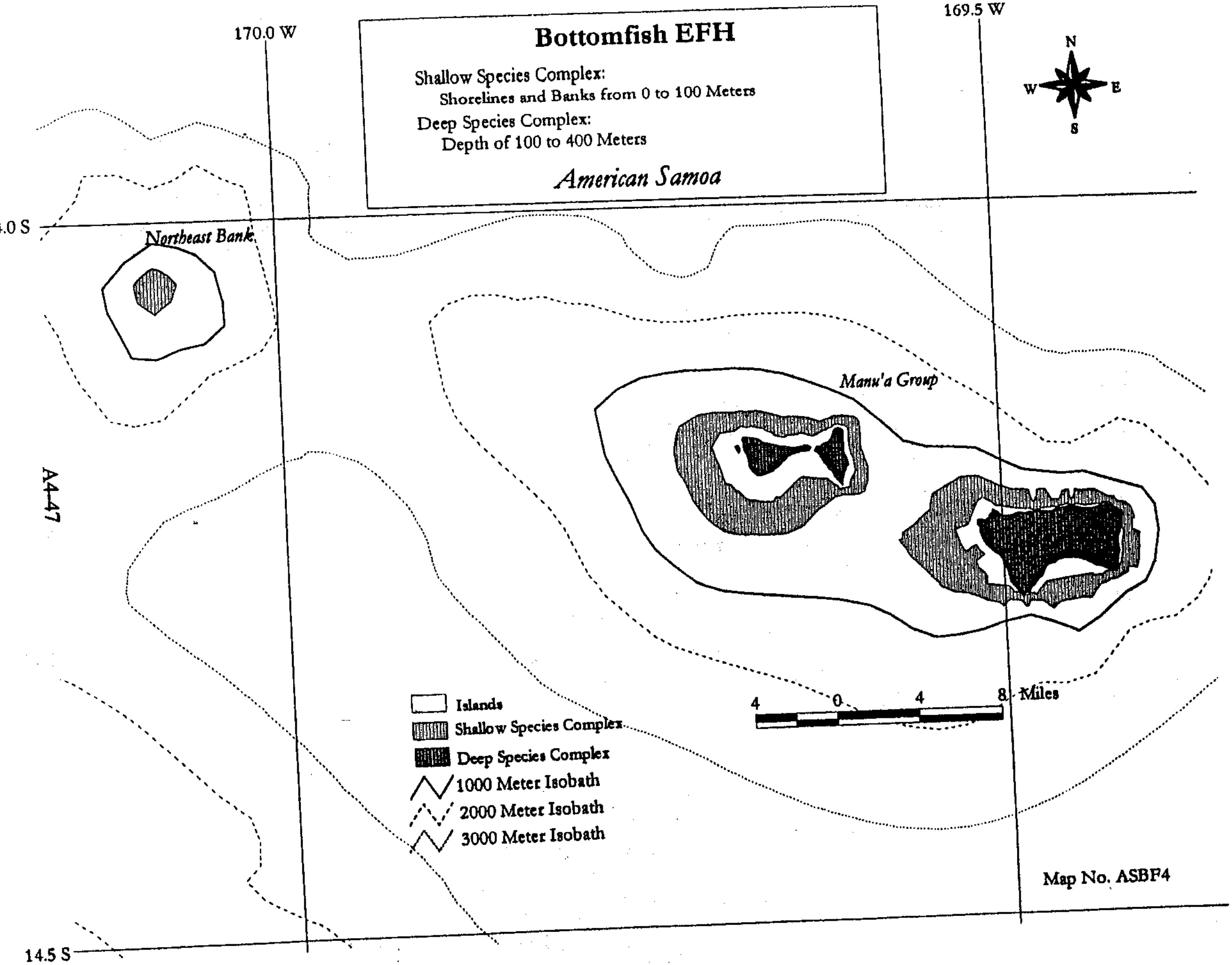


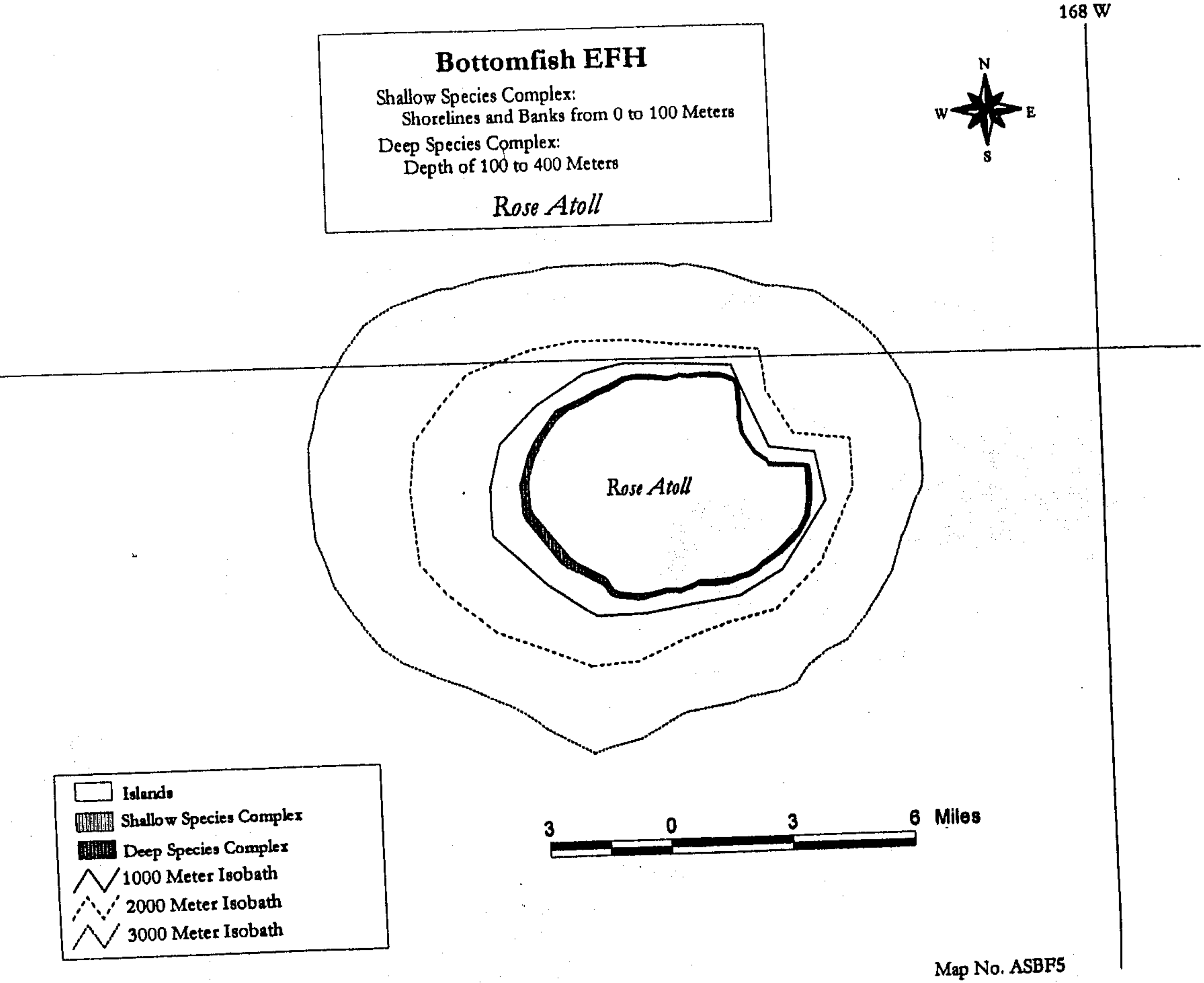
171.0 W
170.5 W
170.0 W
169.5 W
169.0 W
Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meter Depth
American Samoa
N
W
E
S
Northeast Bank
Manu'a Group
Tutuila
Southeast Bank
South Bank
4.5 S
15.0 S
Islands
EFH for Shallow Species Complex
EFH for Deep Species Complex
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
EEZ Boundary
6 0 6 12 Miles
Map No. ASBF2

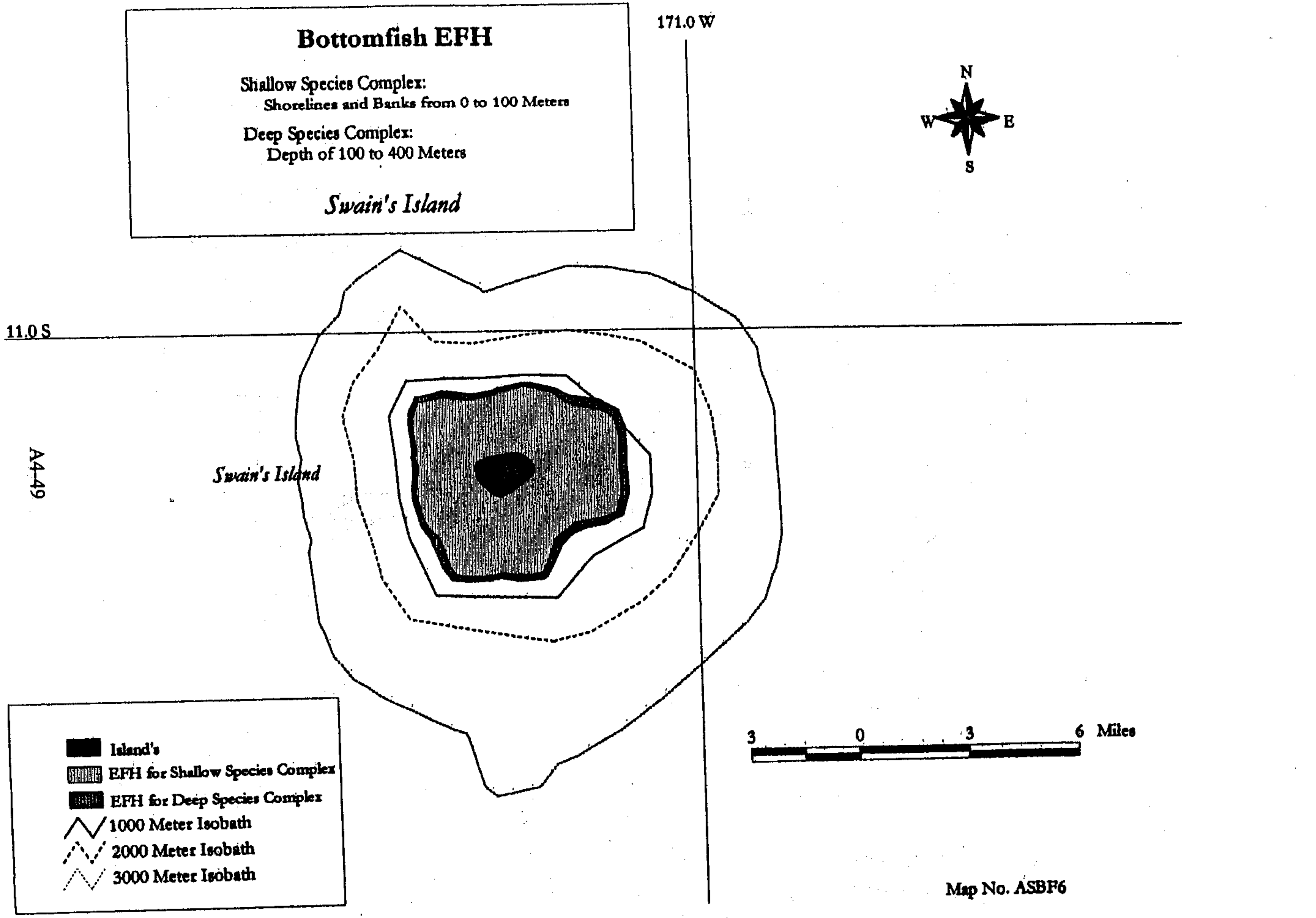


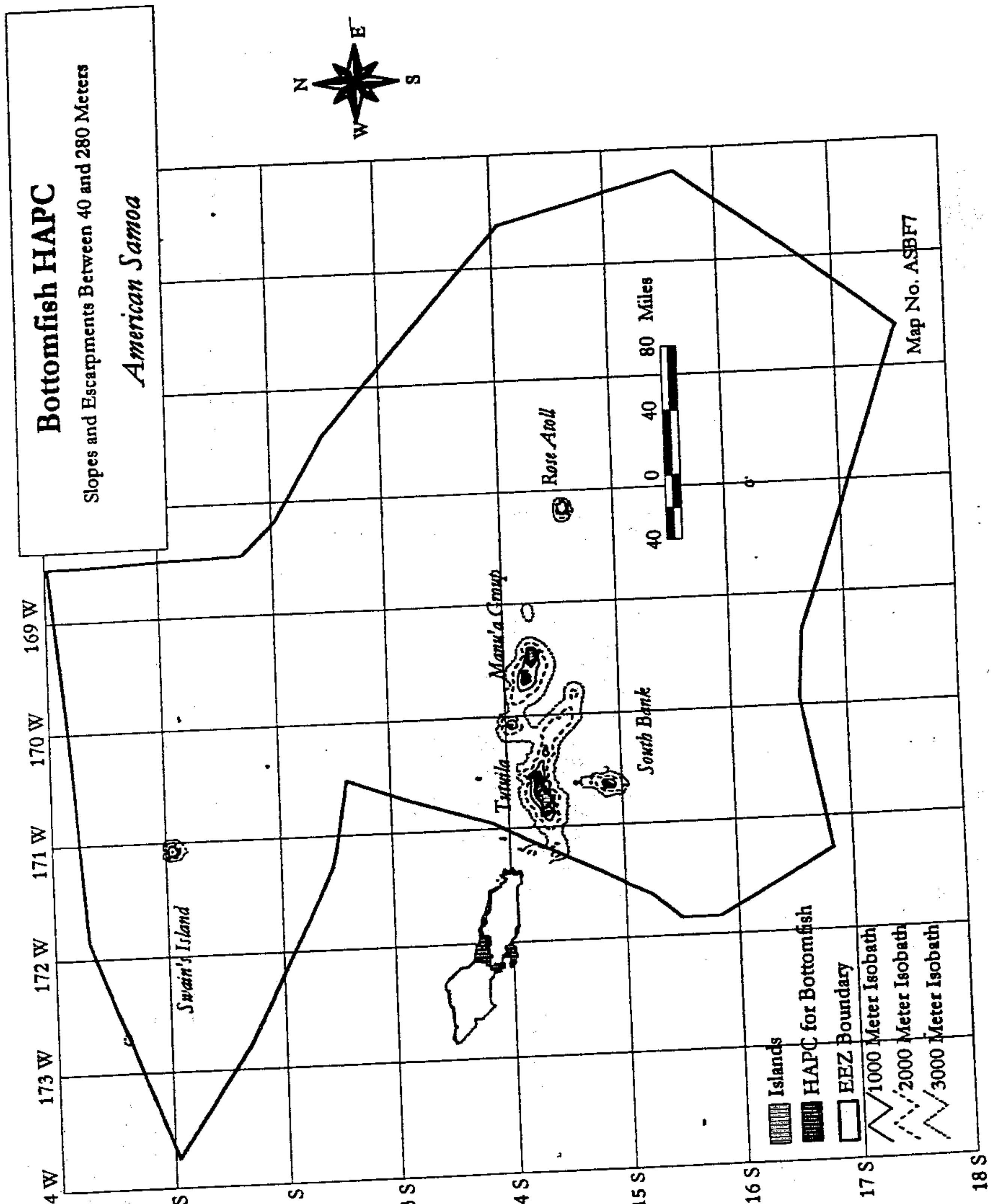
171.0 W
170.5 W
Bottomfish EFH
Shallow Species Complex:
Shoreline and Banks to 100 Meters
Deep Species Complex:
100 to 400 Meters
American Samoa
N
W
E
S
14.0 S
Tutuila
14.5 S
4 0 4 8 Miles
Islands
EFH for Shallow Species Complex
EFH for Deep Species Complex
EEZ Boundary
South Bank
15.0 S

Map No. ASBF3

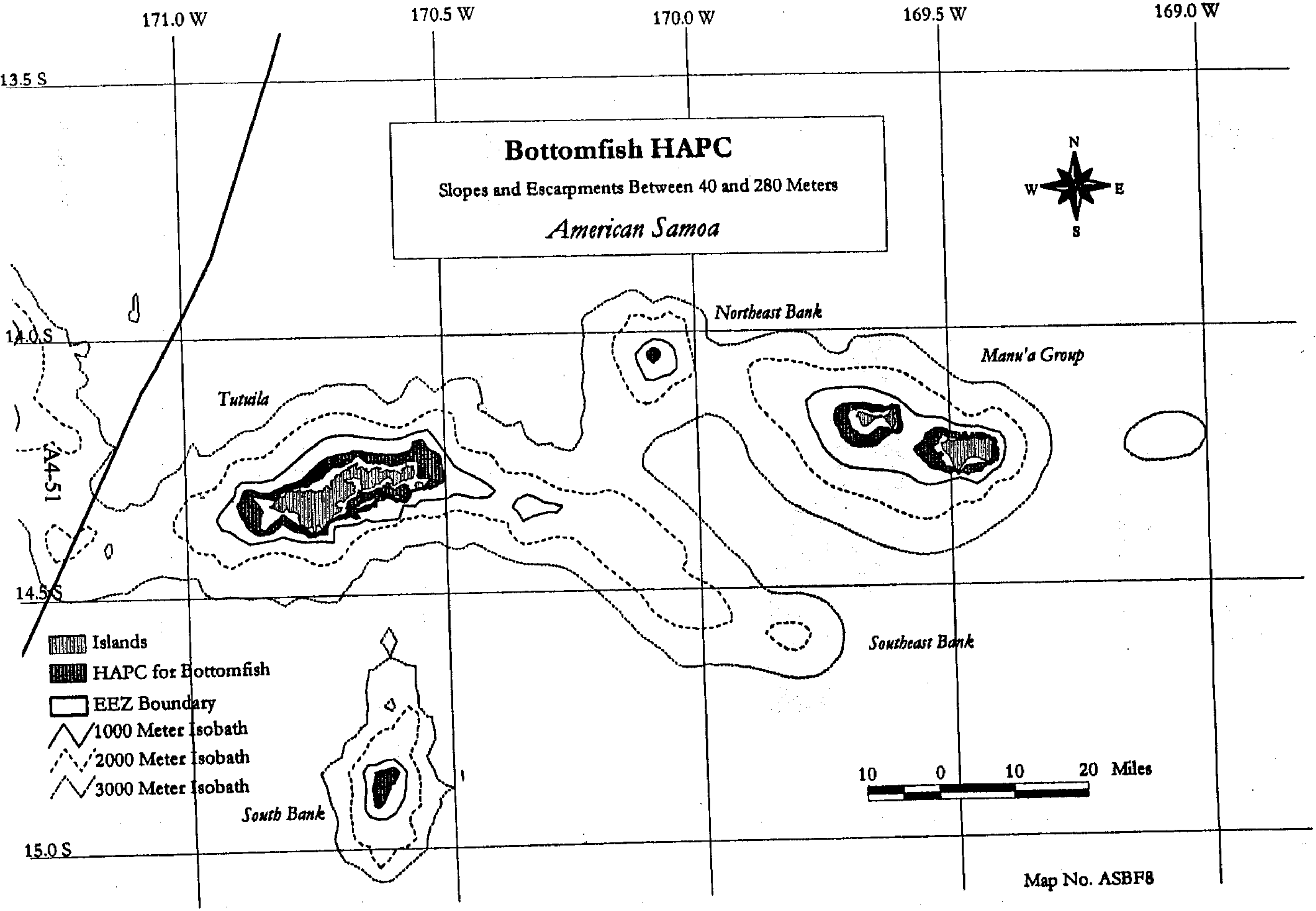

Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
American Samoa
170.0 W
169.5 W
14.5 S
N
W
E
S
Northeast Bank
Manu'a Group
4 0 4 8 Miles
Islands
Shallow Species Complex
Deep Species Complex
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
Map No. ASBF4


Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Rose Atoll
168 W
N
W
E
S
14.5 S
Rose Atoll
Islands
Shallow Species Complex
Deep Species Complex
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
3
0
3
6
Miles
Map No. ASBF5

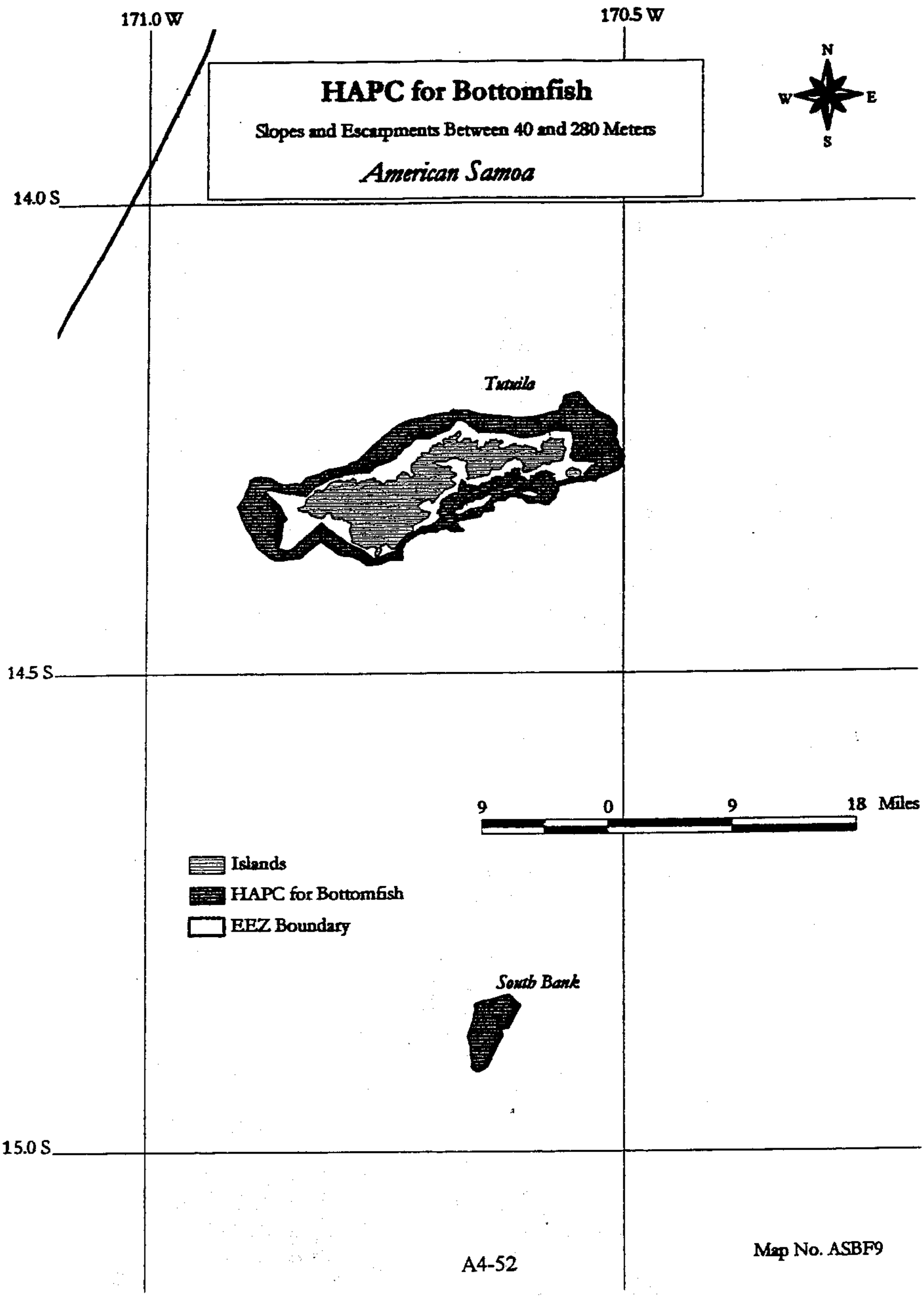

Bottomfish EFH
Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Deep Species Complex:
Depth of 100 to 400 Meters
Swain's Island
171.0 W
N
W
E
S
11.0 S
Swain's Island
Island's
EFH for Shallow Species Complex
EFH for Deep Species Complex
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
3
0
3
6 Miles
Map No. ASBF6



Bottomfish HAPC
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
N
E
S
W
Swain's Island
Tutuila
Manu'a Group
Rose Atoll
South Bank
40 0 40 80 Miles
Map No. ASBF7
Islands
HAPC for Bottomfish
EEZ Boundary
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
174 W
173 W
172 W
171 W
170 W
169 W
10 S
11 S
12 S
13 S
14 S
15 S
16 S
17 S
18 S

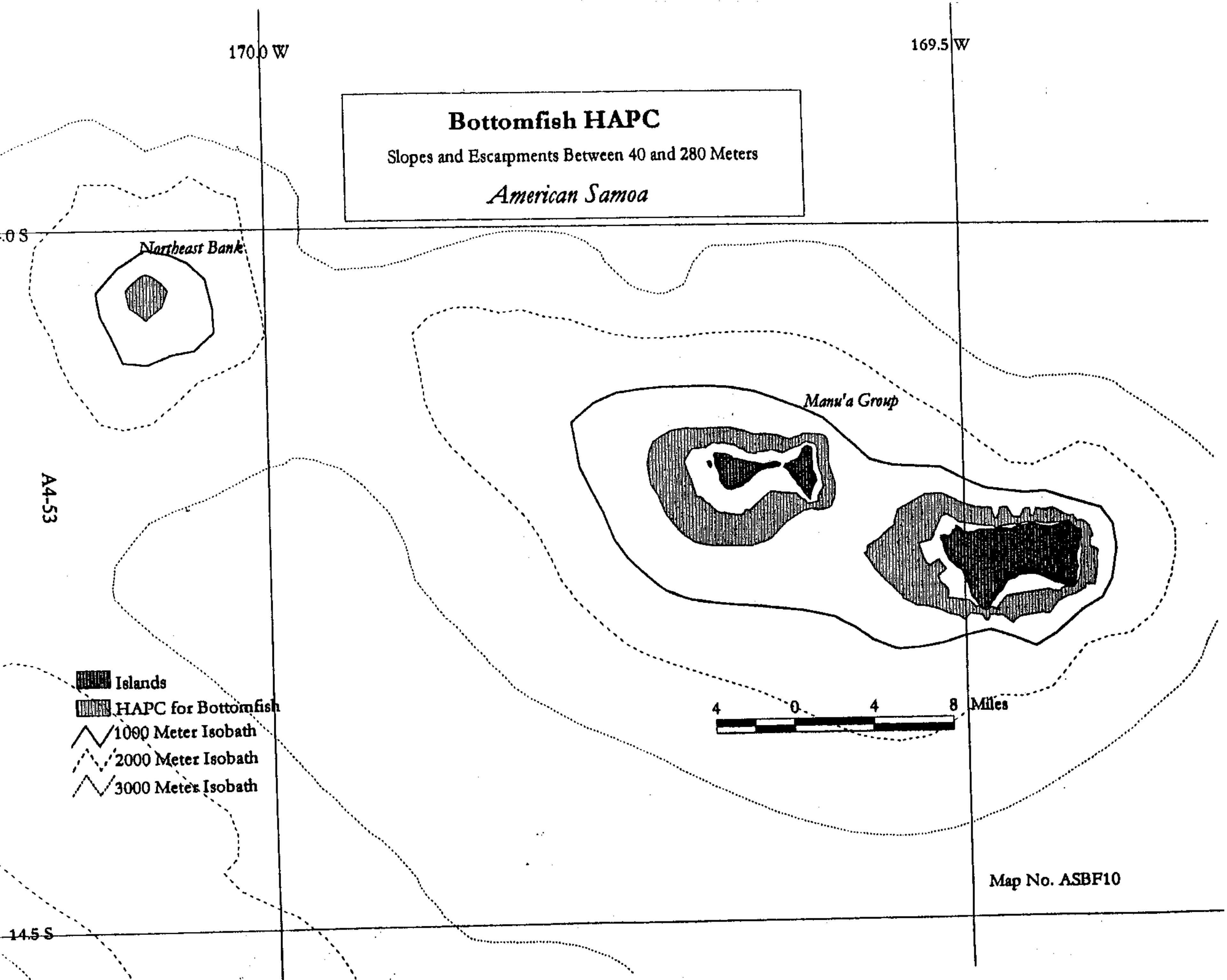


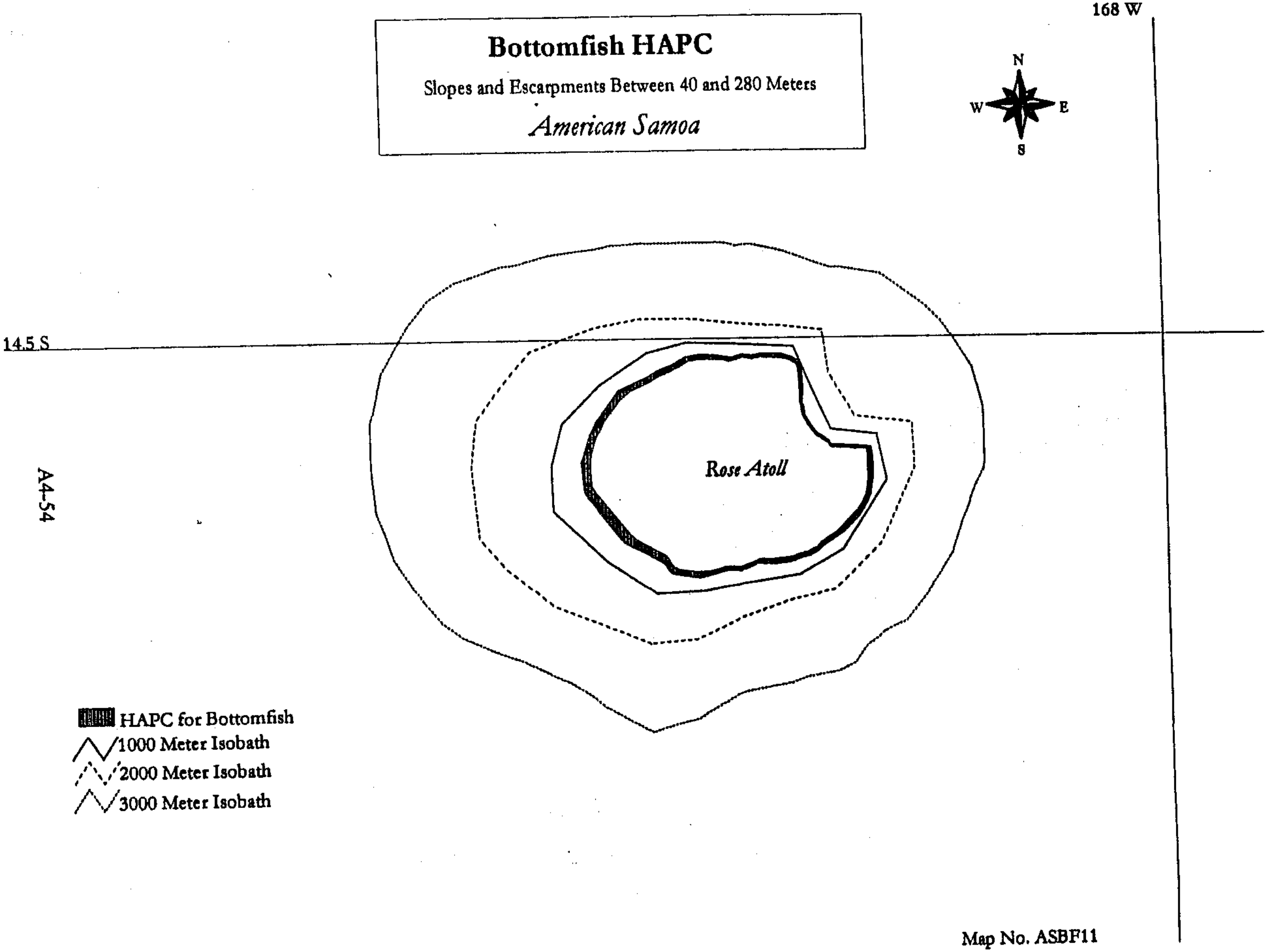
Bottomfish HAPC
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
171.0 W
170.5 W
170.0 W
169.5 W
169.0 W
13.5 S
14.0 S
14.5 S
15.0 S
N
W
E
S
Northeast Bank
Manu'a Group
Tutuila
Southeast Bank
South Bank
Islands
HAPC for Bottomfish
EEZ Boundary
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
10
0
10
20
Miles
Map No. ASBF8



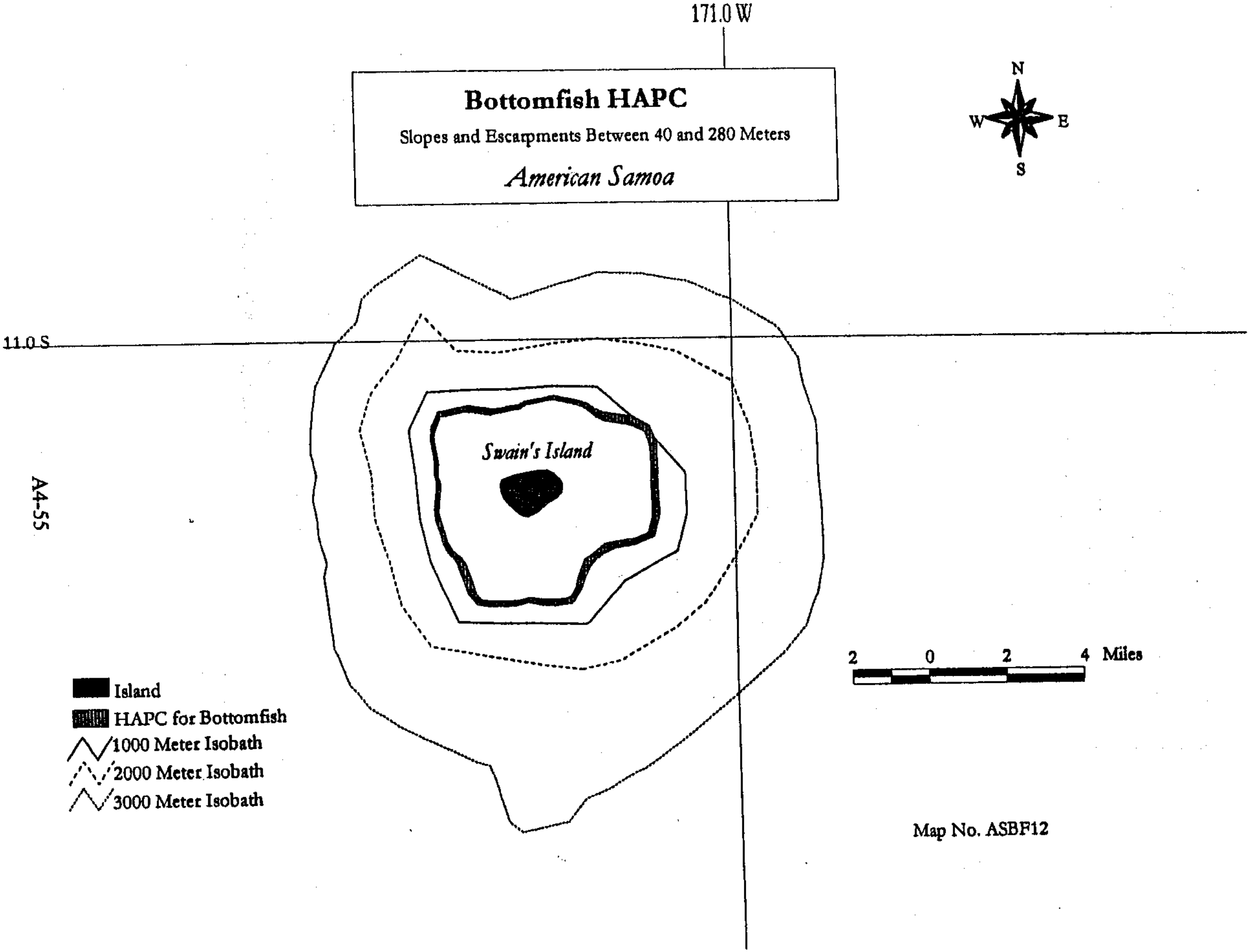
171.0 W
170.5 W
HAPC for Bottomfish
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
N
W
E
S
14.0 S
Tutuila
14.5 S
9
0
9
18 Miles
Islands
HAPC for Bottomfish
EEZ Boundary
South Bank
15.0 S

Map No. ASBF9


170.0 W
169.5 W
Bottomfish HAPC
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
.0 S
Northeast Bank
Manu'a Group
4 0 4 8 Miles
Islands
HAPC for Bottomfish
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
Map No. ASBF10
14.5 S

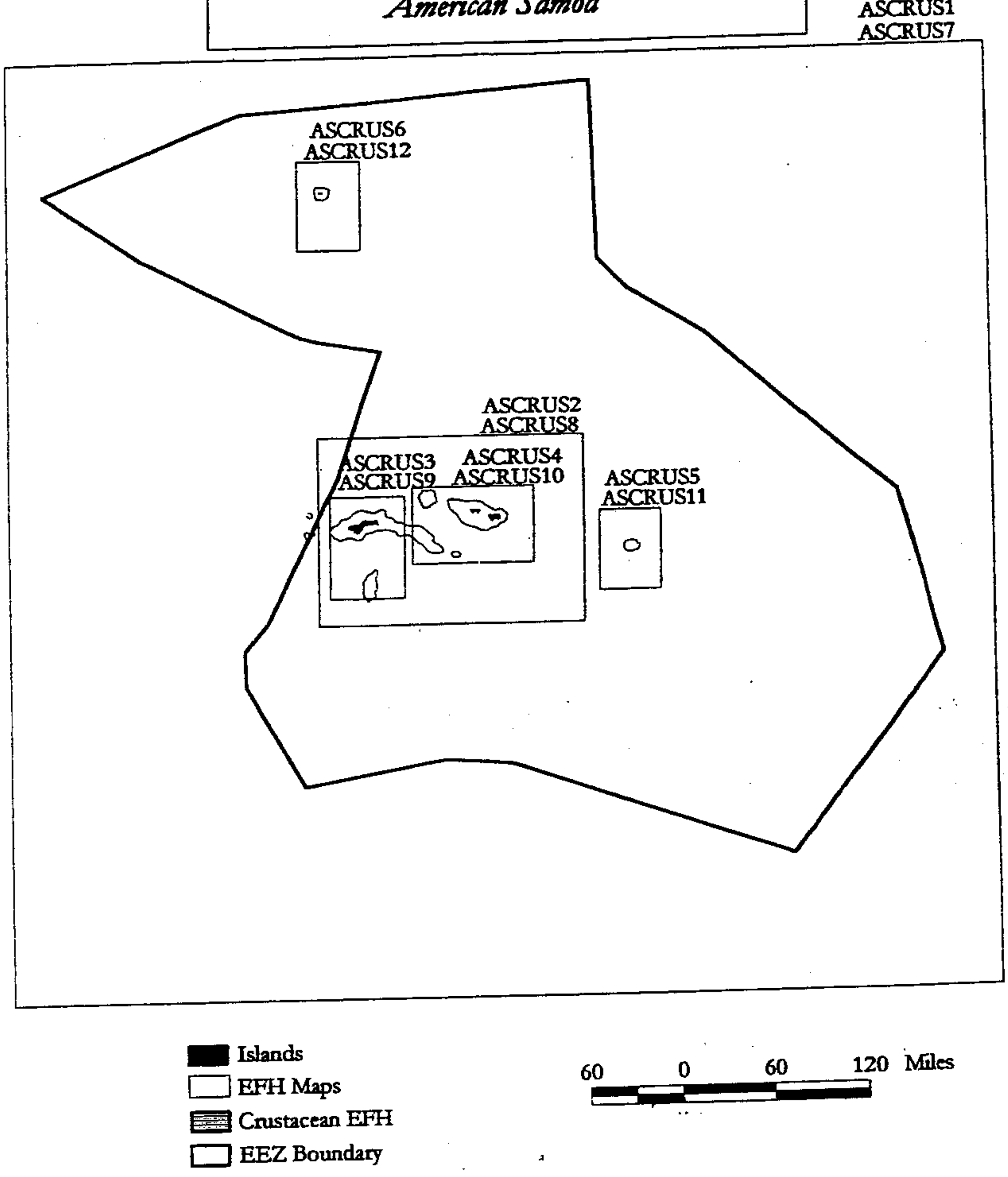


Bottomfish HAPC
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
N
W
E
S
168 W
14.5 S
Rose Atoll
HAPC for Bottomfish
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
Map No. ASBF11


171.0 W
Bottomfish HAPC
Slopes and Escarpments Between 40 and 280 Meters
American Samoa
N
W
E
S
11.0 S
Swain's Island
Island
HAPC for Bottomfish
1000 Meter Isobath
2000 Meter Isobath
3000 Meter Isobath
2 0 2 4 Miles
Map No. ASBF12

Crustacean EFH and HAPC Maps

American Samoa

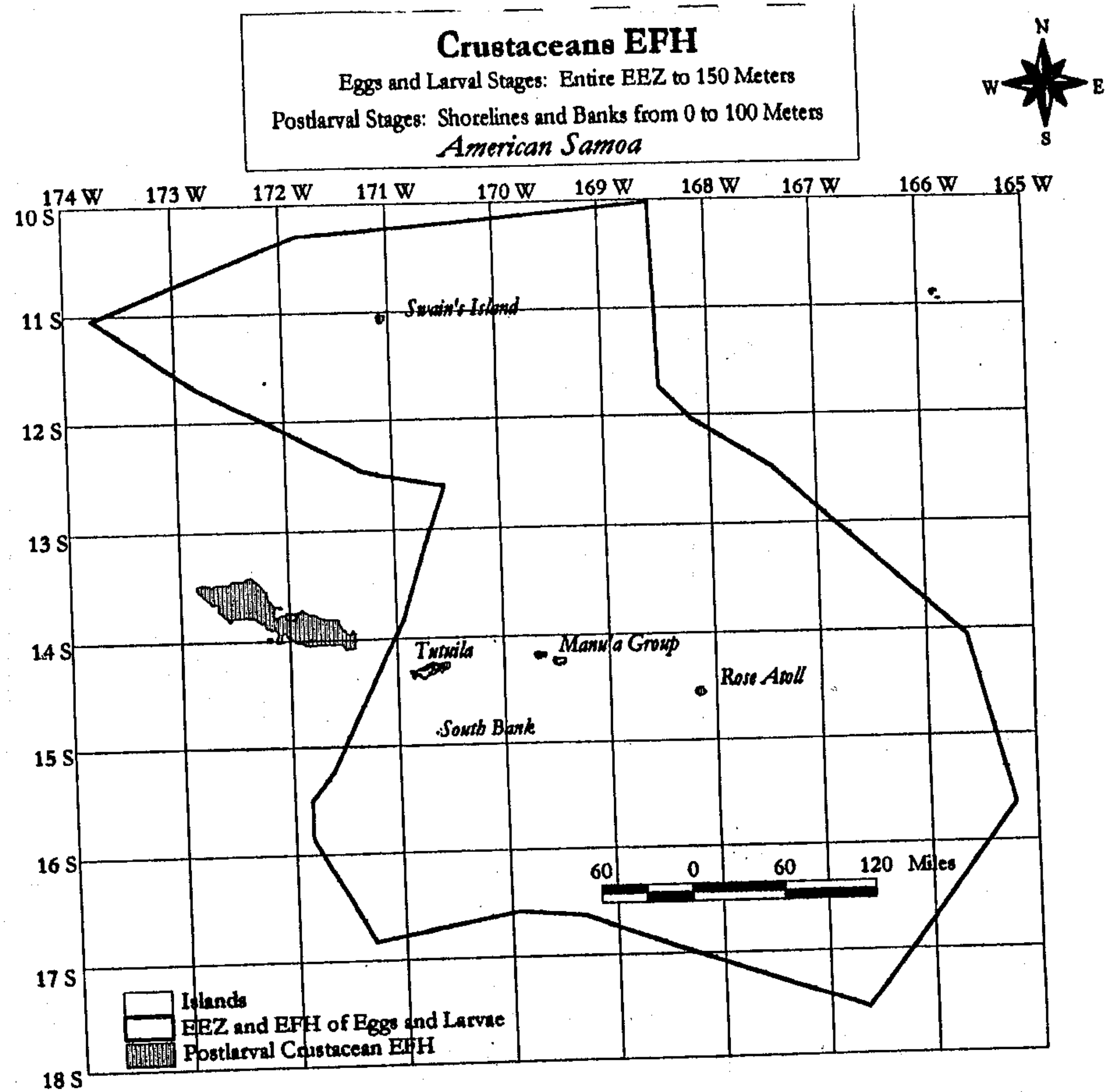


Crustaceans EFH

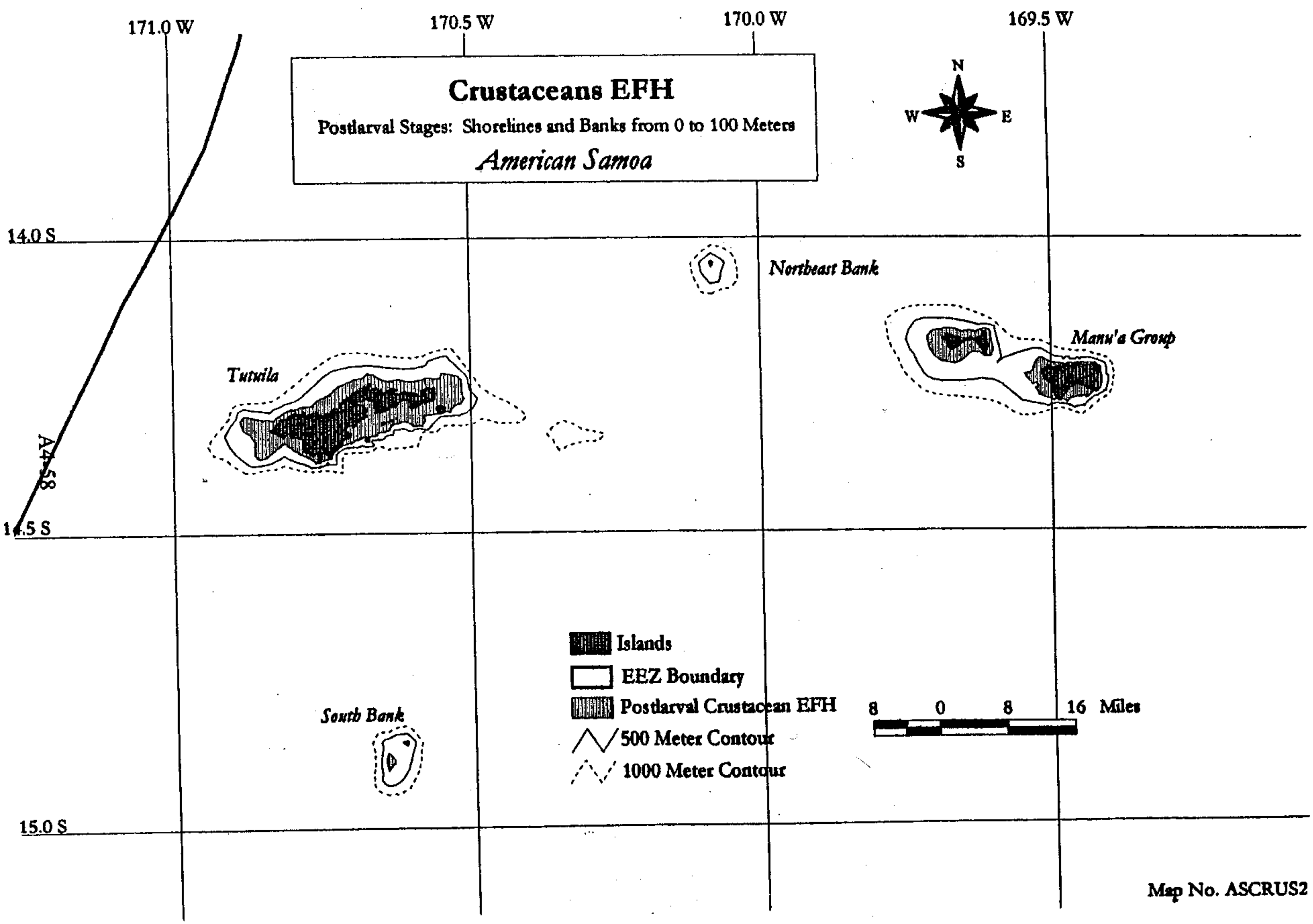
Eggs and Larval Stages: Entire EEZ to 150 Meters

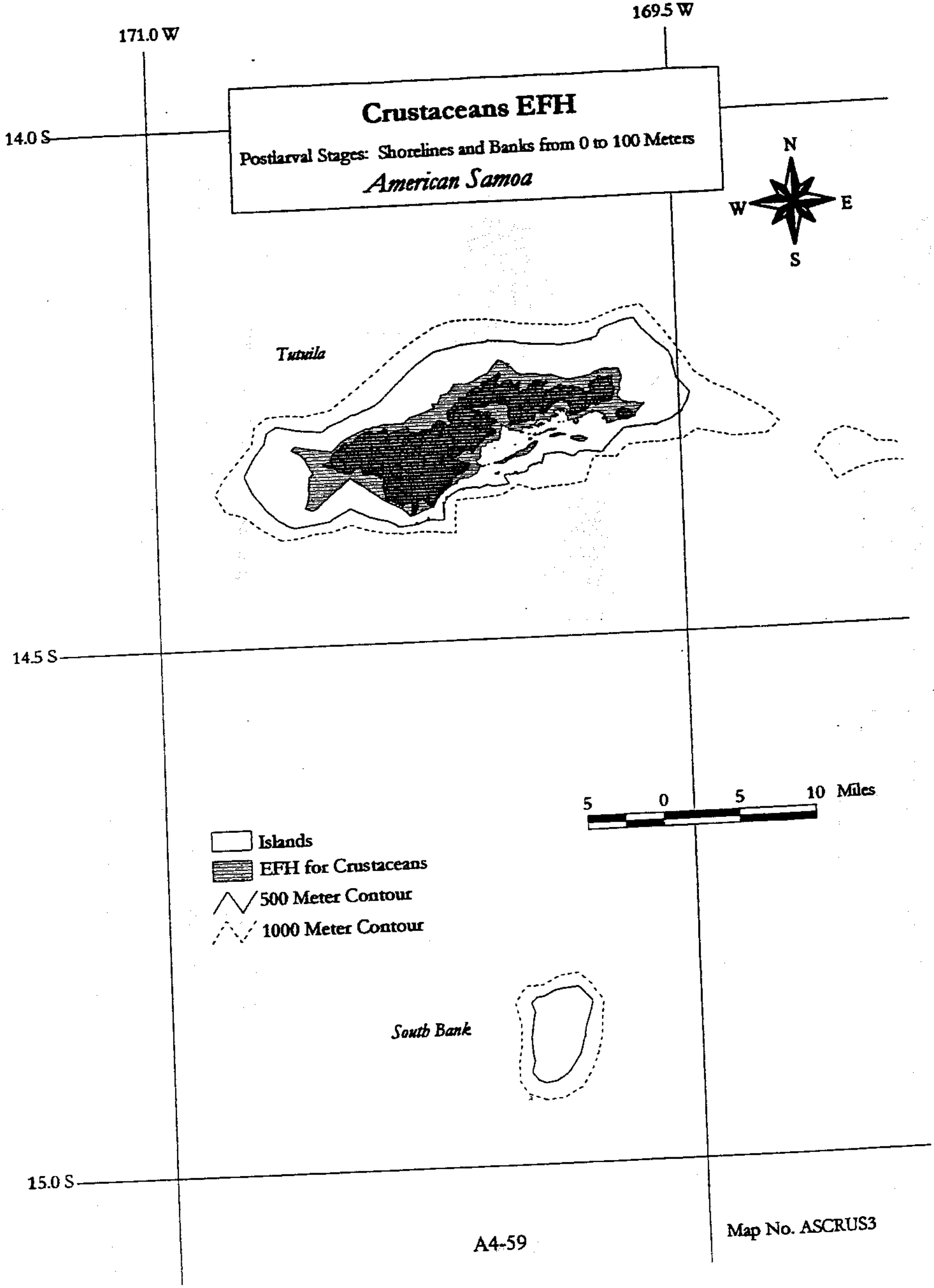
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters

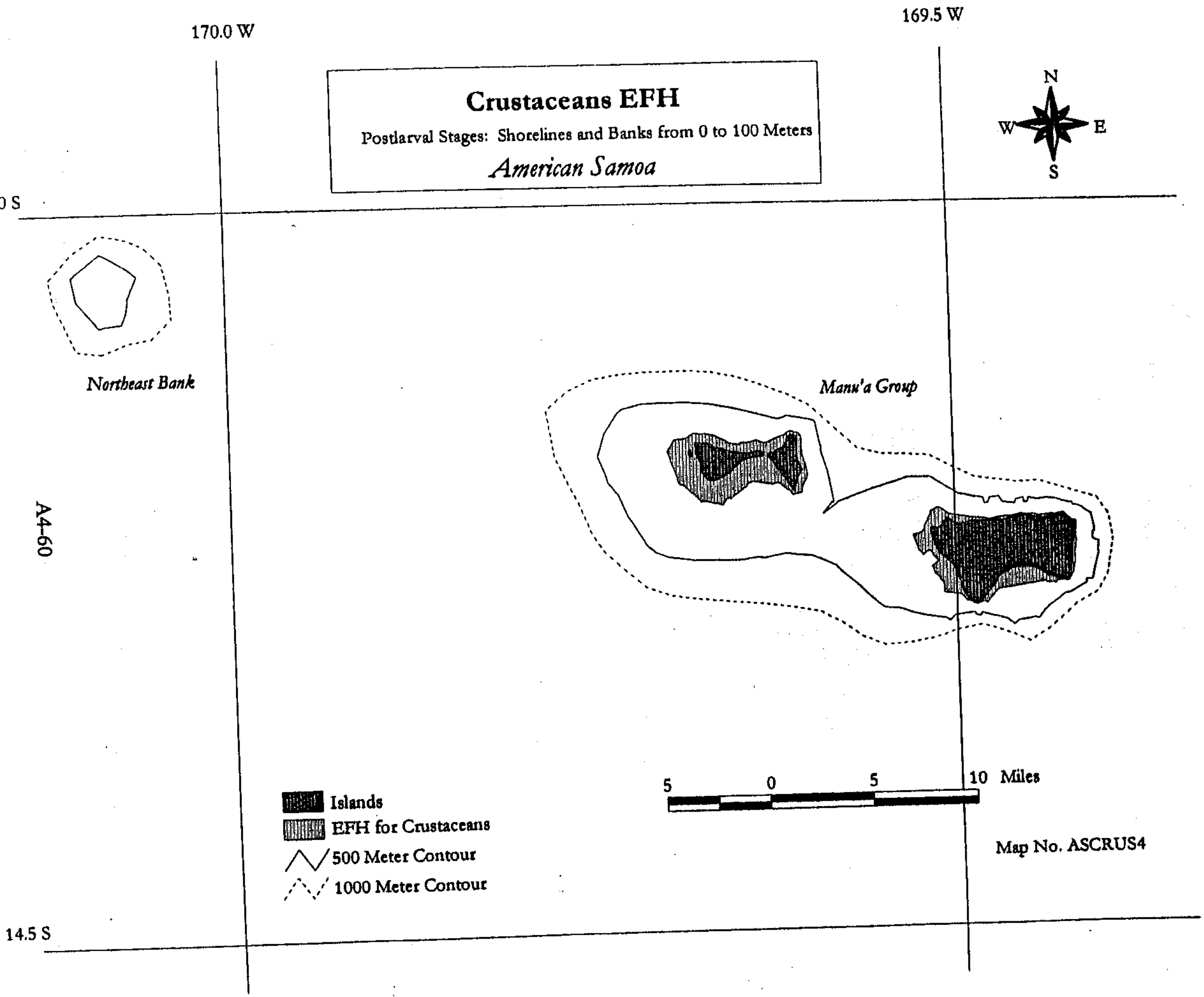
American Samoa



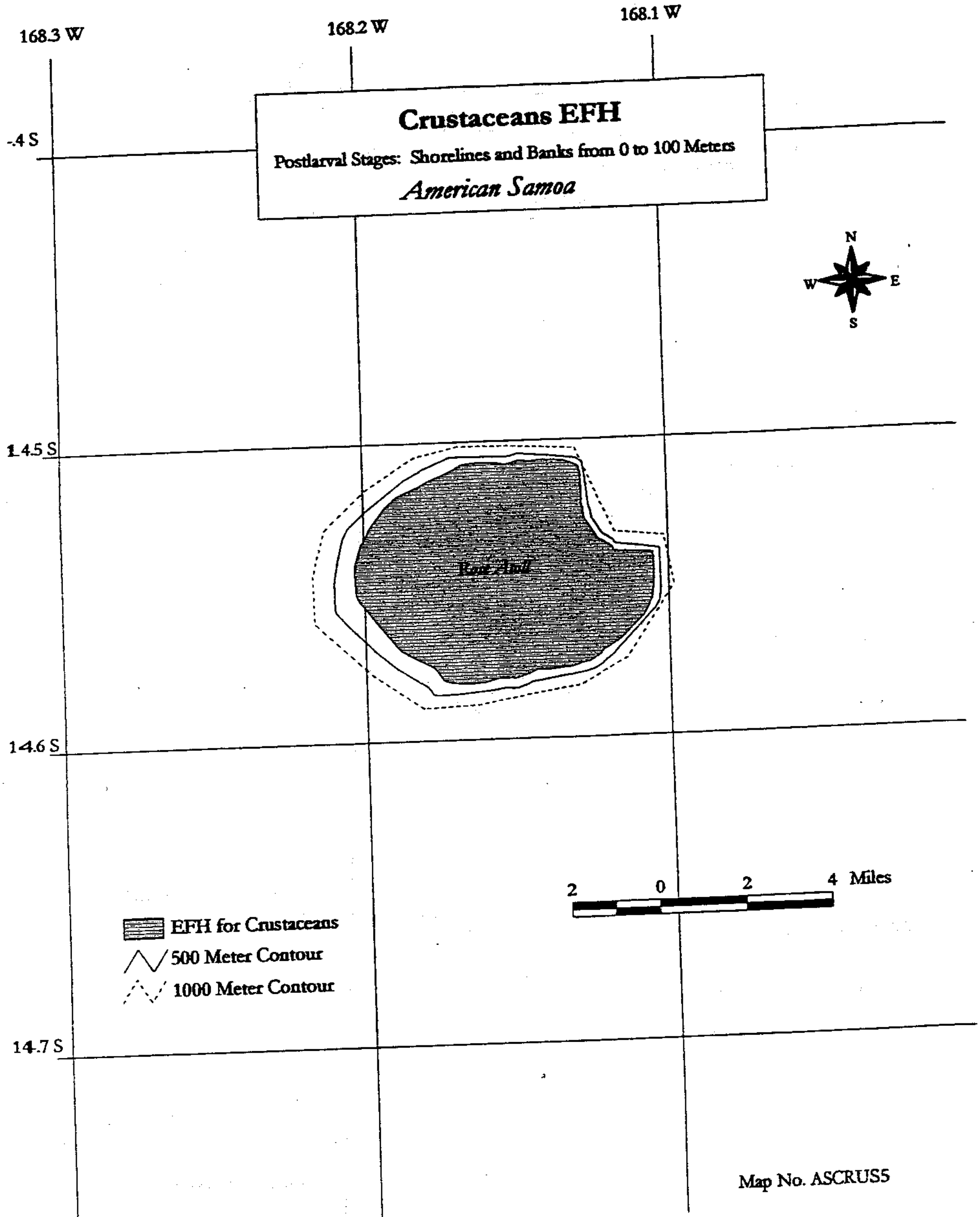
Map No. ASCRUS1


Crustaceans EFH
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters
American Samoa
171.0 W
170.5 W
170.0 W
169.5 W
N
W
E
S
14.0 S
14.5 S
15.0 S
Northeast Bank
Manu'a Group
Tutuila
South Bank
Islands
EEZ Boundary
Postlarval Crustacean EFH
500 Meter Contour
1000 Meter Contour
8 0 8 16 Miles
Map No. ASCRUS2

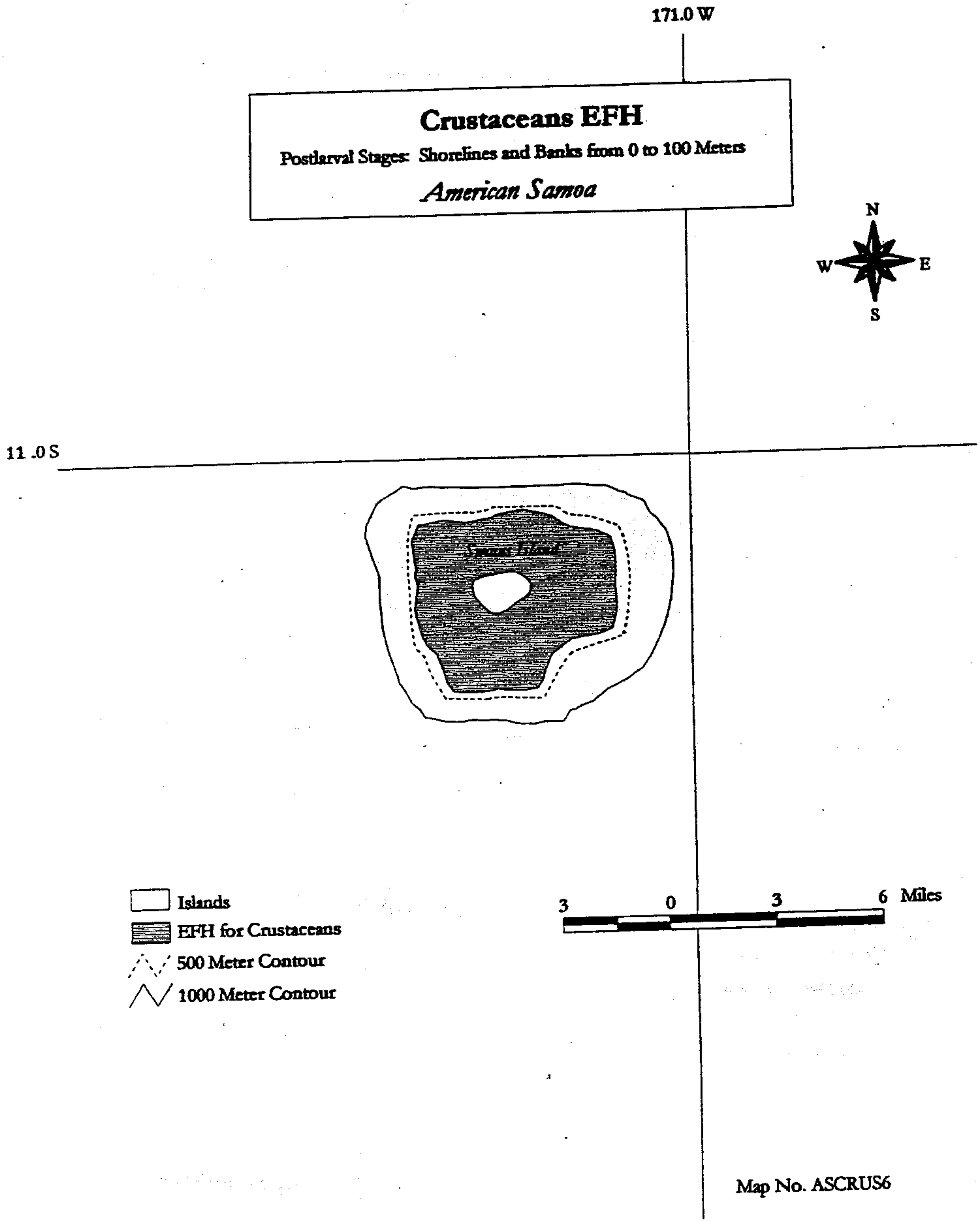

171.0 W
169.5 W
Crustaceans EFH
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters
American Samoa
14.0 S
14.5 S
15.0 S
N
S
E
W
Tutuila
South Bank
5
0
5
10
Miles
Islands
EFH for Crustaceans
500 Meter Contour
1000 Meter Contour
Map No. ASCRUS3

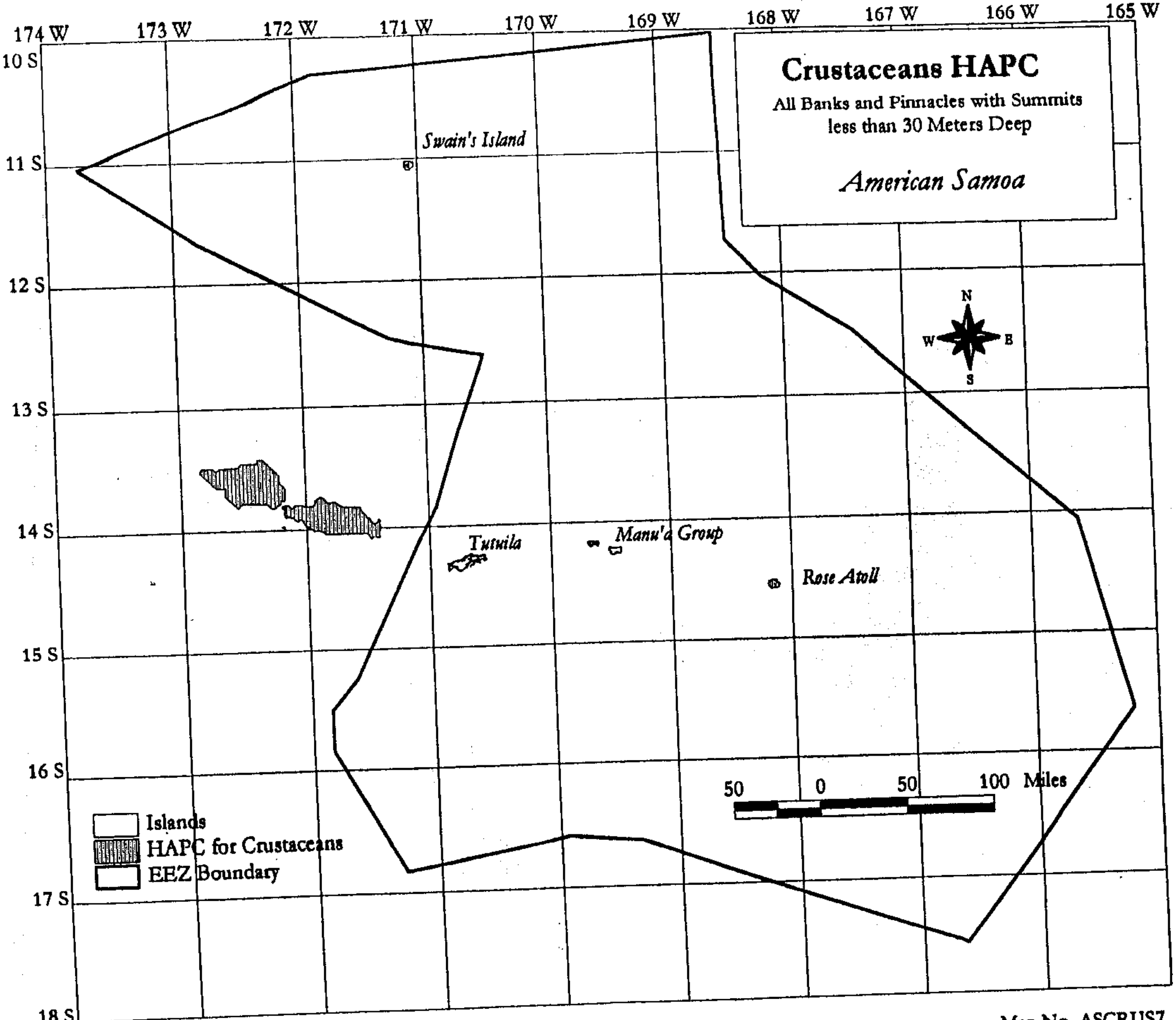


170.0 W
169.5 W
Crustaceans EFH
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters
American Samoa
N
W
E
S
Northeast Bank
Manu'a Group
5 0 5 10 Miles
Islands
EFH for Crustaceans
500 Meter Contour
1000 Meter Contour
Map No. ASCRUS4
14.5 S

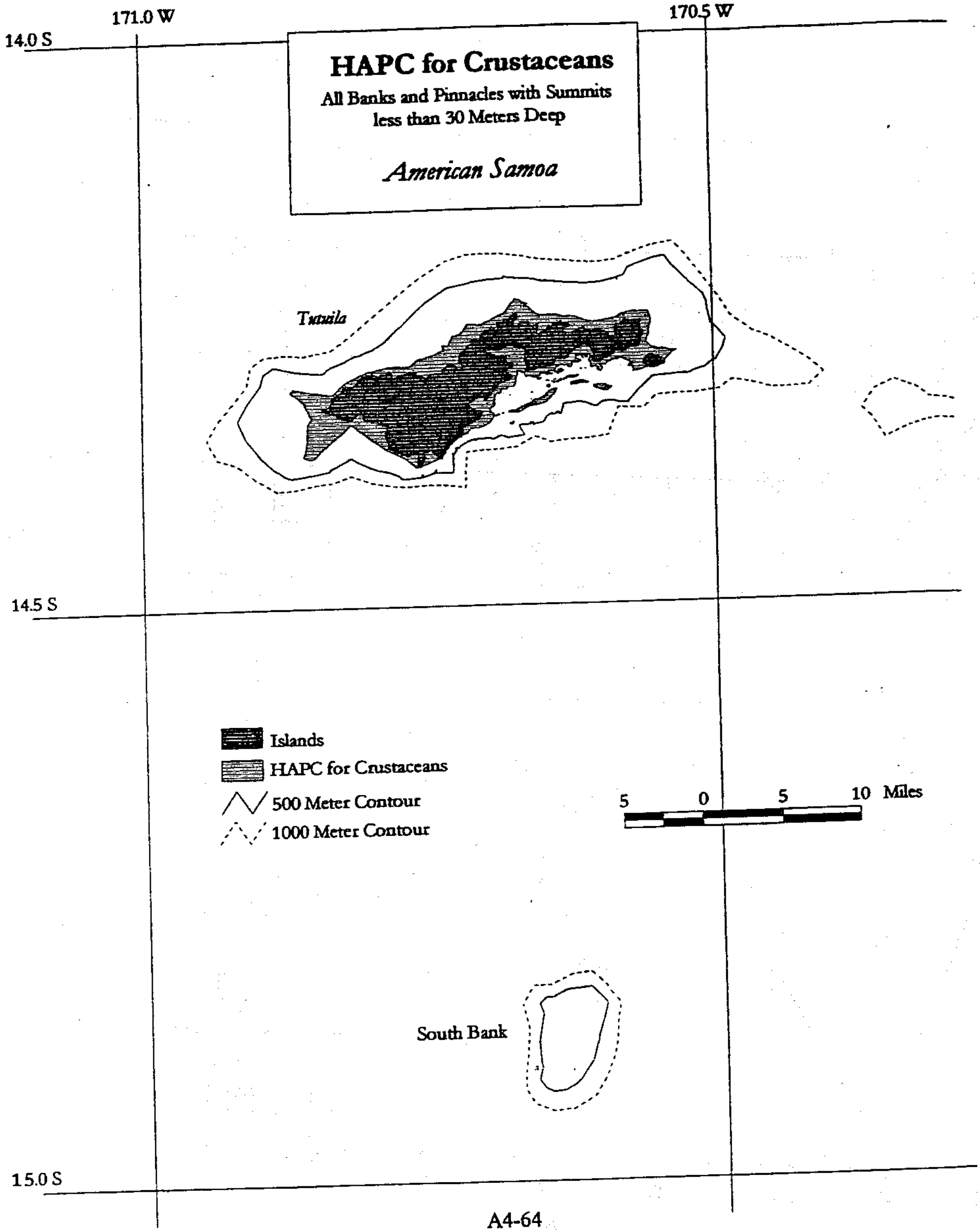


Crustaceans EFH
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters
American Samoa
168.3 W
168.2 W
168.1 W
14.5 S
14.6 S
14.7 S
N
S
E
W
2
0
2
4
Miles
EFH for Crustaceans
500 Meter Contour
1000 Meter Contour
Map No. ASCRUS5

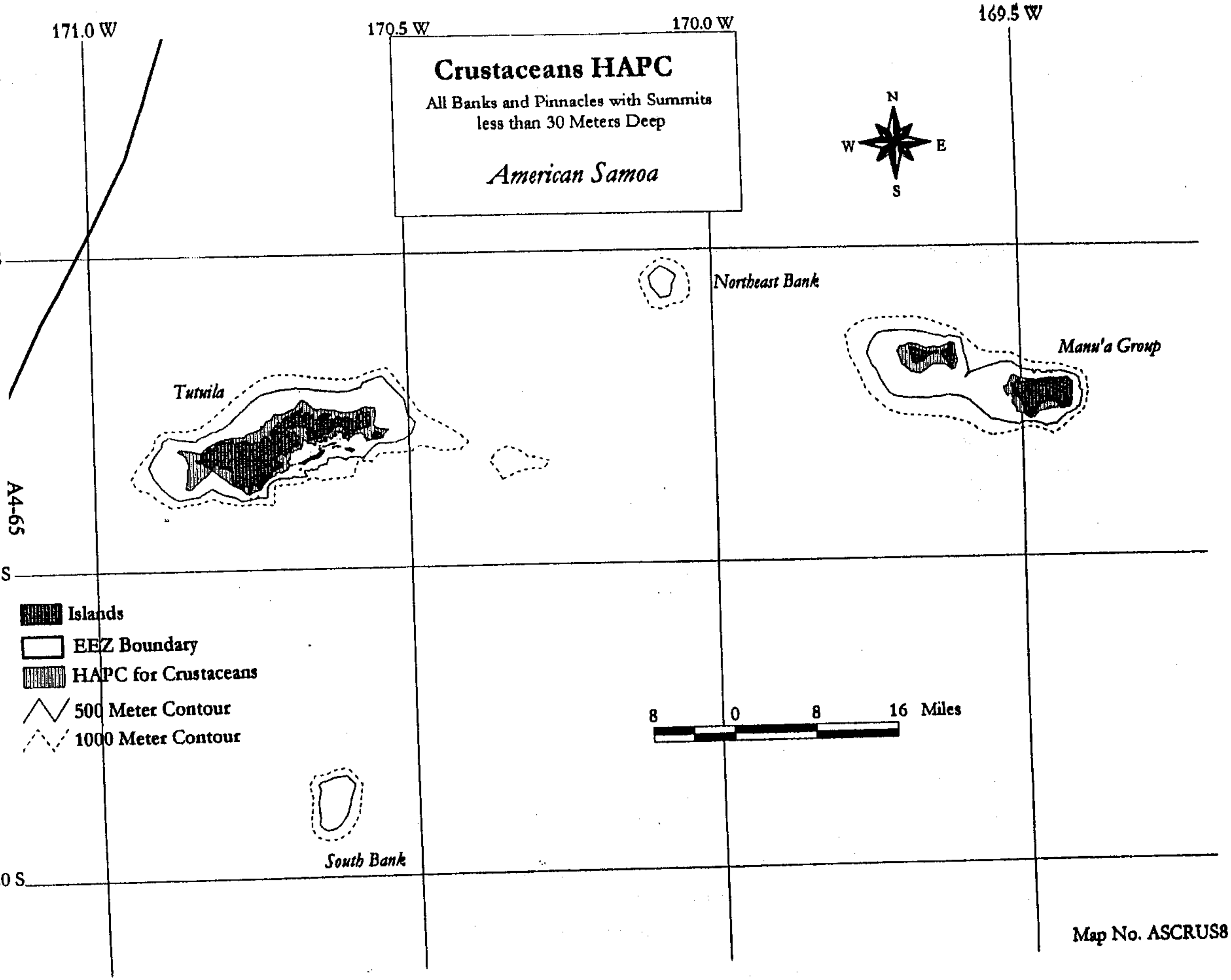

171.0 W
Crustaceans EFH
Postlarval Stages: Shorelines and Banks from 0 to 100 Meters
American Samoa
N
W
E
S
11 .0 S
Islands
EFH for Crustaceans
500 Meter Contour
1000 Meter Contour
3
0
3
6
Miles
Map No. ASCRUS6



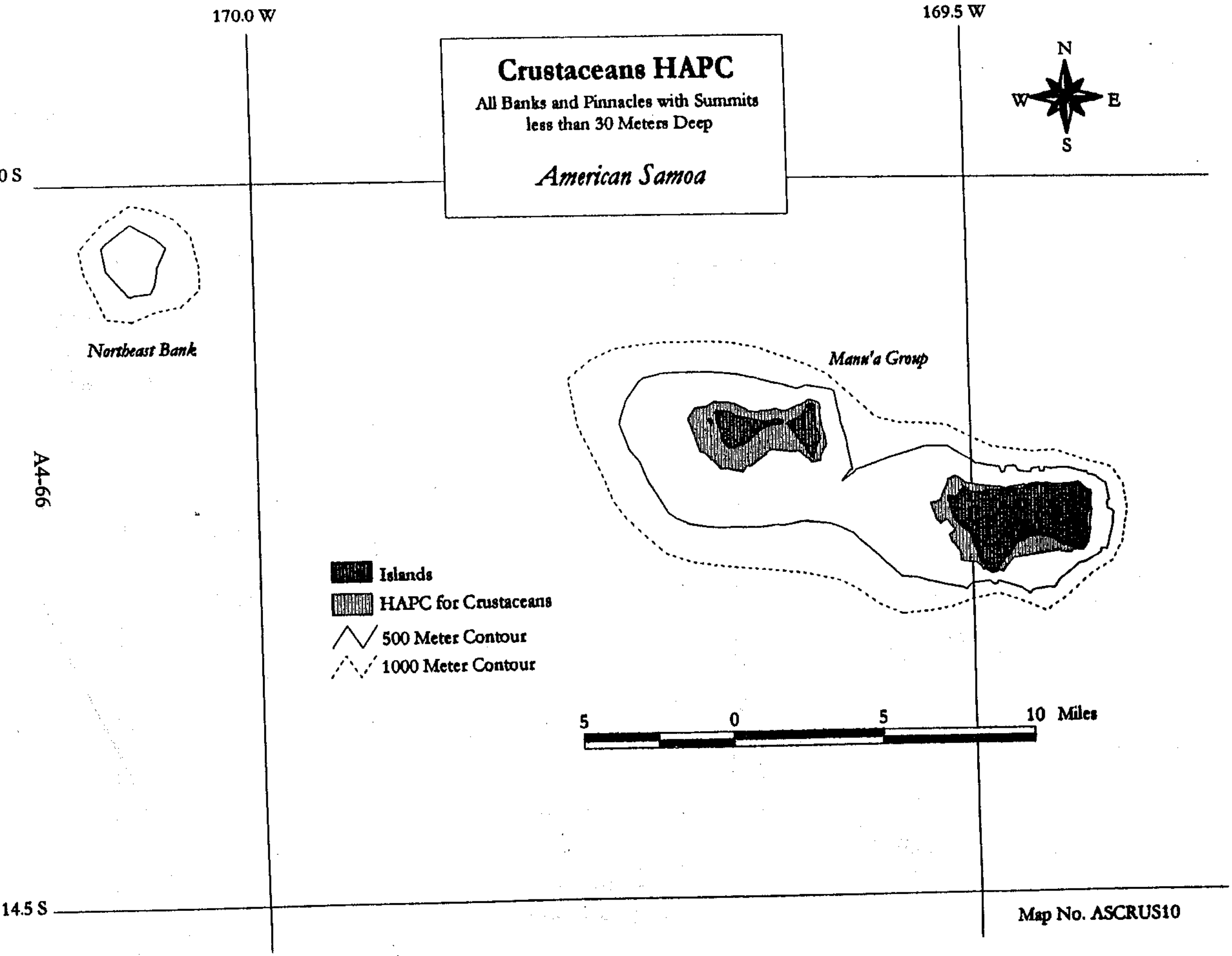
Map No. ASCRUS7

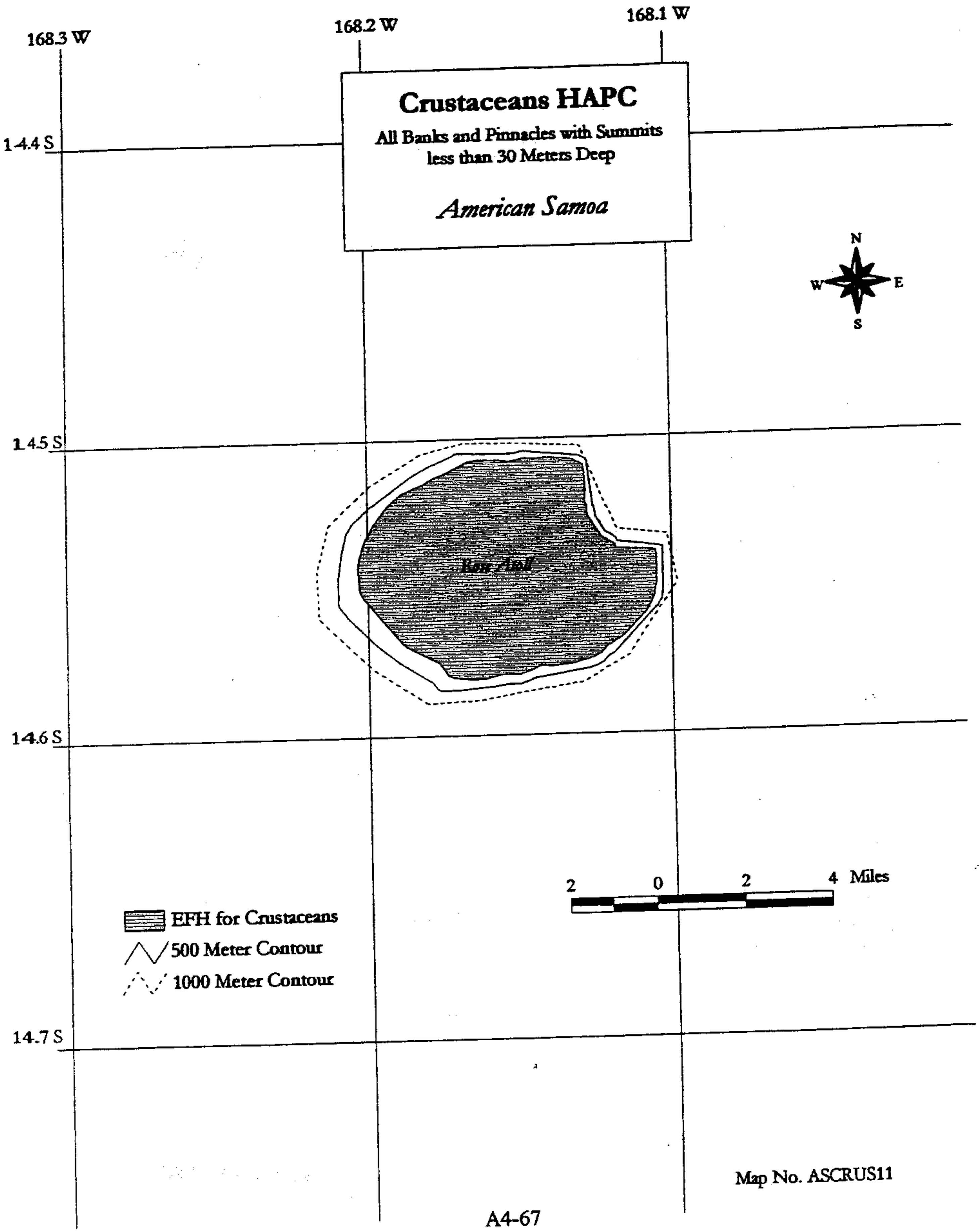


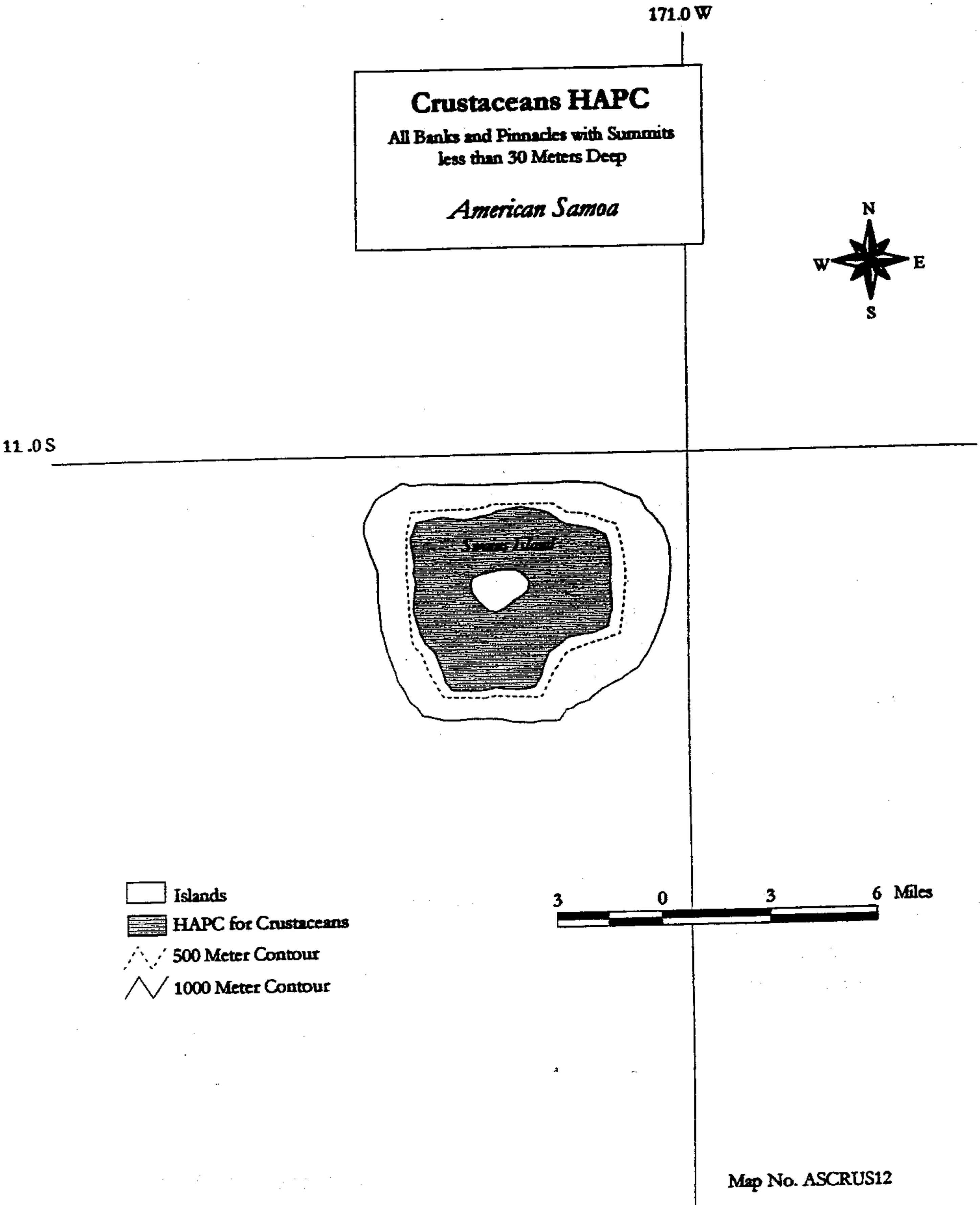
Map No. ASCRUS9



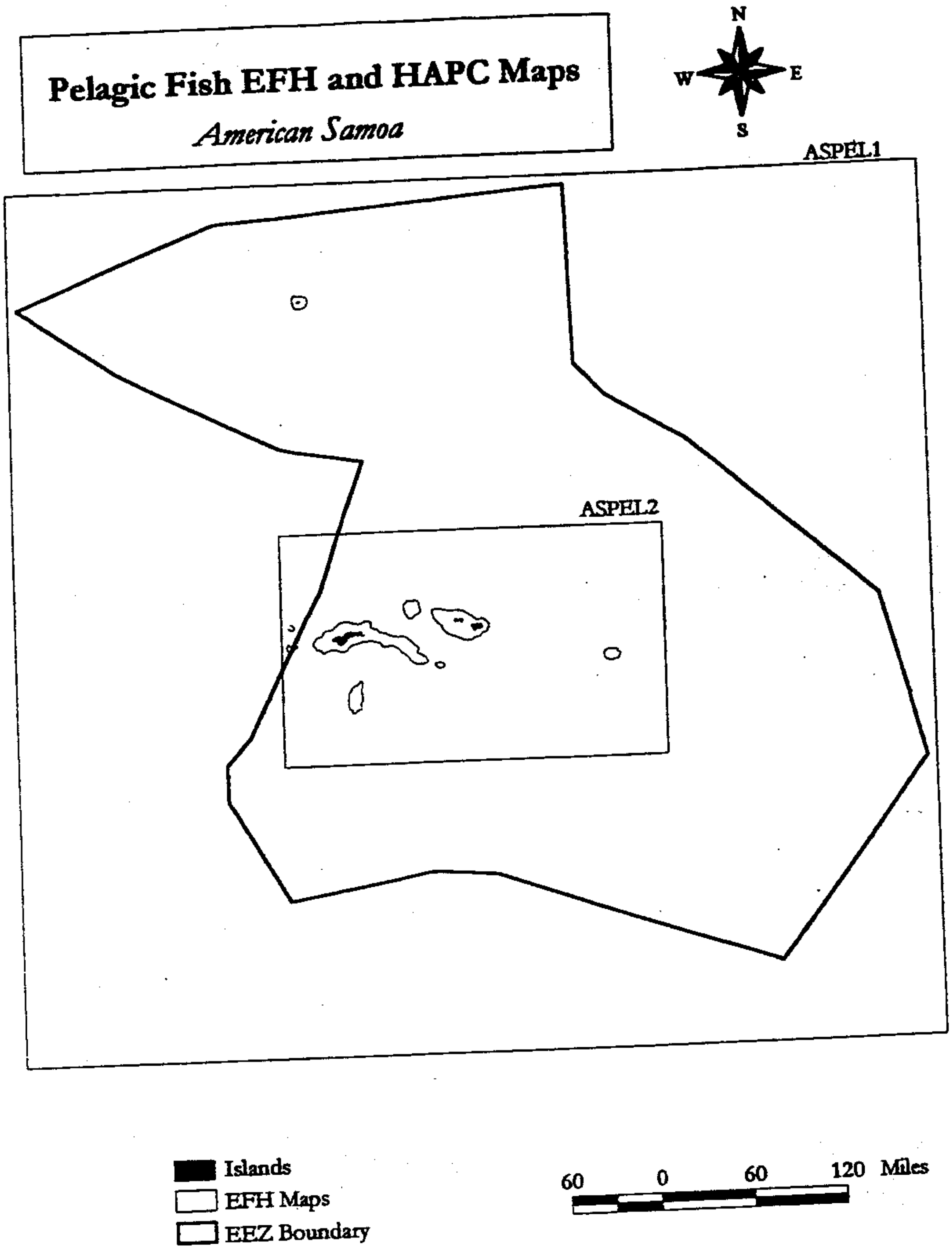
Crustaceans HAPC
All Banks and Pinnacles with Summits less than 30 Meters Deep
American Samoa
171.0 W
170.5 W
170.0 W
169.5 W
14.0 S
14.5 S
15.0 S
N
W
E
S
Tutuila
Northeast Bank
Manu'a Group
South Bank
Islands
EEZ Boundary
HAPC for Crustaceans
500 Meter Contour
1000 Meter Contour
8
0
8
16
Miles
Map No. ASCRUS8

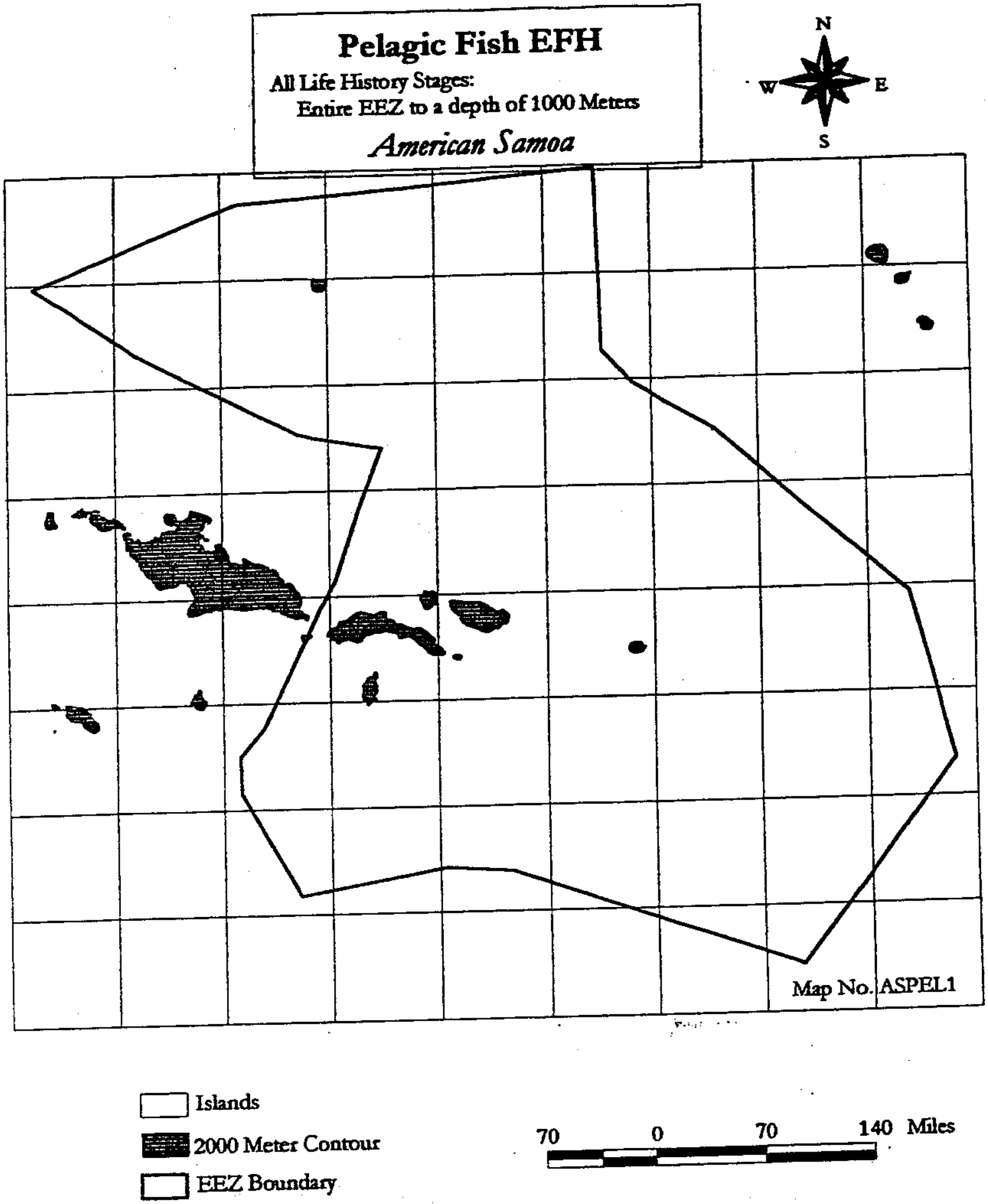

Crustaceans HAPC
All Banks and Pinnacles with Summits
less than 30 Meters Deep
American Samoa
170.0 W
169.5 W
N
W
E
S
0 S
14.5 S
Northeast Bank
Manu'a Group
Islands
HAPC for Crustaceans
500 Meter Contour
1000 Meter Contour
5
0
5
10 Miles
Map No. ASCRUS10

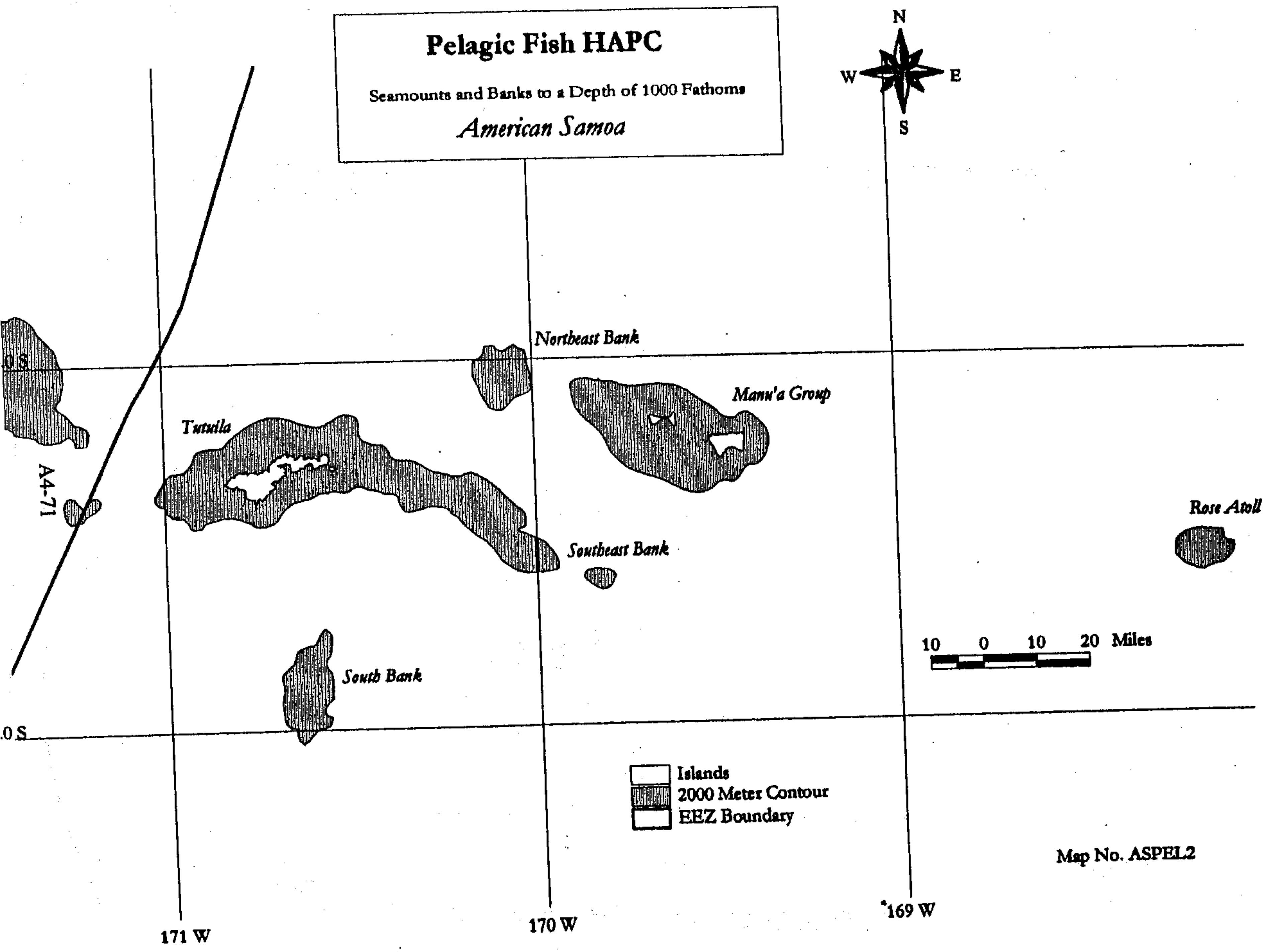

168.3 W
168.2 W
168.1 W
Crustaceans HAPC
All Banks and Pinnacles with Summits less than 30 Meters Deep
American Samoa
14.4 S
14.5 S
14.6 S
14.7 S
N
W
E
S
2
0
2
4 Miles
EFH for Crustaceans
500 Meter Contour
1000 Meter Contour
Map No. ASCRUS11



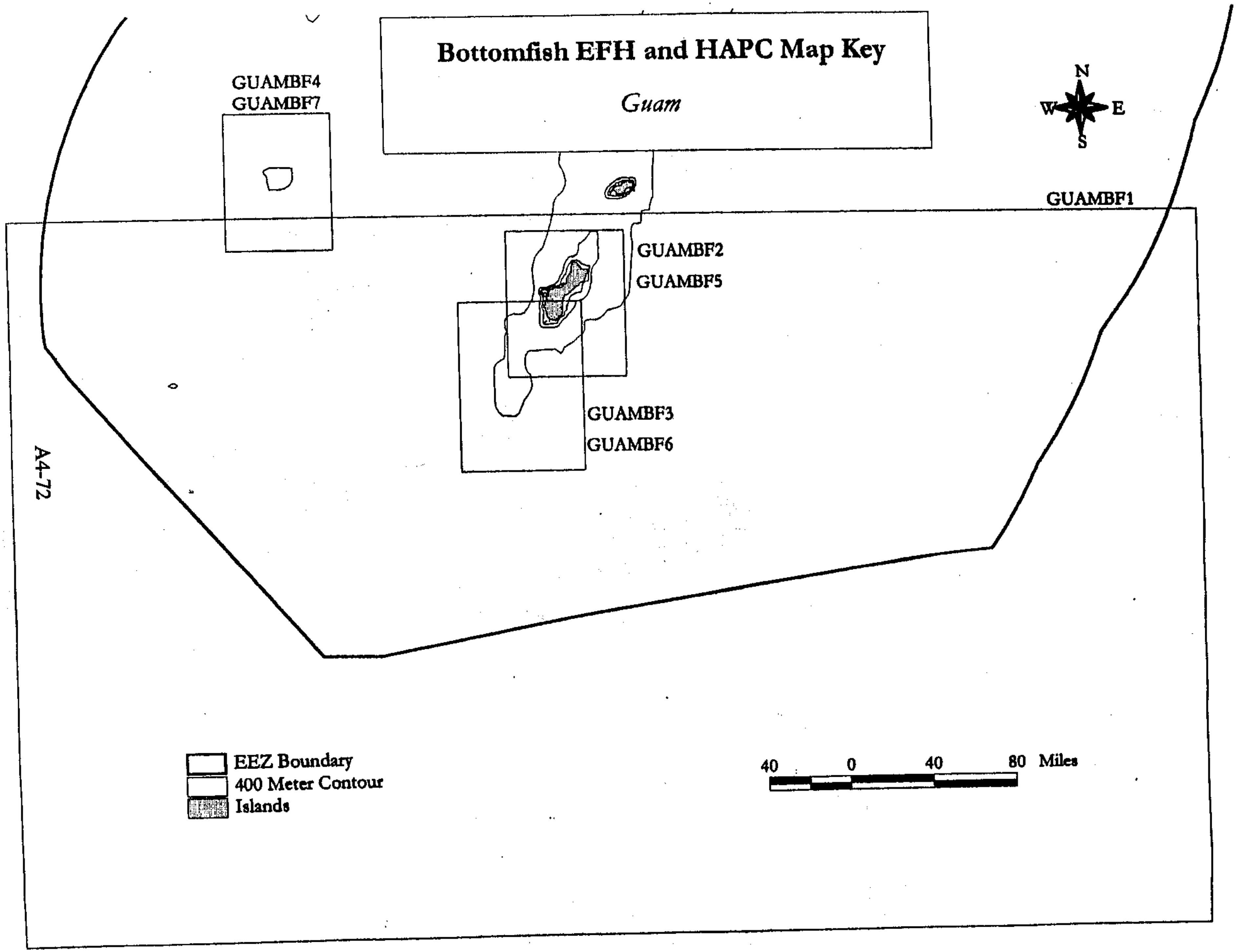
Crustaceans HAPC
All Banks and Pinnacles with Summits
less than 30 Meters Deep
American Samoa
171.0 W
11 .0 S
N
W
E
S
Islands
HAPC for Crustaceans
500 Meter Contour
1000 Meter Contour
3
0
3
6
Miles
Map No. ASCRUS12


Pelagic Fish EFH and HAPC Maps
American Samoa
N
W
E
S
ASPEL1
ASPEL2
Islands
EFH Maps
EEZ Boundary
60
0
60
120
Miles

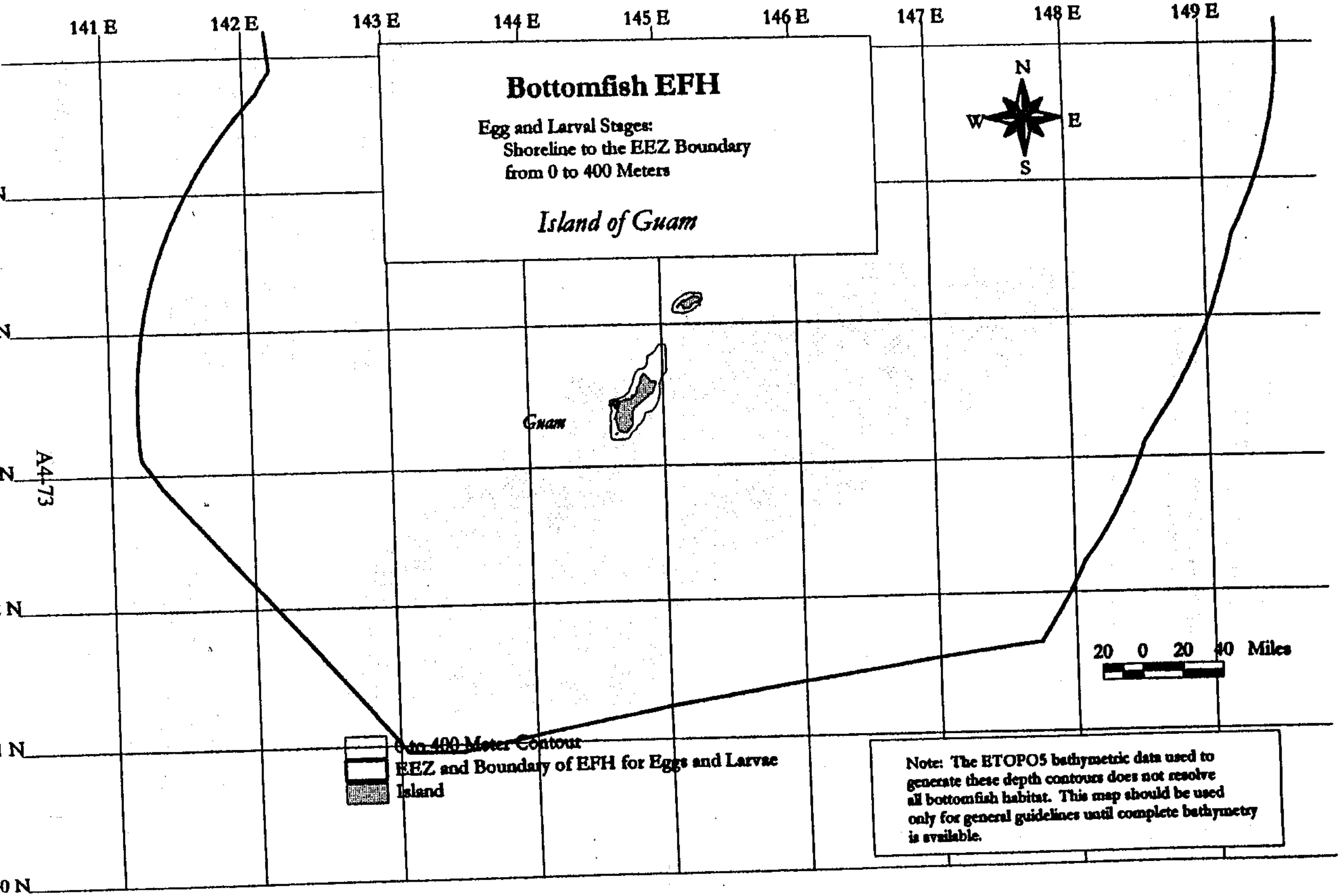

Pelagic Fish EFH
All Life History Stages:
Entire EEZ to a depth of 1000 Meters
American Samoa
N
W
E
S
Map No. ASPEL1
Islands
2000 Meter Contour
EEZ Boundary
70
0
70
140 Miles



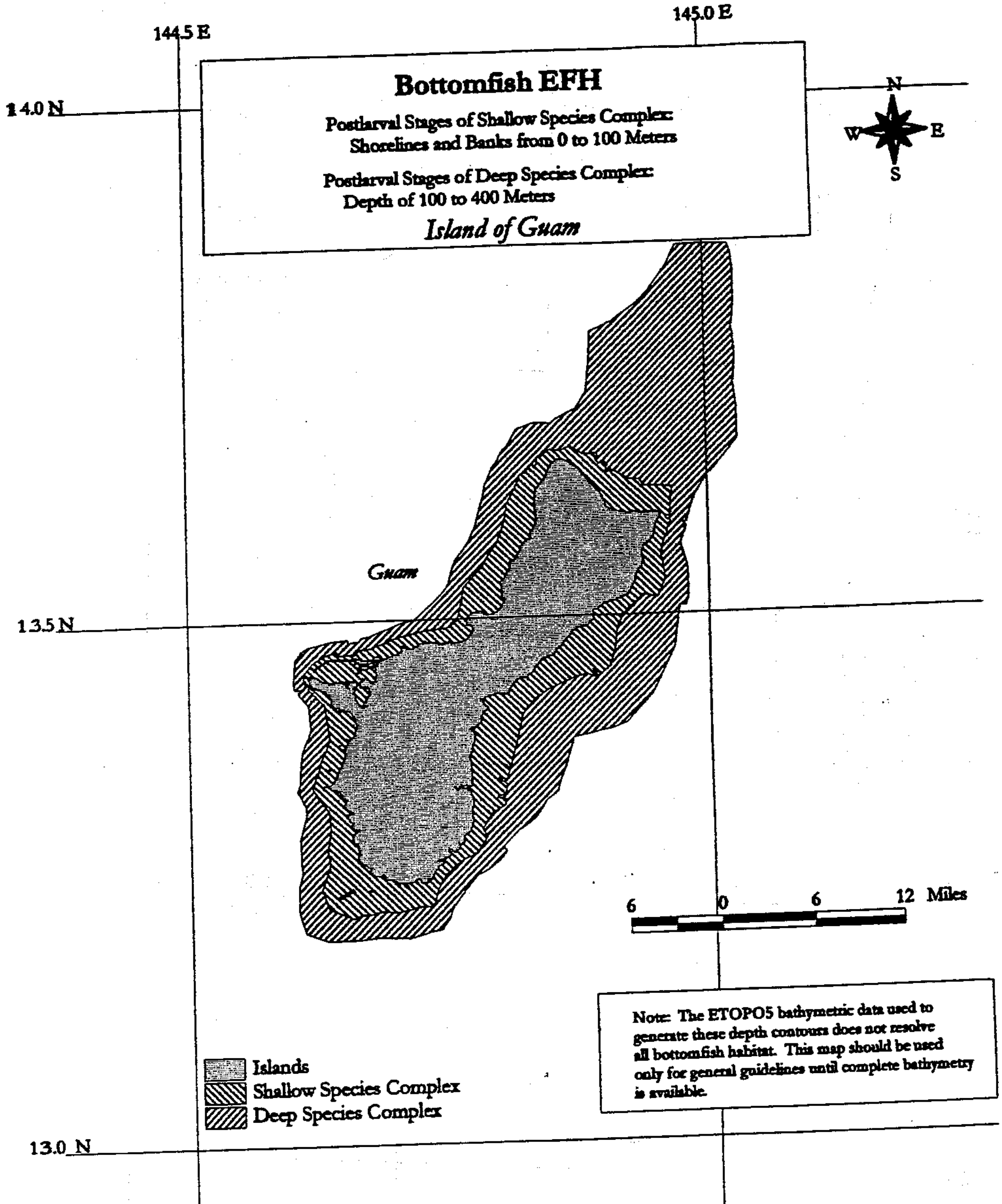
Pelagic Fish HAPC
Seamounts and Banks to a Depth of 1000 Fathoms
American Samoa
N
W
E
S
Northeast Bank
Manu'a Group
Tutuila
Southeast Bank
Rose Atoll
South Bank
10 0 10 20 Miles
Islands
2000 Meter Contour
EEZ Boundary
Map No. ASPEL2
171 W
170 W
169 W



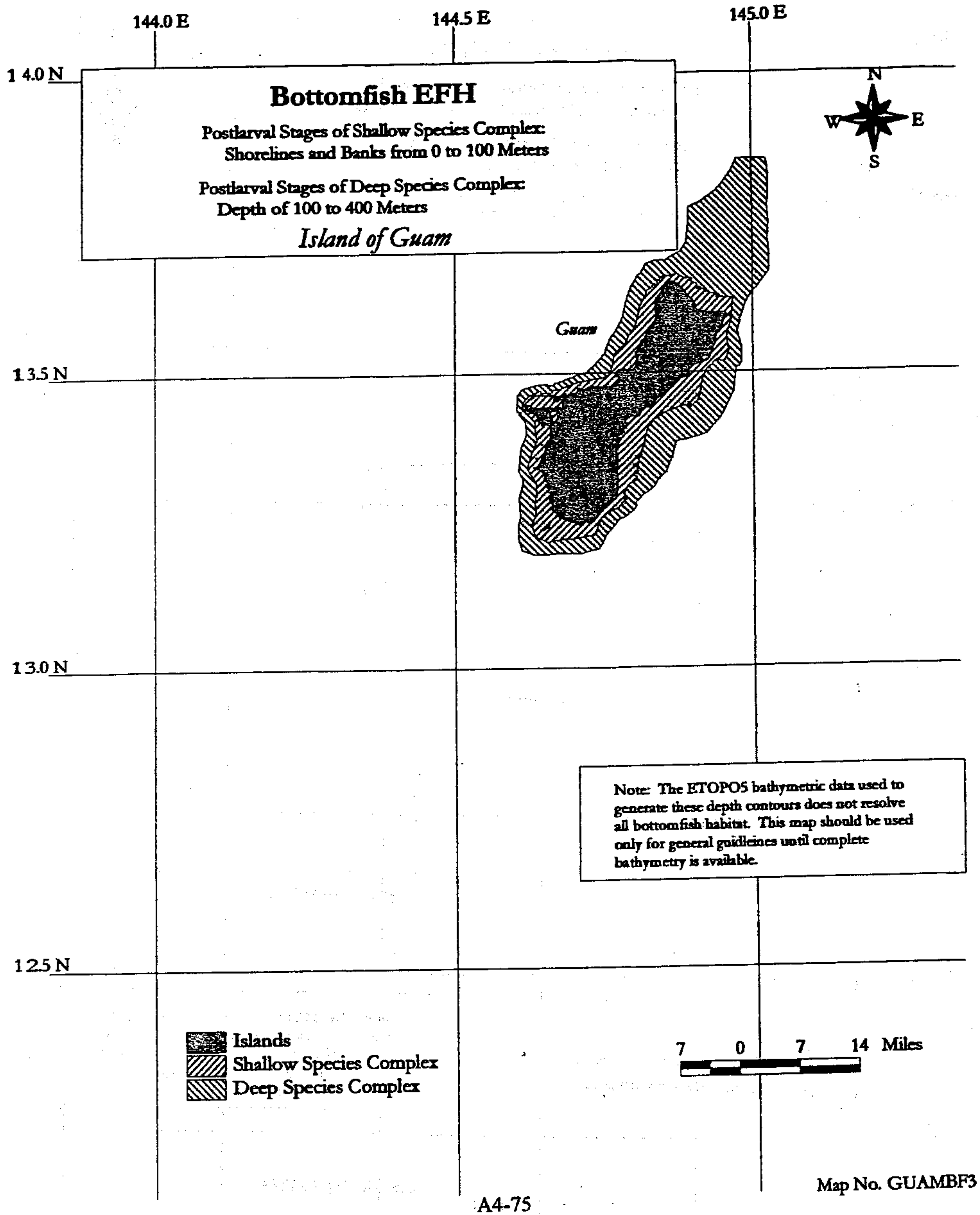
Bottomfish EFH and HAPC Map Key
Guam
N
W
E
S
GUAMBF1
GUAMBF2
GUAMBF5
GUAMBF3
GUAMBF6
GUAMBF4
GUAMBF7
EEZ Boundary
400 Meter Contour
Islands
40
0
40
80
Miles

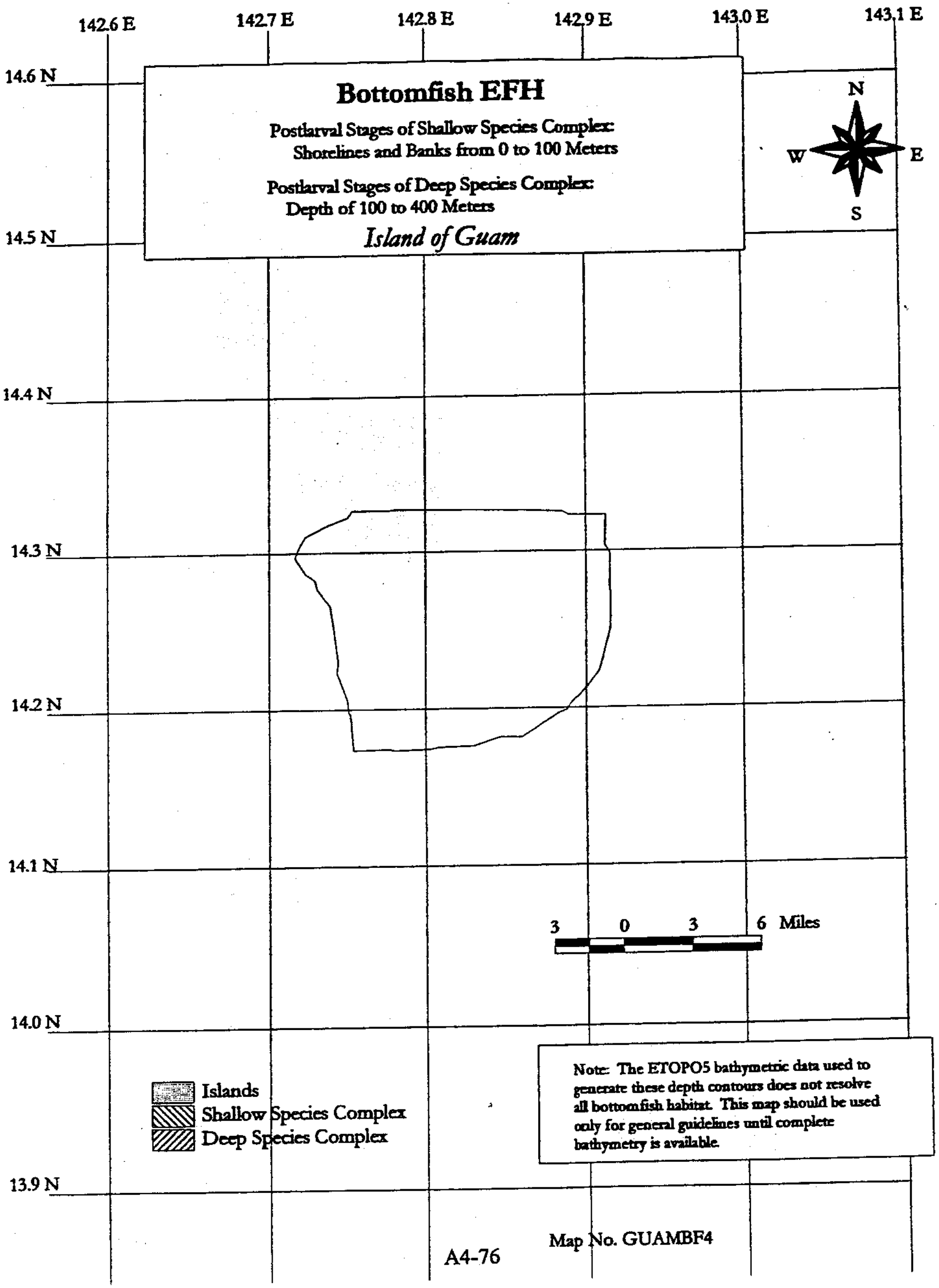


Map No. GUAMBF1

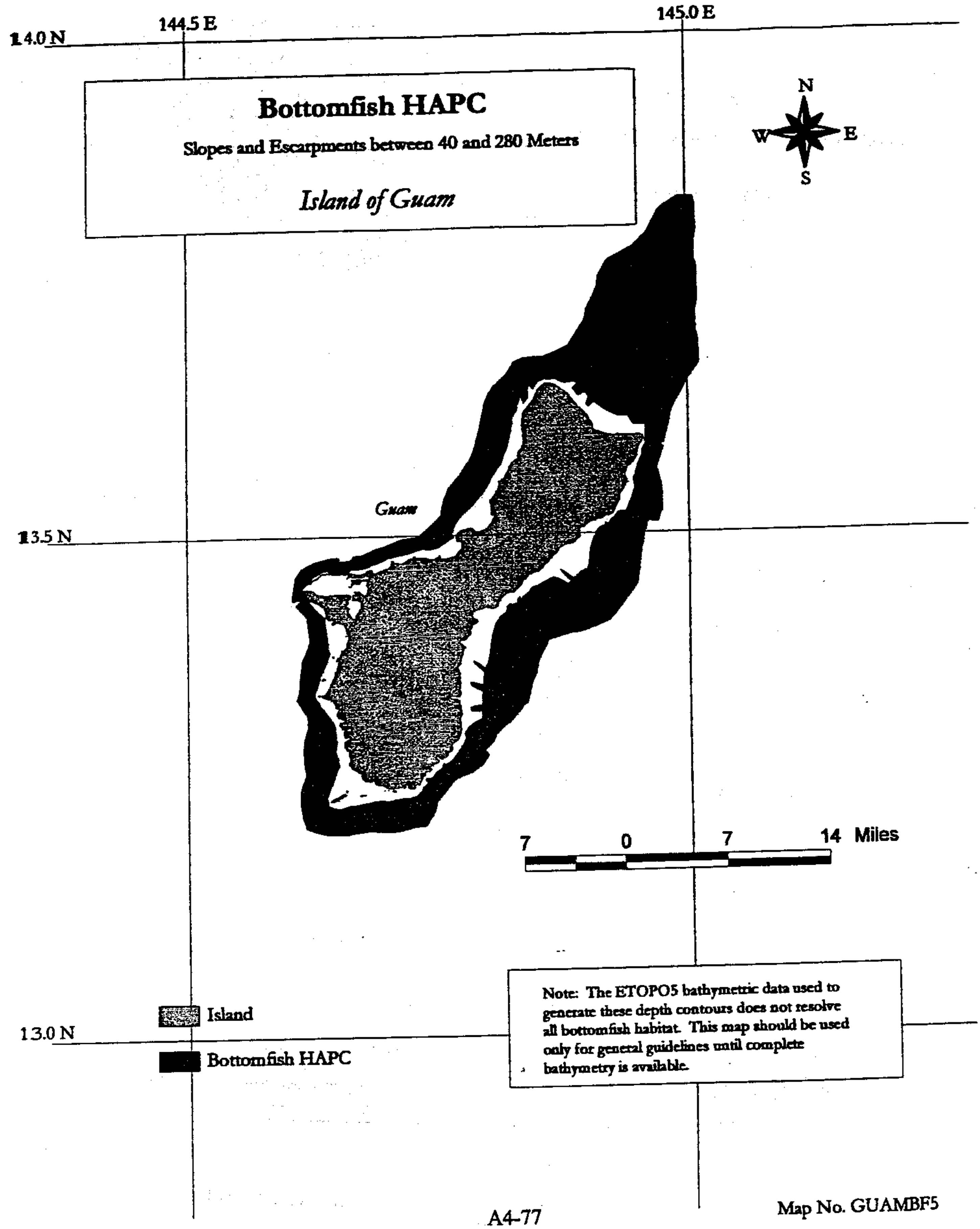


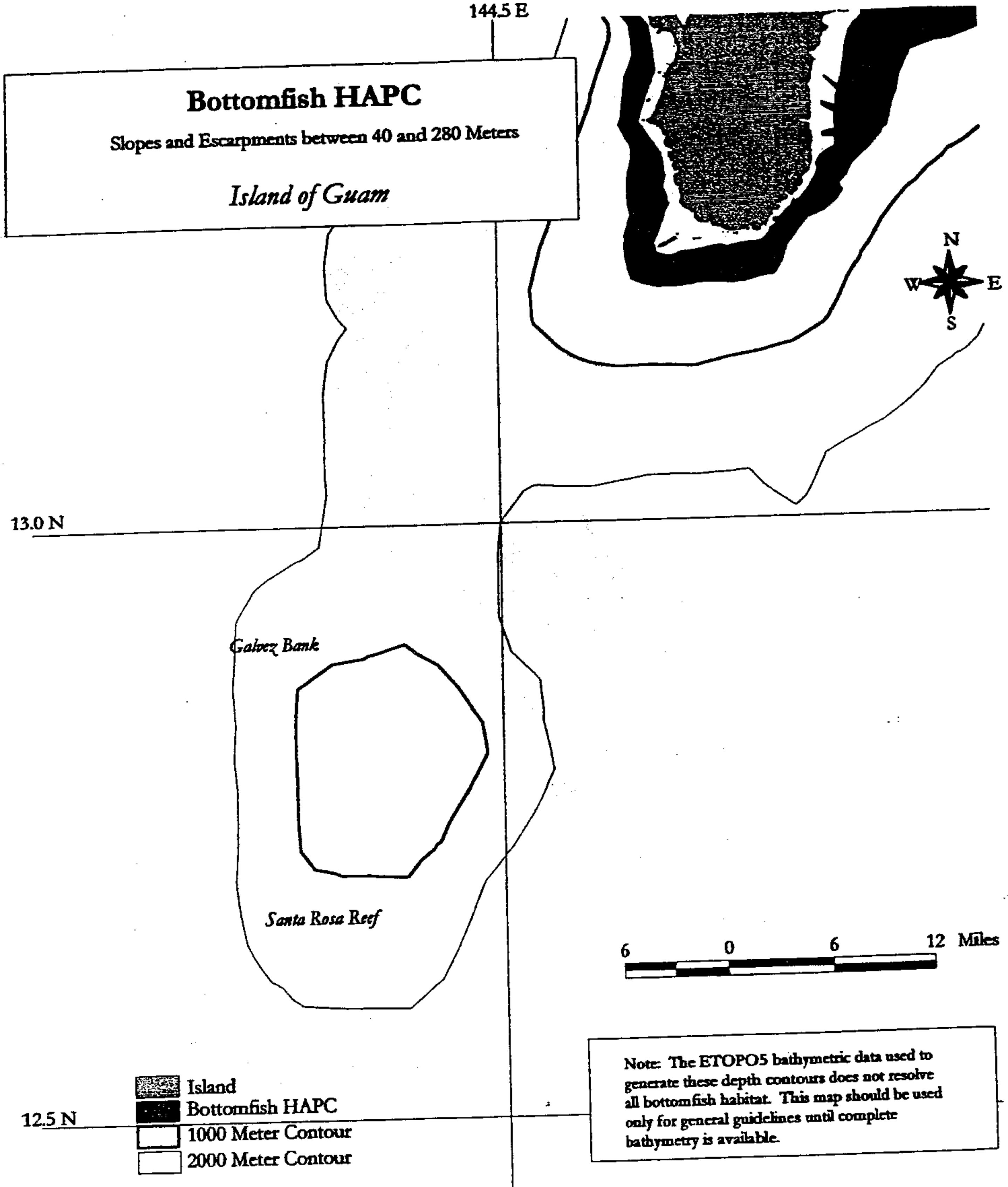
Map No. GUAMBF2


144.0 E
144.5 E
145.0 E
14.0 N
13.5 N
13.0 N
12.5 N
Bottomfish EFH
Postlarval Stages of Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex:
Depth of 100 to 400 Meters
Island of Guam
N
W
E
S
Guam
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidleines until complete bathymetry is available.
Islands
Shallow Species Complex
Deep Species Complex
7
0
7
14
Miles
Map No. GUAMBF3

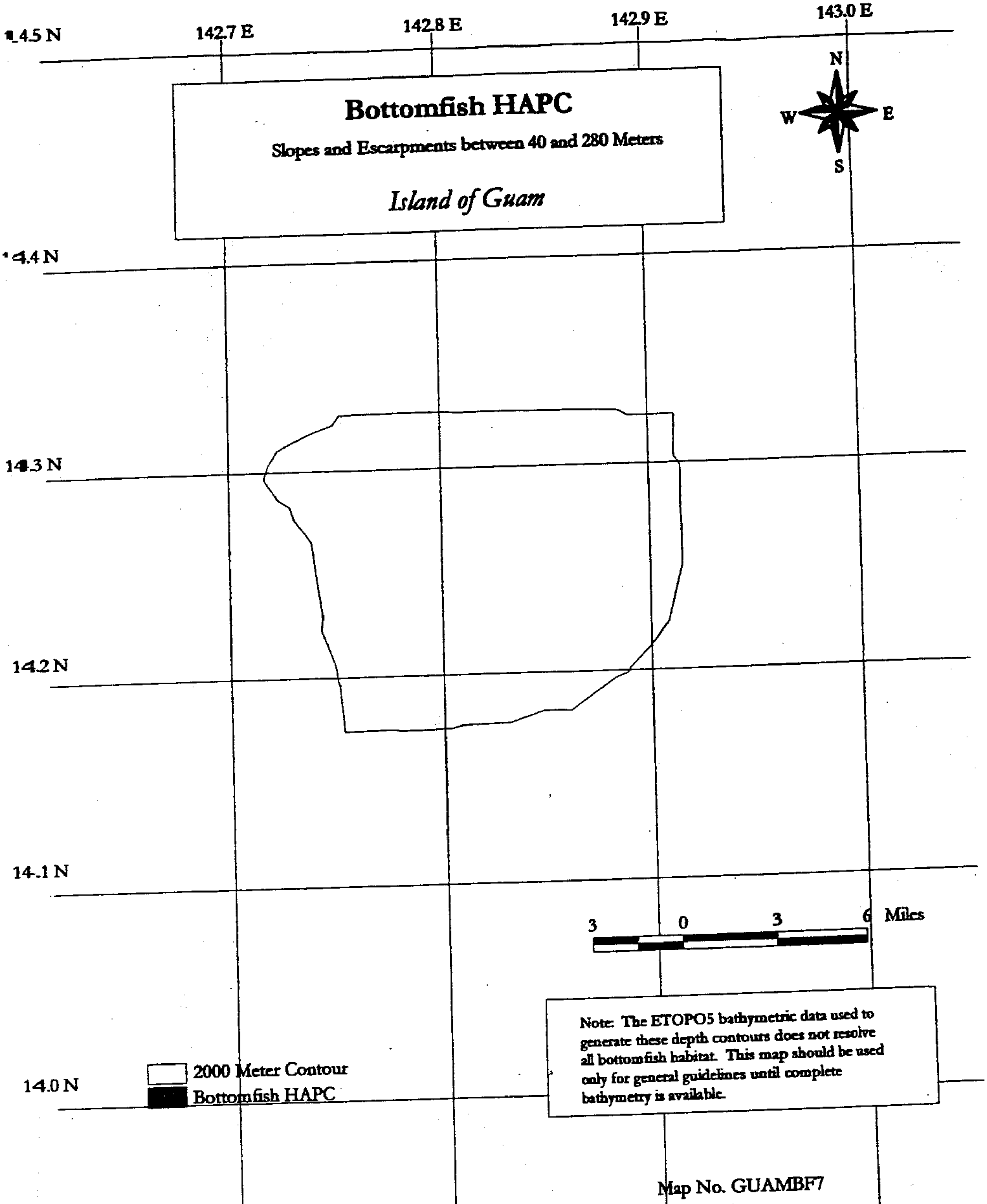


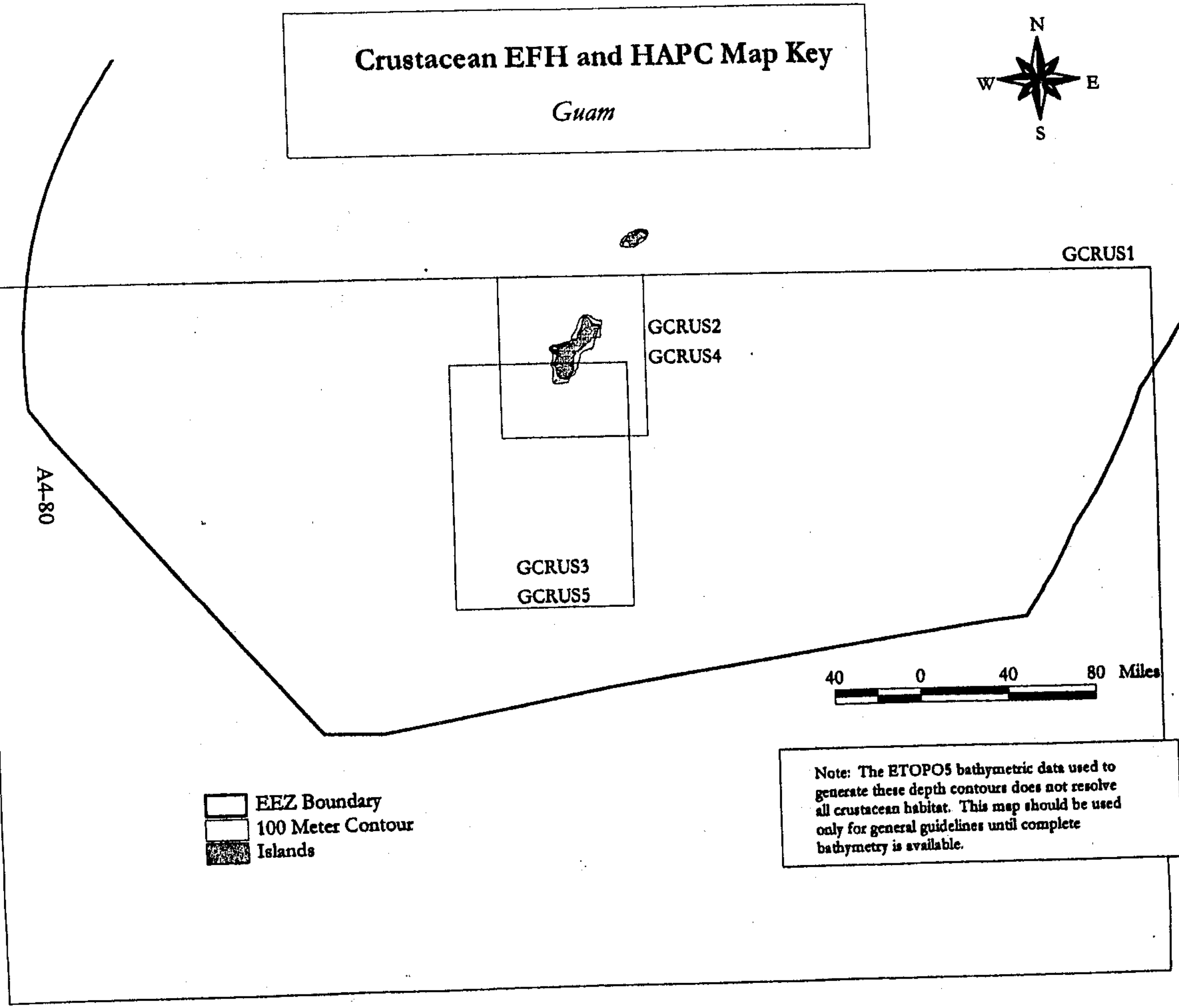
142.6 E
142.7 E
142.8 E
142.9 E
143.0 E
143.1 E
14.6 N
14.5 N
14.4 N
14.3 N
14.2 N
14.1 N
14.0 N
13.9 N
Bottomfish EFH
Postlarval Stages of Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex:
Depth of 100 to 400 Meters
Island of Guam
N
W
E
S
3 0 3 6 Miles
Islands
Shallow Species Complex
Deep Species Complex
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. GUAMBF4

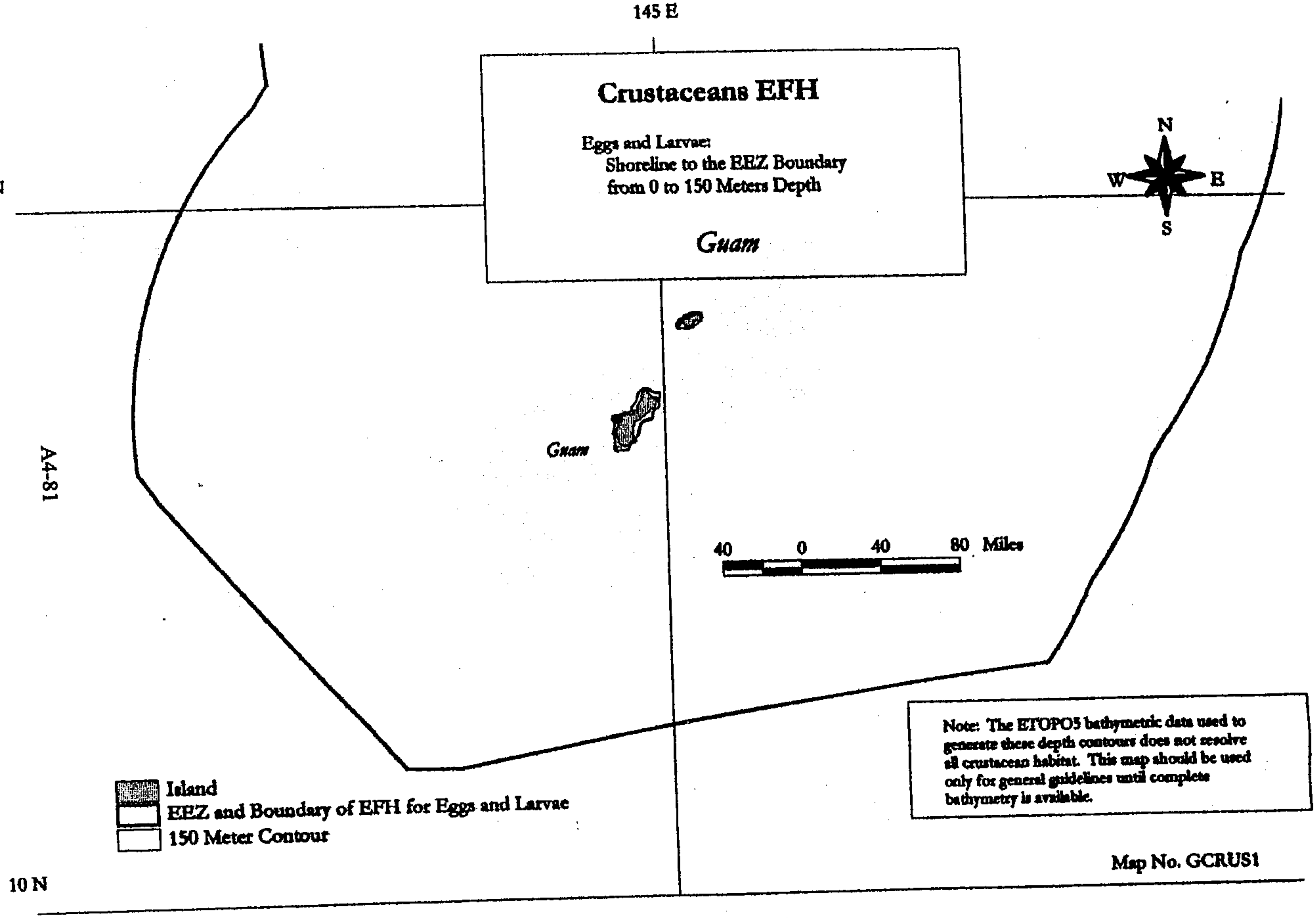

Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Island of Guam
144.5 E
145.0 E
14.0 N
13.5 N
13.0 N
N
E
S
W
Guam
7 0 7 14 Miles
Island
Bottomfish HAPC
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.

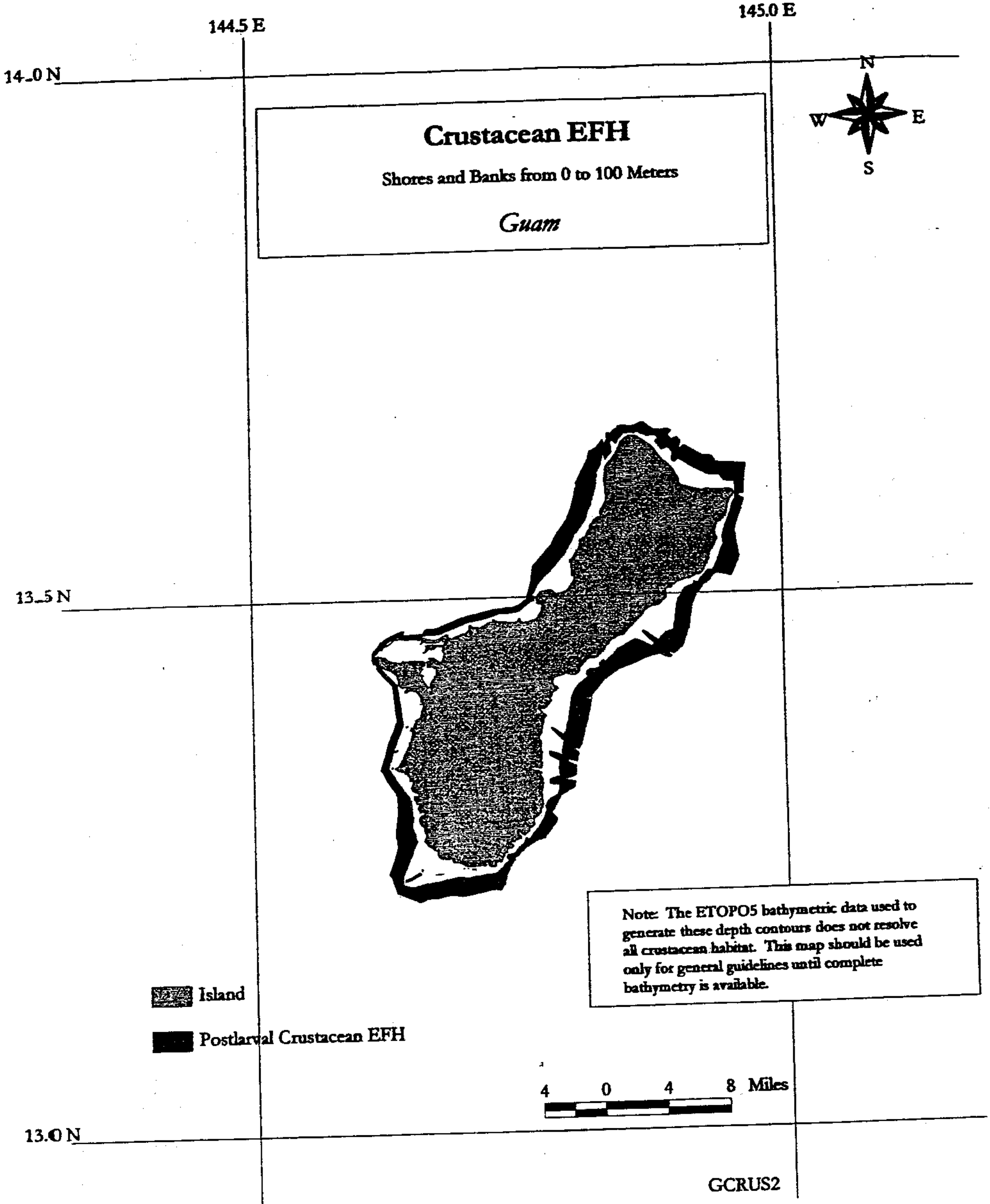


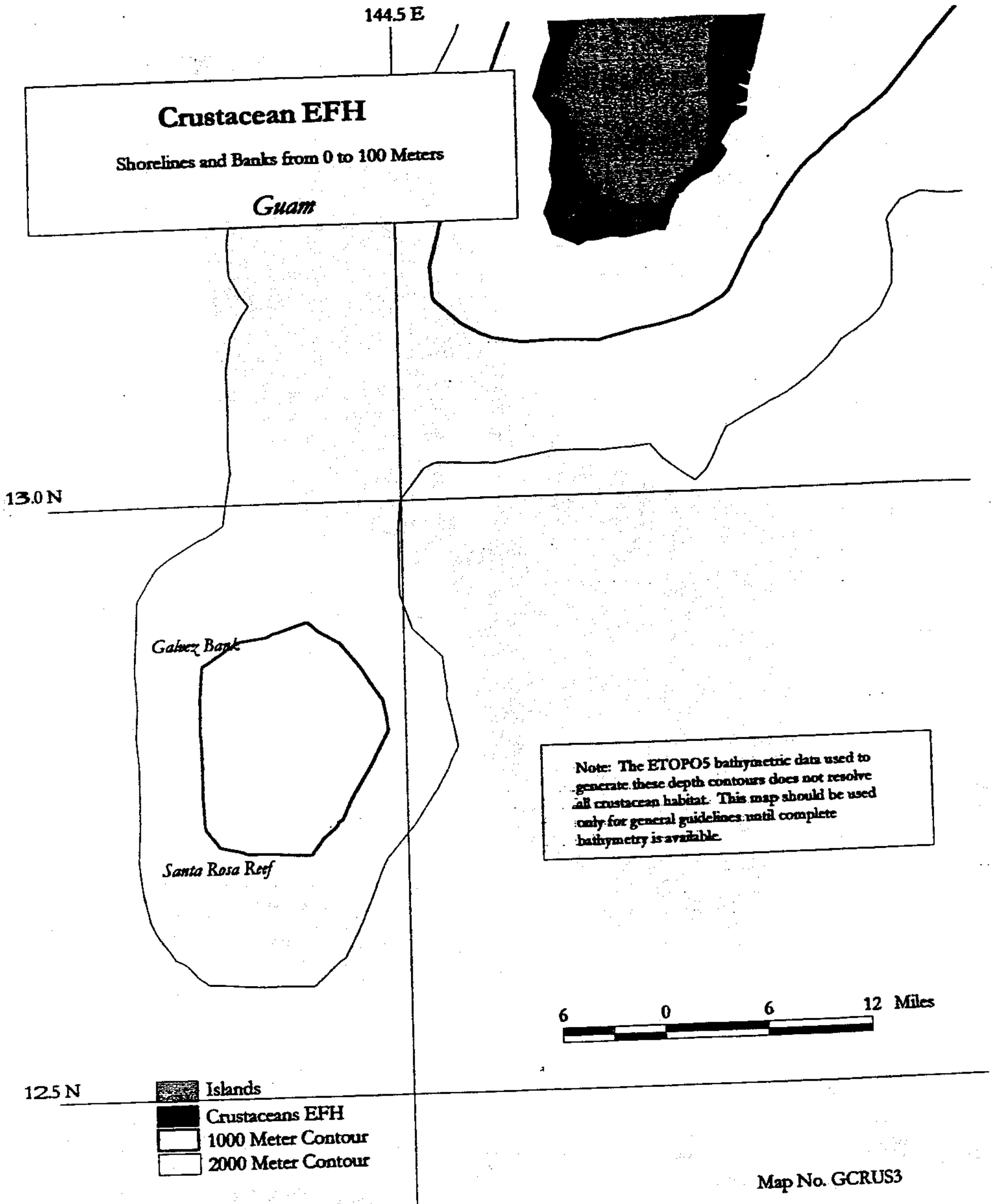
Map No. GUAMBF6

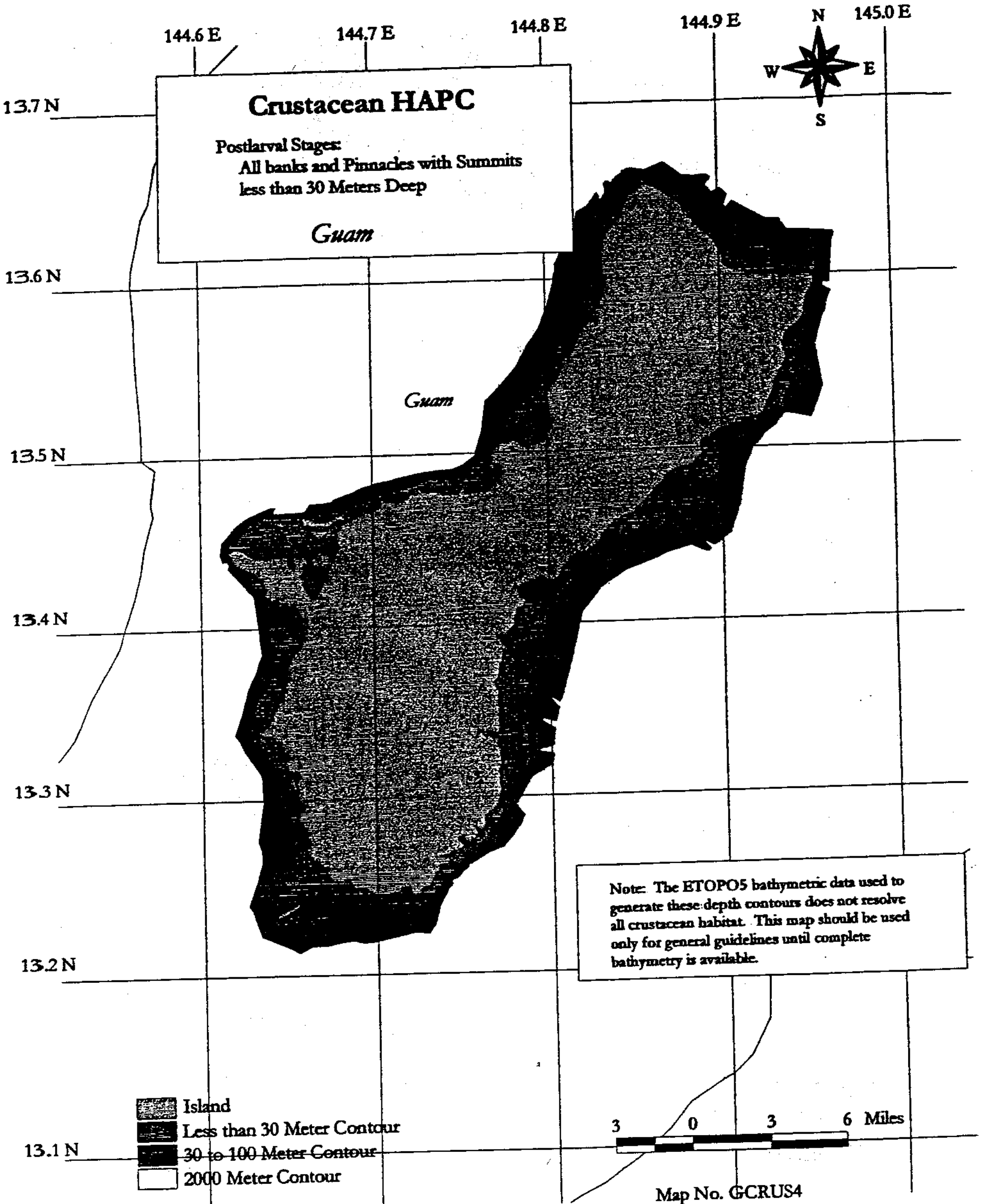

Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Island of Guam
142.7 E
142.8 E
142.9 E
143.0 E
14.5 N
14.4 N
14.3 N
14.2 N
14.1 N
14.0 N
N
S
W
E
3
0
3
6
Miles
2000 Meter Contour
Bottomfish HAPC
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. GUAMBF7

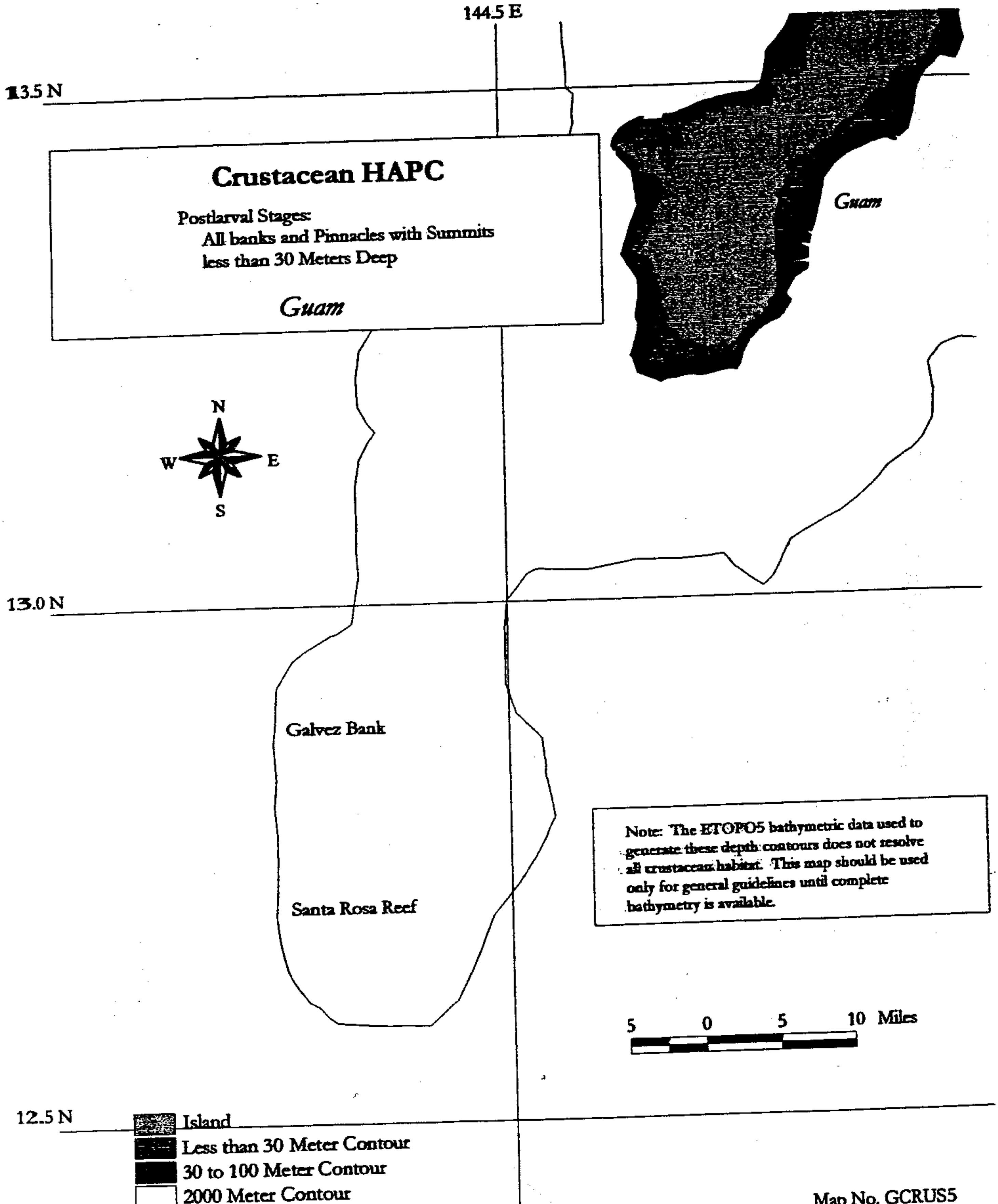

Crustacean EFH and HAPC Map Key
Guam
N
W
E
S
GCRUS1
GCRUS2
GCRUS4
GCRUS3
GCRUS5
40 0 40 80 Miles
EEZ Boundary
100 Meter Contour
Islands
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.

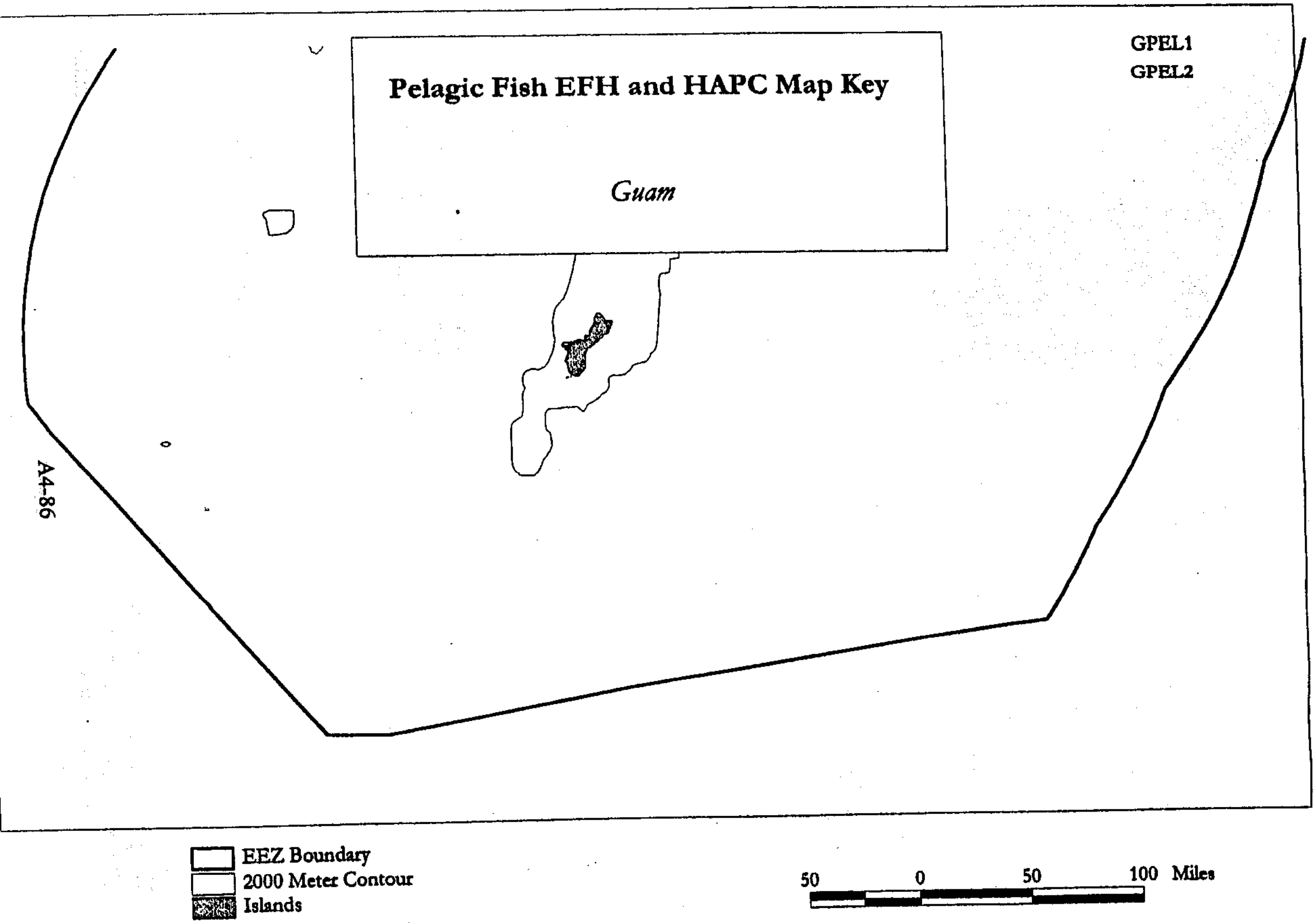

145 E
Crustaceans EFH
Eggs and Larvae:
Shoreline to the EEZ Boundary
from 0 to 150 Meters Depth
Guam
N
W
E
S
Guam
40
0
40
80
Miles
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Island
EEZ and Boundary of EFH for Eggs and Larvae
150 Meter Contour
Map No. GCRUS1
10 N

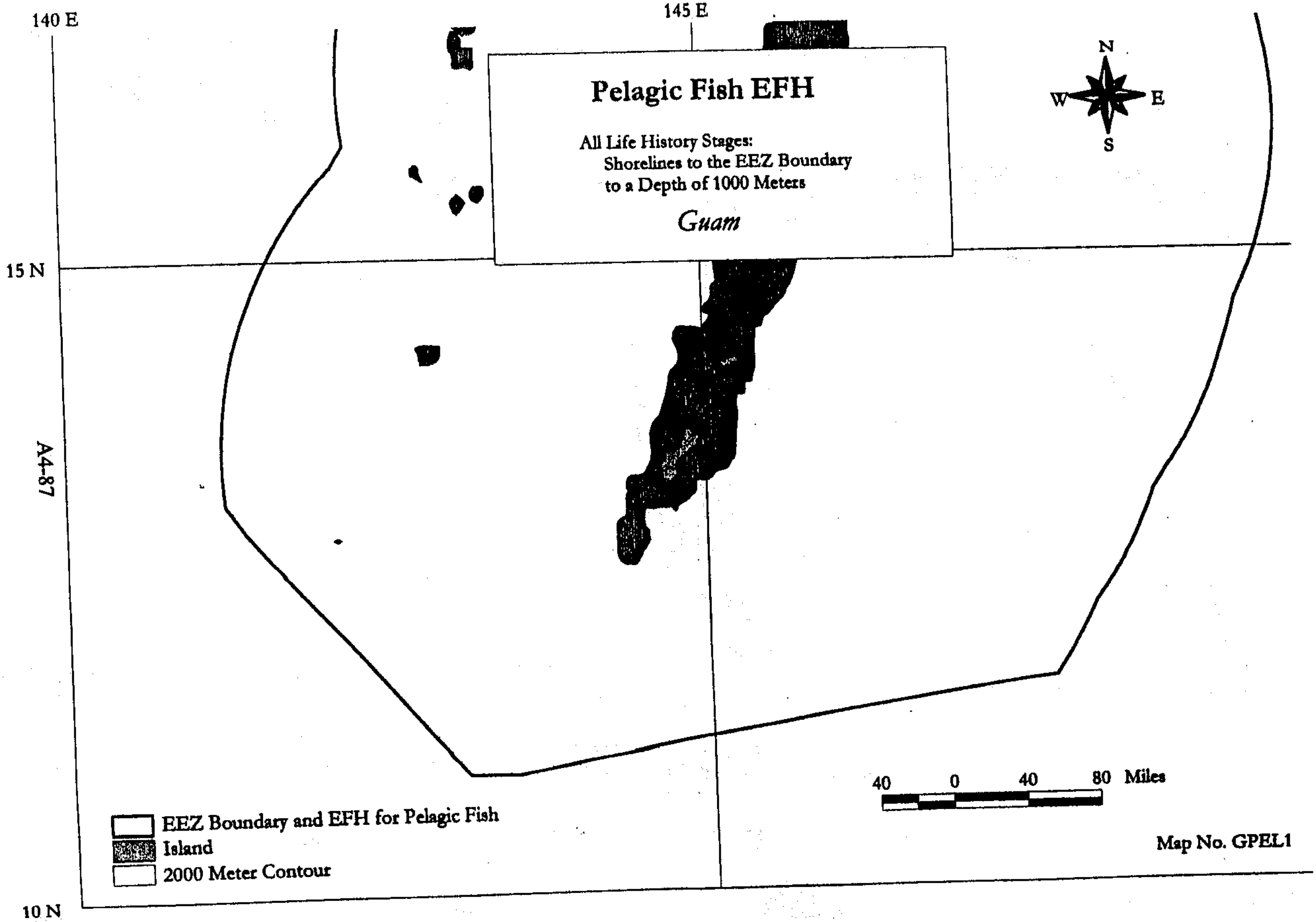

Crustacean EFH
Shores and Banks from 0 to 100 Meters
Guam
144.5 E
145.0 E
14.0 N
13.5 N
13.0 N
N
S
E
W
Island
Postlarval Crustacean EFH
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
4 0 4 8 Miles
GCRUS2

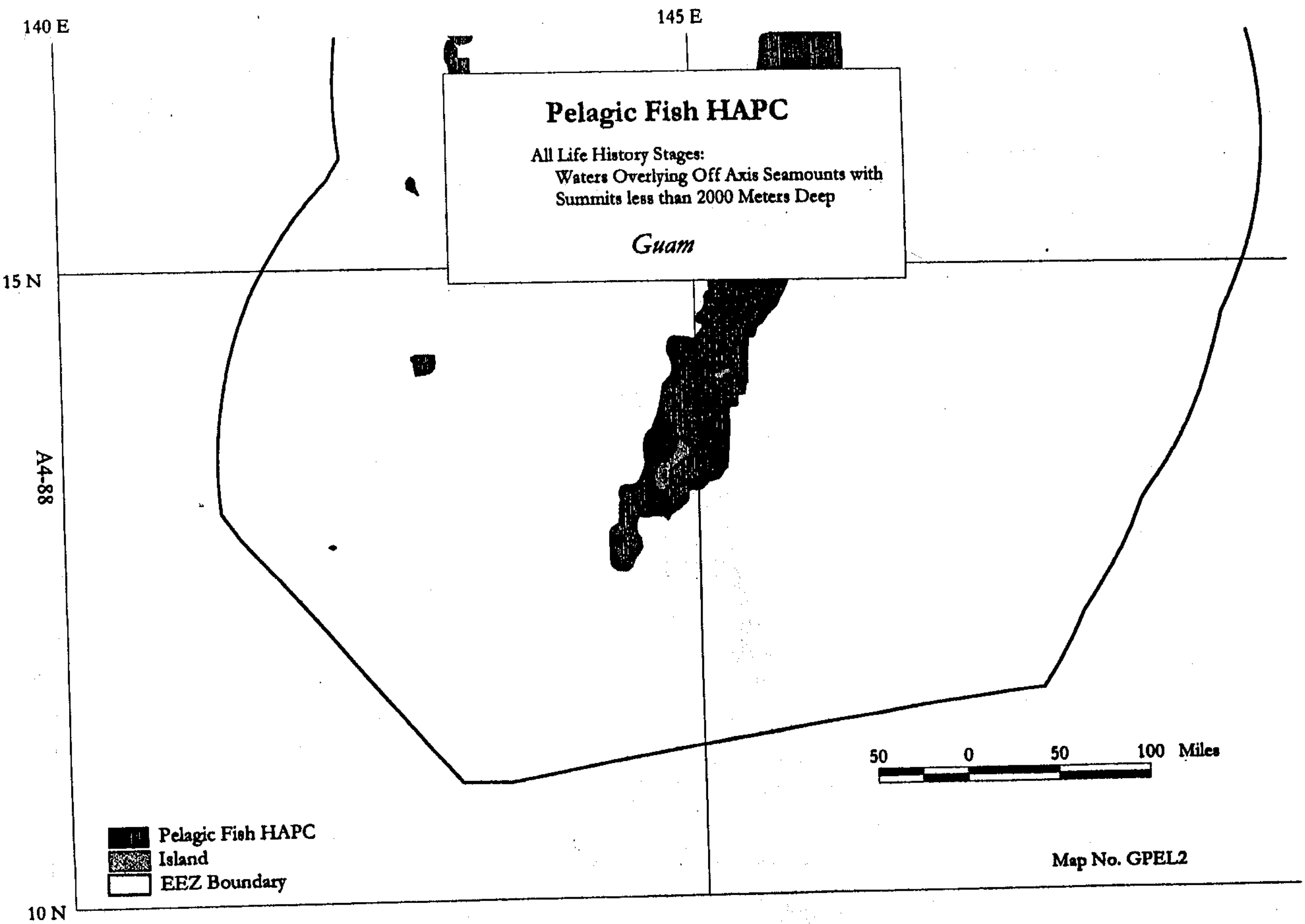

144.5 E
Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Guam
13.0 N
Galvez Bank
Santa Rosa Reef
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
6 0 6 12 Miles
12.5 N
Islands
Crustaceans EFH
1000 Meter Contour
2000 Meter Contour
Map No. GCRUS3


Crustacean HAPC
Postlarval Stages:
All banks and Pinnacles with Summits less than 30 Meters Deep
Guam
144.6 E
144.7 E
144.8 E
144.9 E
145.0 E
13.7 N
13.6 N
13.5 N
13.4 N
13.3 N
13.2 N
13.1 N
N
S
E
W
Guam
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Island
Less than 30 Meter Contour
30 to 100 Meter Contour
2000 Meter Contour
3 0 3 6 Miles
Map No. GCRUS4

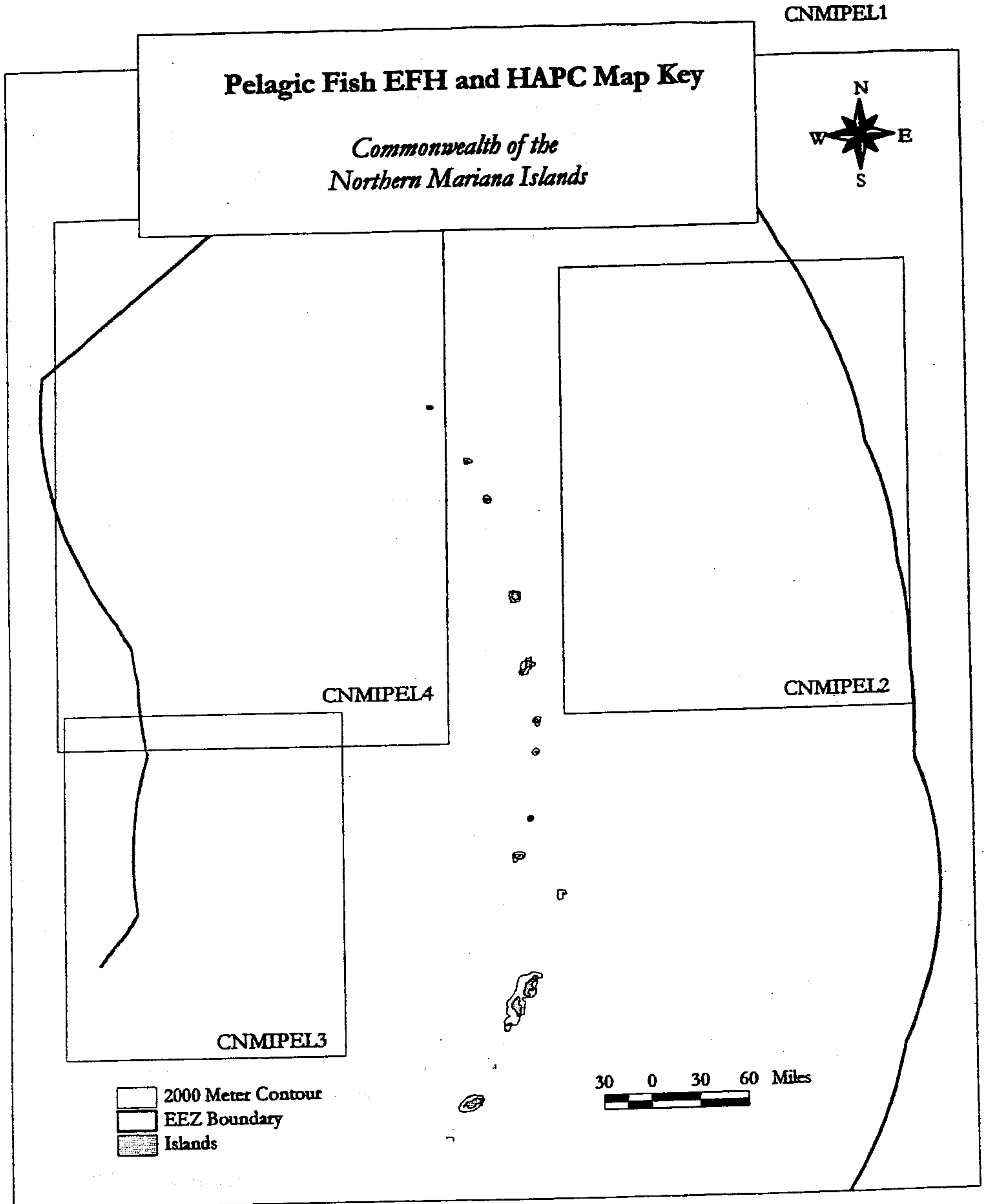

144.5 E
13.5 N
Crustacean HAPC
Postlarval Stages:
All banks and Pinnacles with Summits
less than 30 Meters Deep
Guam
Guam
N
W
E
S
13.0 N
Galvez Bank
Santa Rosa Reef
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
5 0 5 10 Miles
12.5 N
Island
Less than 30 Meter Contour
30 to 100 Meter Contour
2000 Meter Contour
Map No. GCRUS5

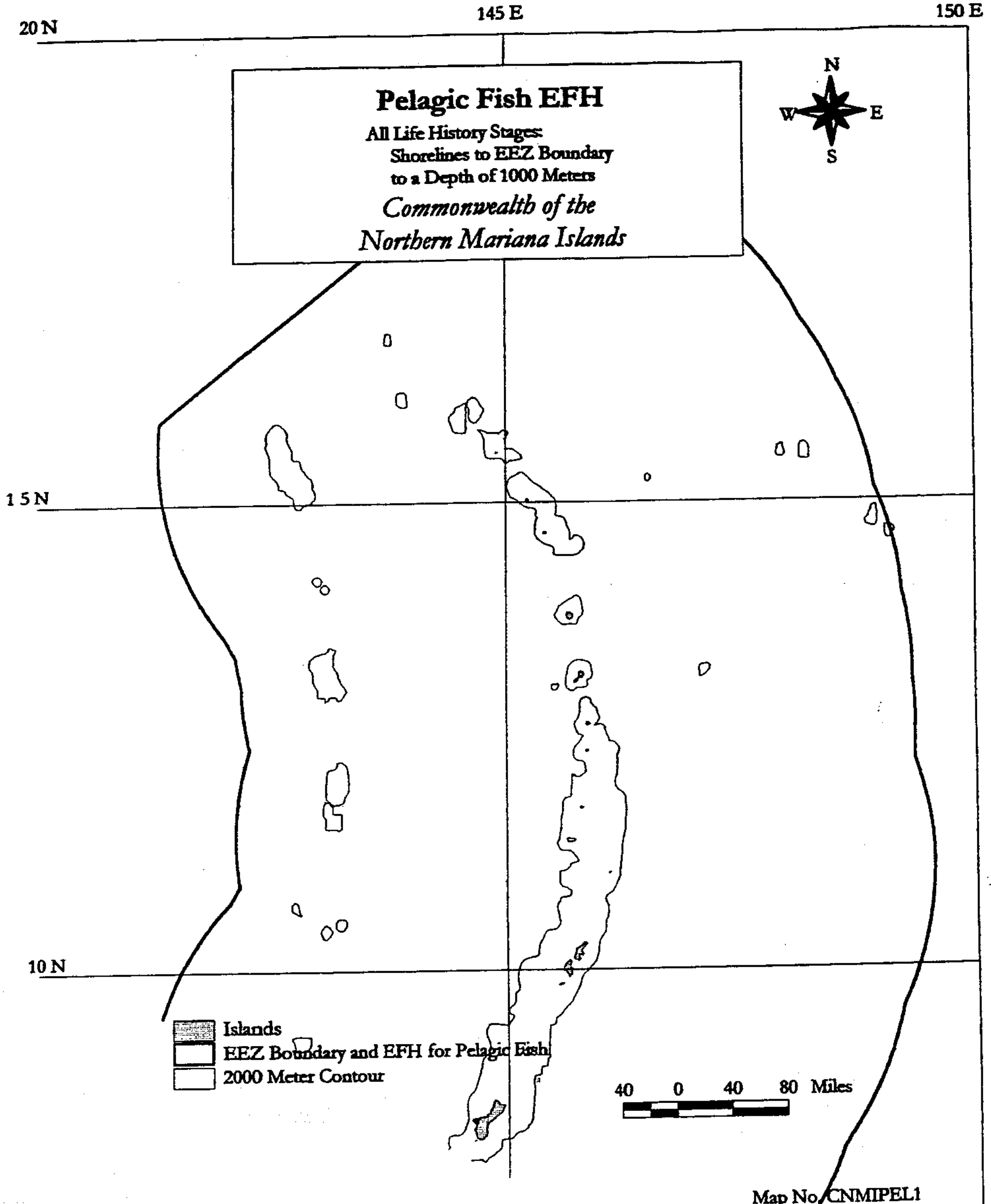

Pelagic Fish EFH and HAPC Map Key
Guam
GPEL1
GPEL2
EEZ Boundary
2000 Meter Contour
Islands
50
0
50
100 Miles


140 E
145 E
15 N
10 N
Pelagic Fish EFH
All Life History Stages:
Shorelines to the EEZ Boundary
to a Depth of 1000 Meters
Guam
N
W
E
S
40
0
40
80
Miles
Map No. GPEL1
EEZ Boundary and EFH for Pelagic Fish
Island
2000 Meter Contour

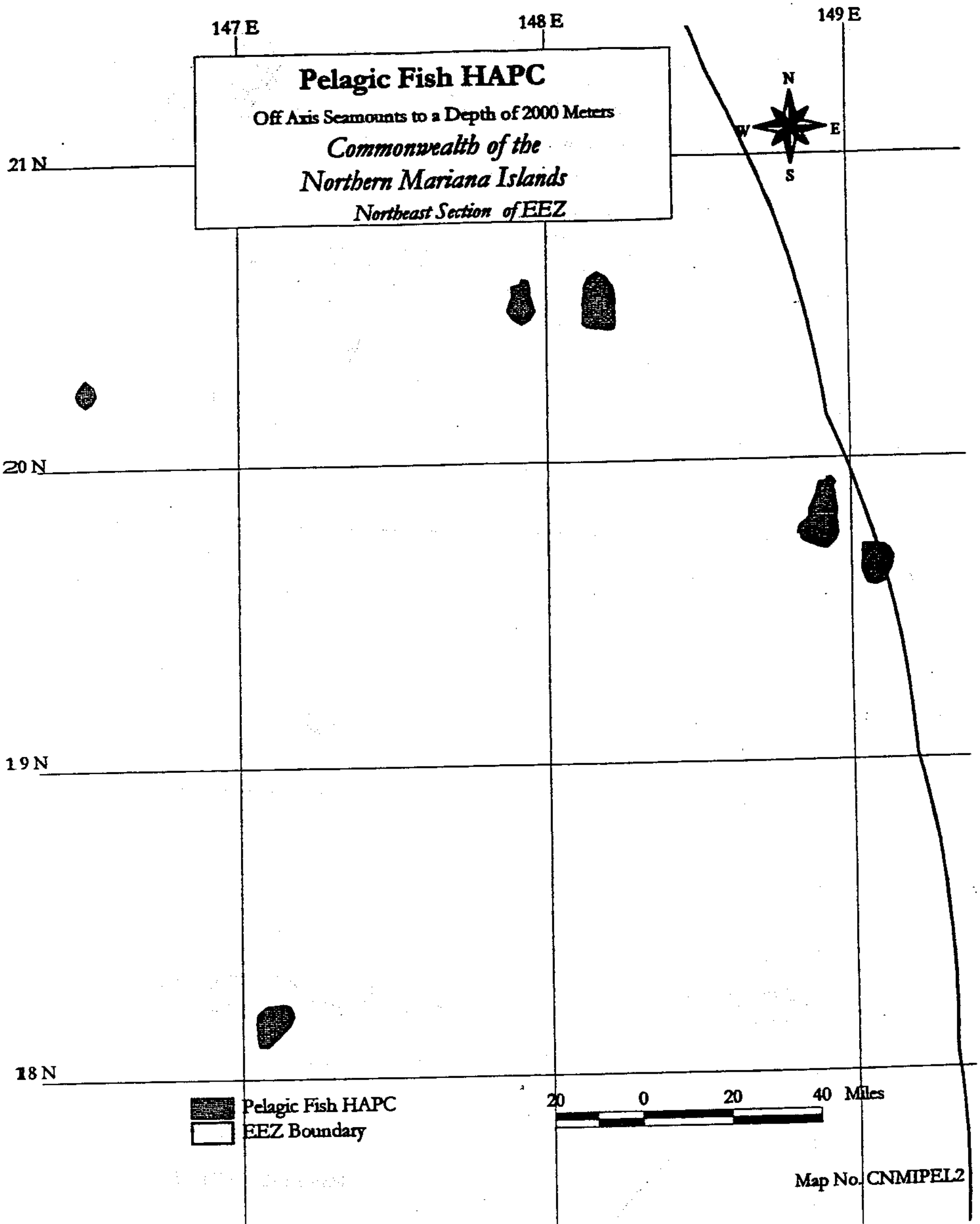


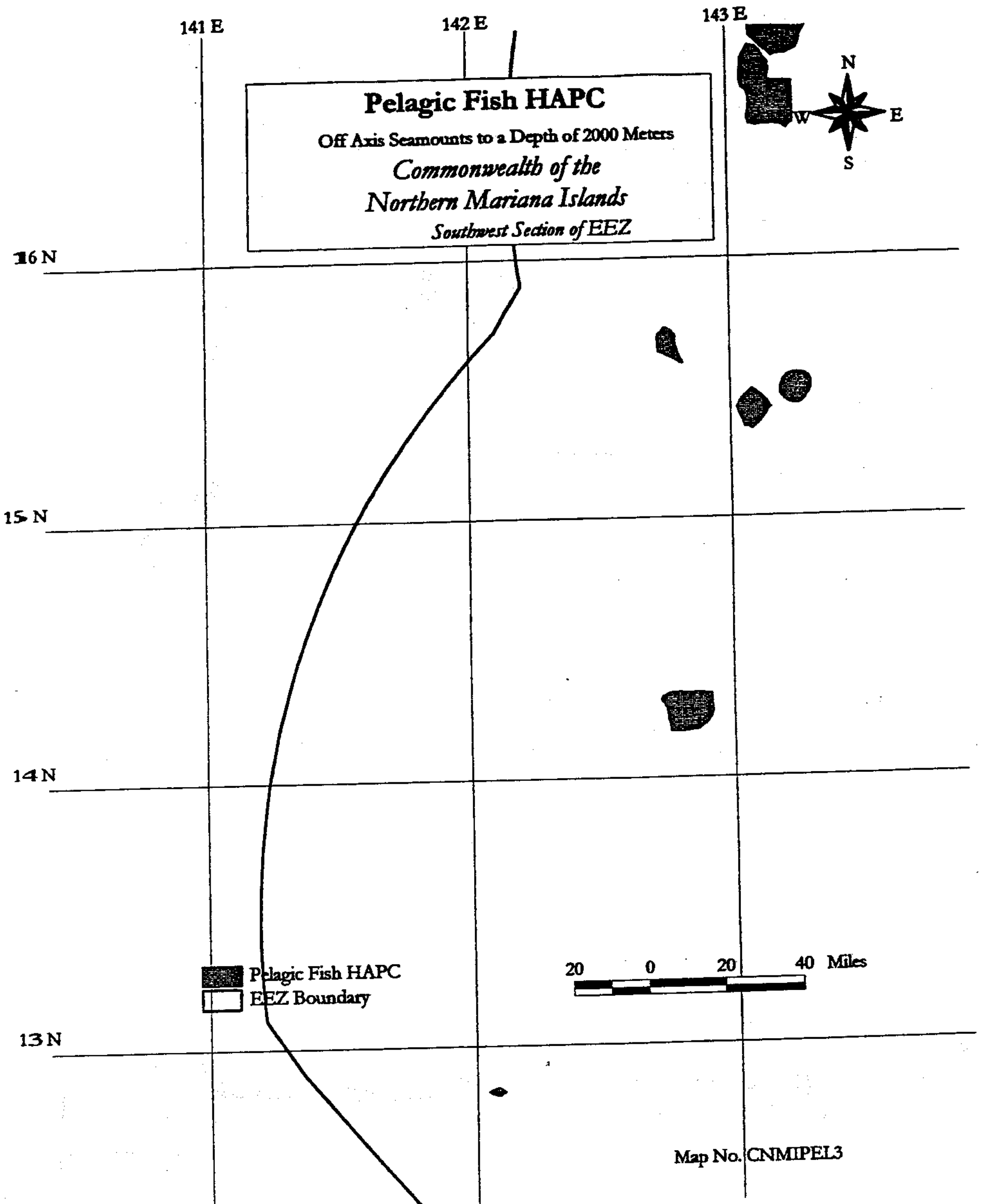
Pelagic Fish HAPC
All Life History Stages:
Waters Overlying Off Axis Seamounts with Summits less than 2000 Meters Deep
Guam
140 E
145 E
15 N
10 N
50
0
50
100 Miles
Pelagic Fish HAPC
Island
EEZ Boundary
Map No. GPEL2

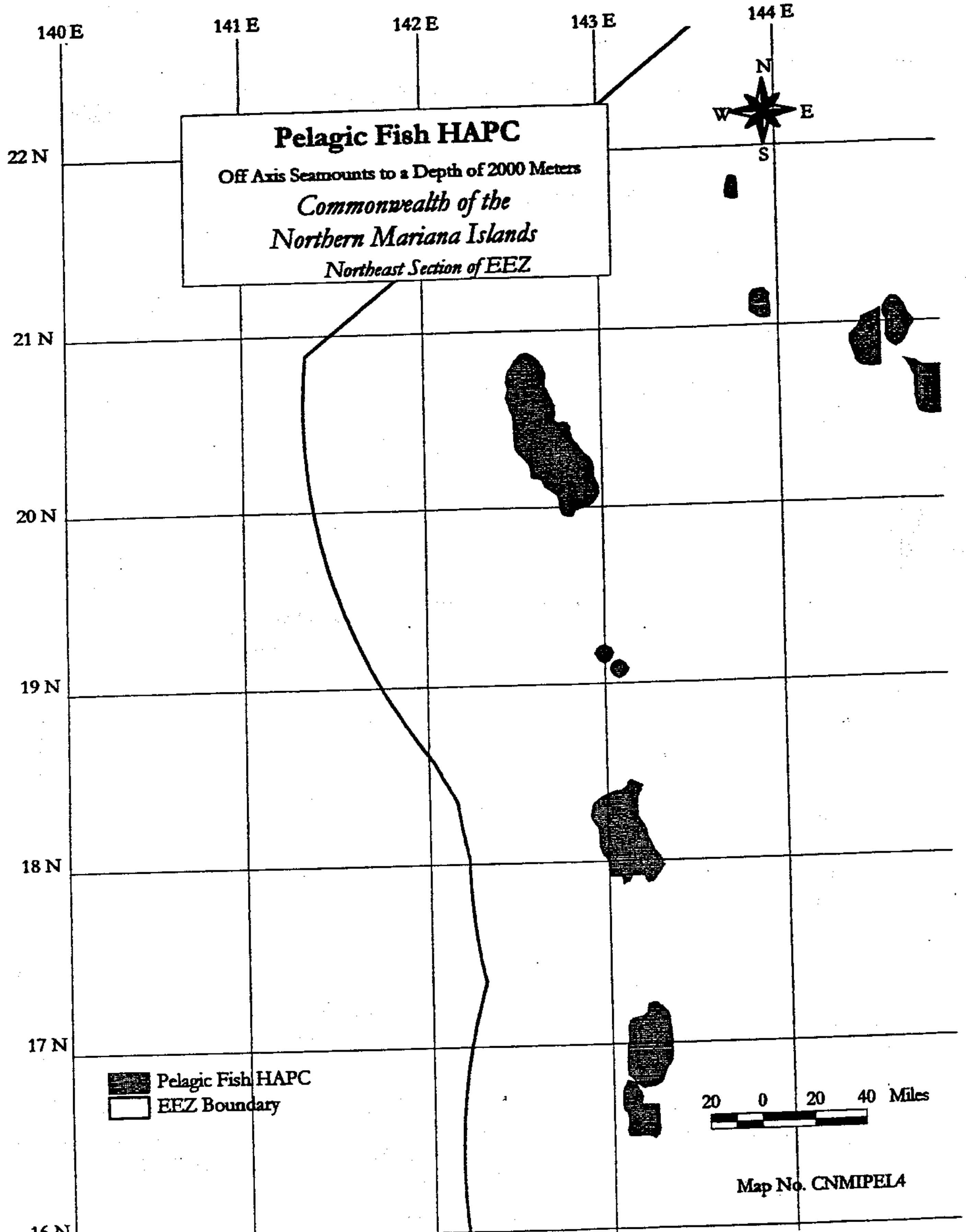

CNMIPEL1
Pelagic Fish EFH and HAPC Map Key
Commonwealth of the
Northern Mariana Islands
N
W
E
S
CNMIPEL4
CNMIPEL2
CNMIPEL3
2000 Meter Contour
EEZ Boundary
Islands
30 0 30 60 Miles

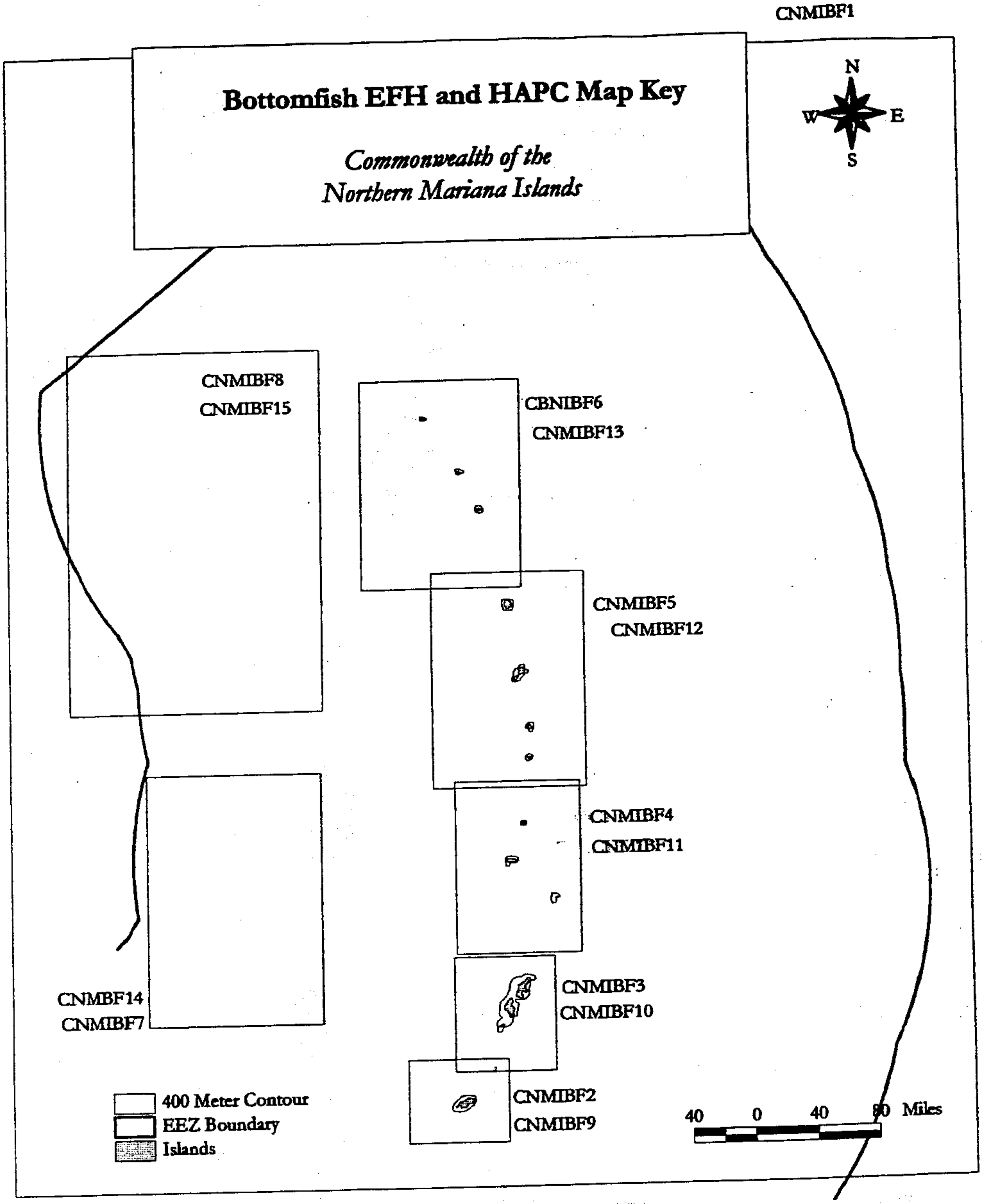


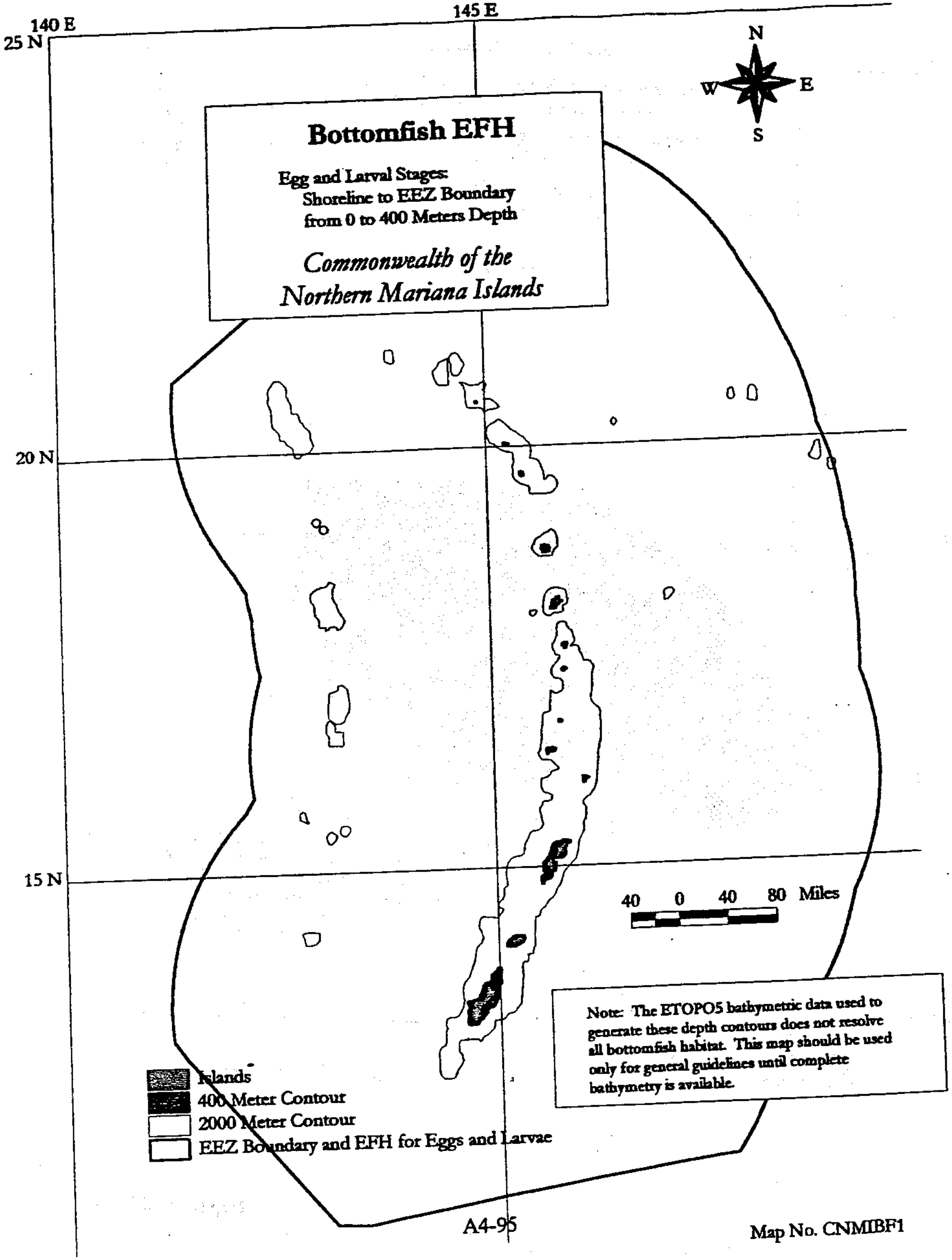
145 E
150 E
20 N
Pelagic Fish EFH
All Life History Stages:
Shorelines to EEZ Boundary
to a Depth of 1000 Meters
Commonwealth of the
Northern Mariana Islands
N
W
E
S
15 N
10 N
Islands
EEZ Boundary and EFH for Pelagic Fish
2000 Meter Contour
40 0 40 80 Miles
Map No. CNMIPEL1


Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 2000 Meters
Commonwealth of the
Northern Mariana Islands
Northeast Section of EEZ
147 E
148 E
149 E
21 N
20 N
19 N
18 N
N
E
S
W
Pelagic Fish HAPC
EEZ Boundary
20 0 20 40 Miles
Map No. CNMIPEL2

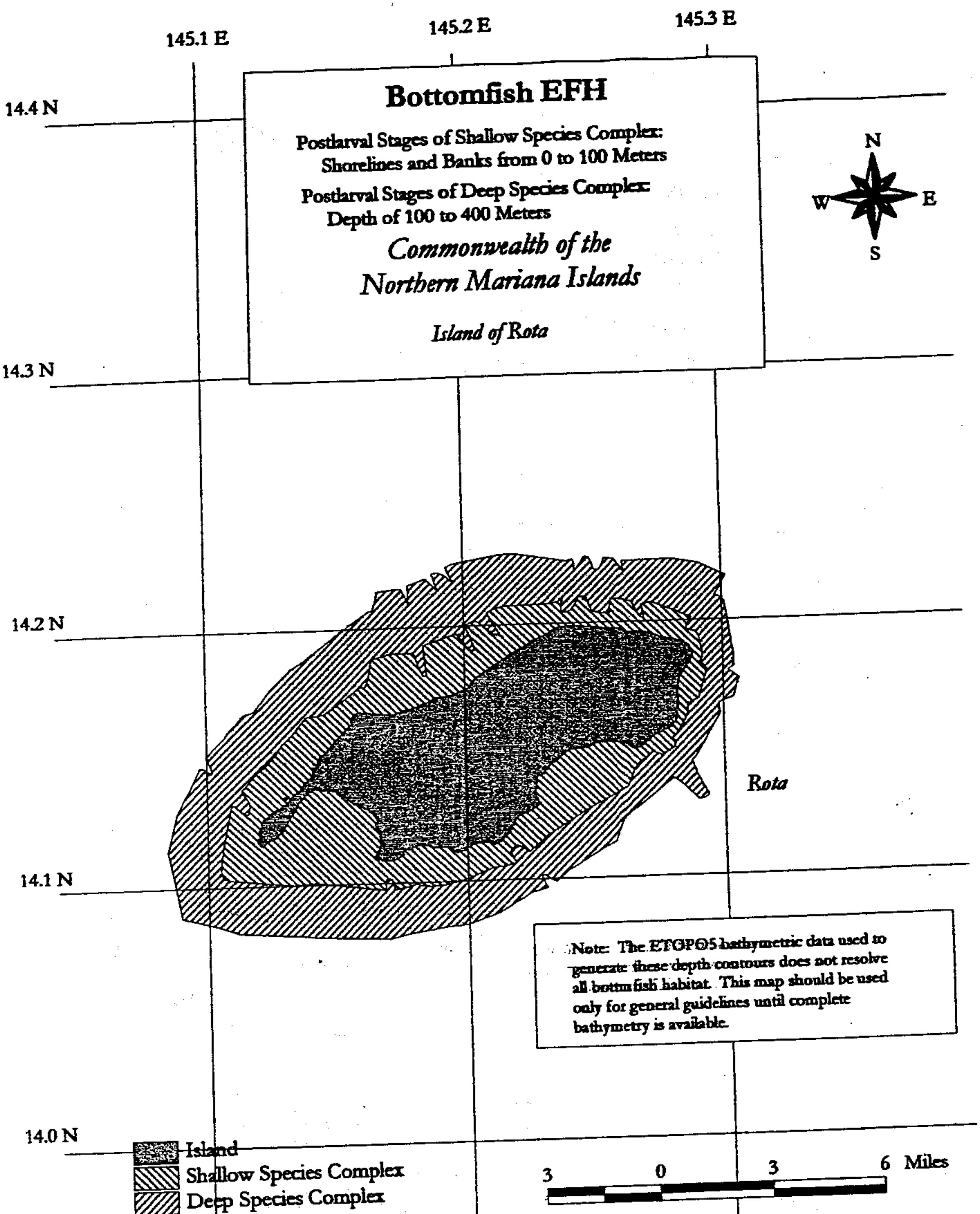

Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 2000 Meters
Commonwealth of the
Northern Mariana Islands
Southwest Section of EEZ
141 E
142 E
143 E
16 N
15 N
14 N
13 N
N
E
S
W
Pelagic Fish HAPC
EEZ Boundary
20
0
20
40
Miles
Map No. CNMIPEL3


Pelagic Fish HAPC
Off Axis Seamounts to a Depth of 2000 Meters
Commonwealth of the
Northern Mariana Islands
Northeast Section of EEZ
140 E
141 E
142 E
143 E
144 E
22 N
21 N
20 N
19 N
18 N
17 N
16 N
N
S
E
W
Pelagic Fish HAPC
EEZ Boundary
20
0
20
40
Miles
Map No. CNMIPEL4

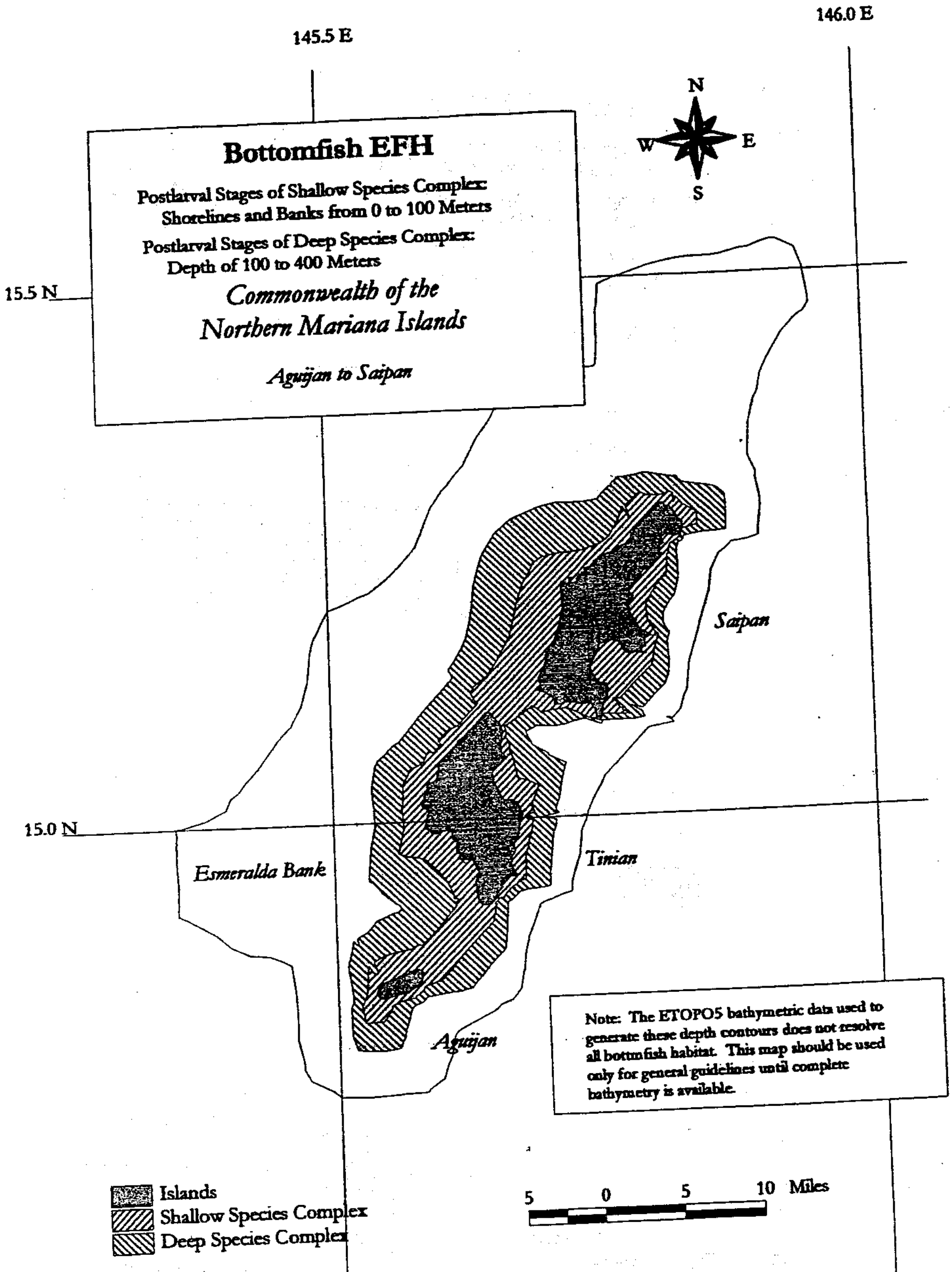

CNMIBF1
Bottomfish EFH and HAPC Map Key
Commonwealth of the Northern Mariana Islands
N
W
E
S
CNMIBF8
CNMIBF15
CBNIBF6
CNMIBF13
CNMIBF5
CNMIBF12
CNMIBF4
CNMIBF11
CNMIBF3
CNMIBF10
CNMBF14
CNMIBF7
CNMIBF2
CNMIBF9
400 Meter Contour
EEZ Boundary
Islands
40 0 40 80 Miles



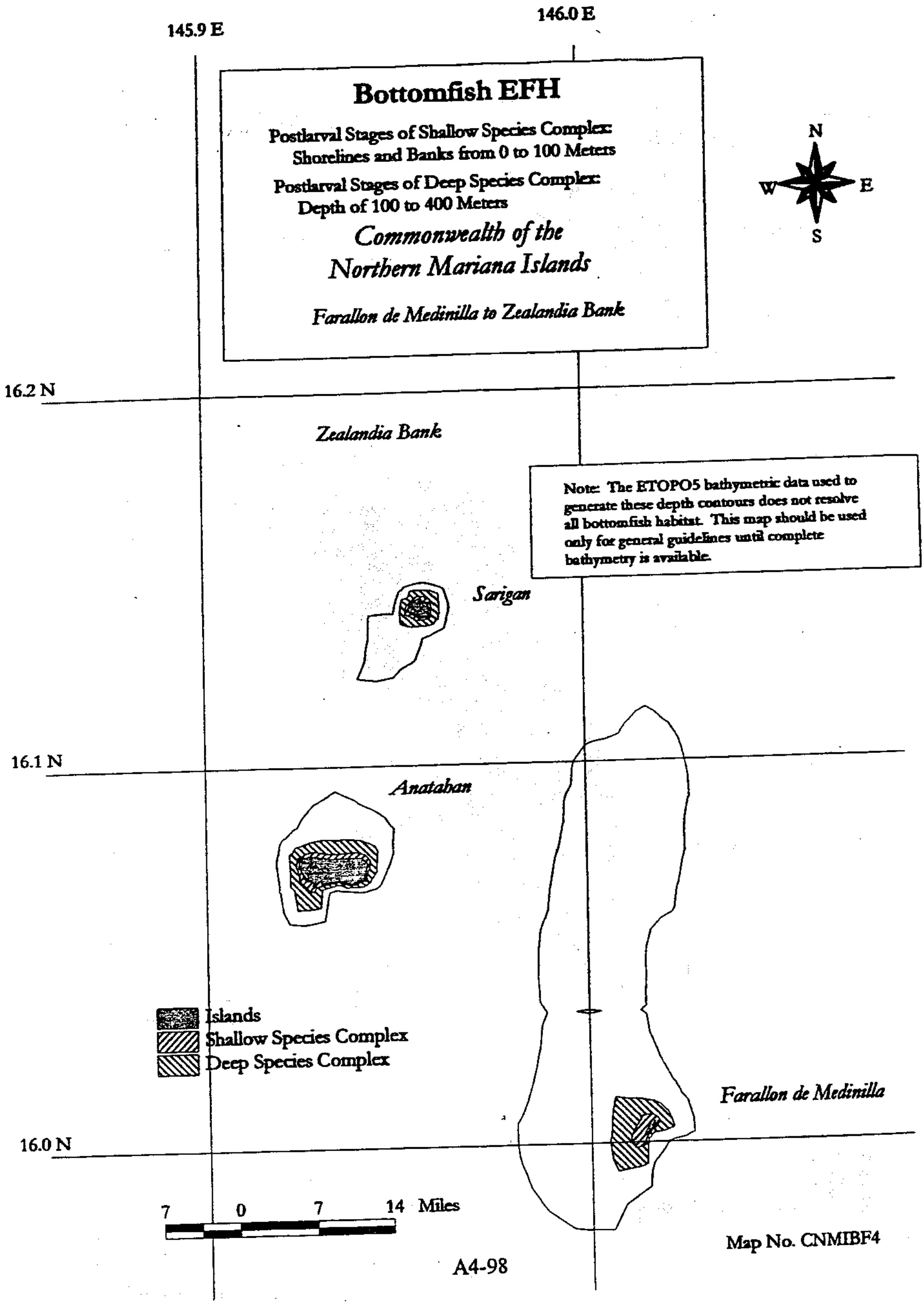
Map No. CNMIBF1

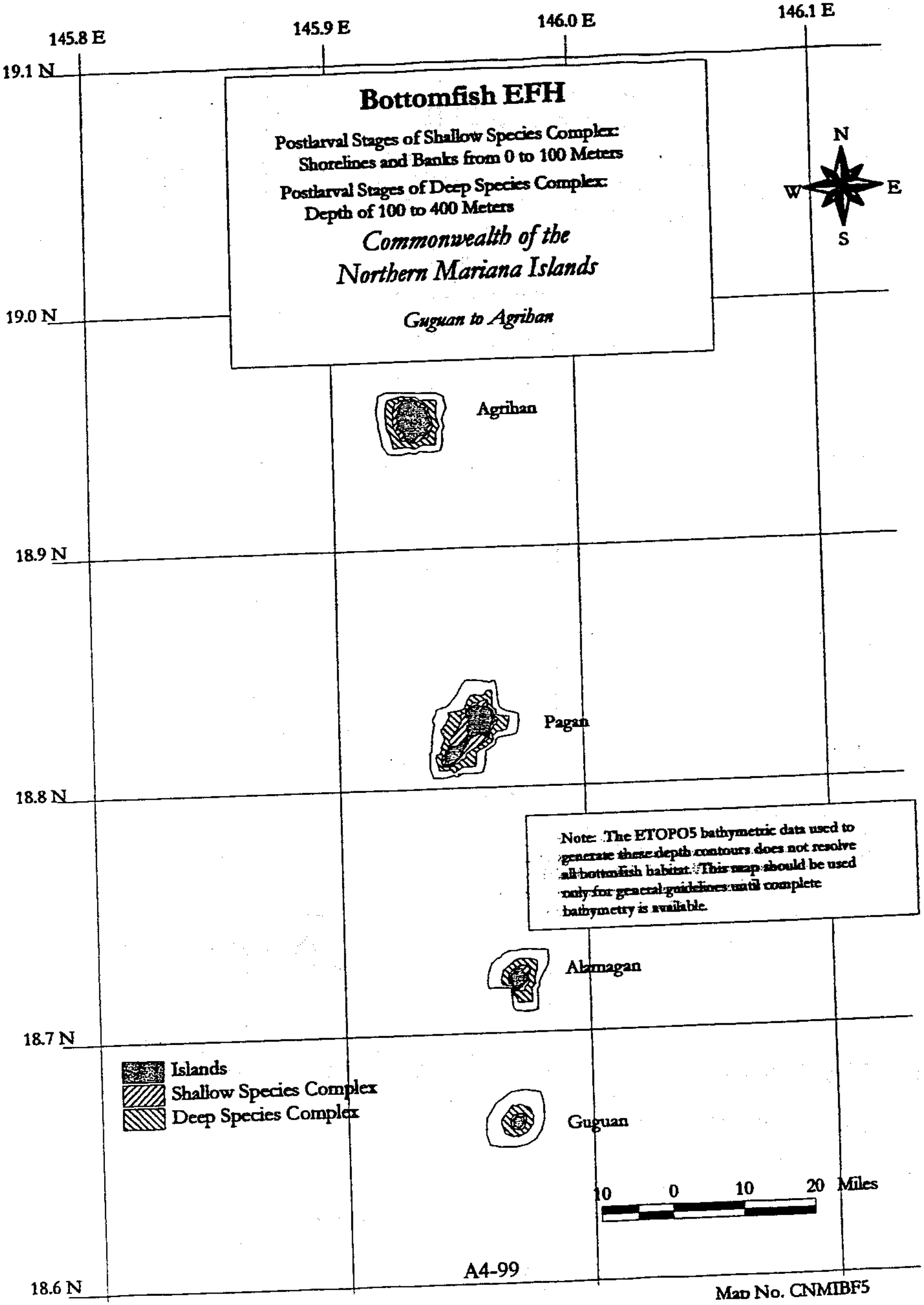


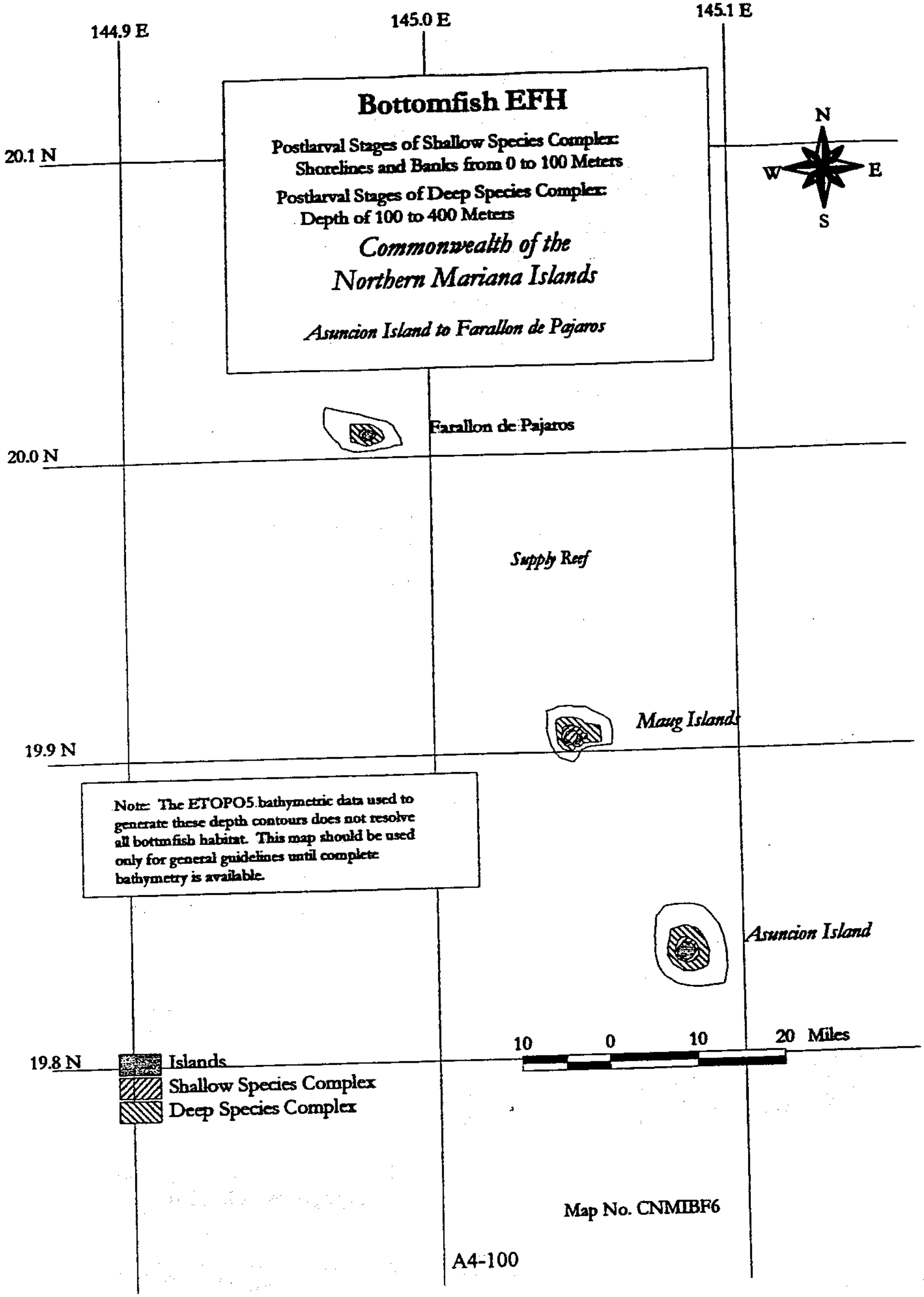
Map No. CNMIBF2



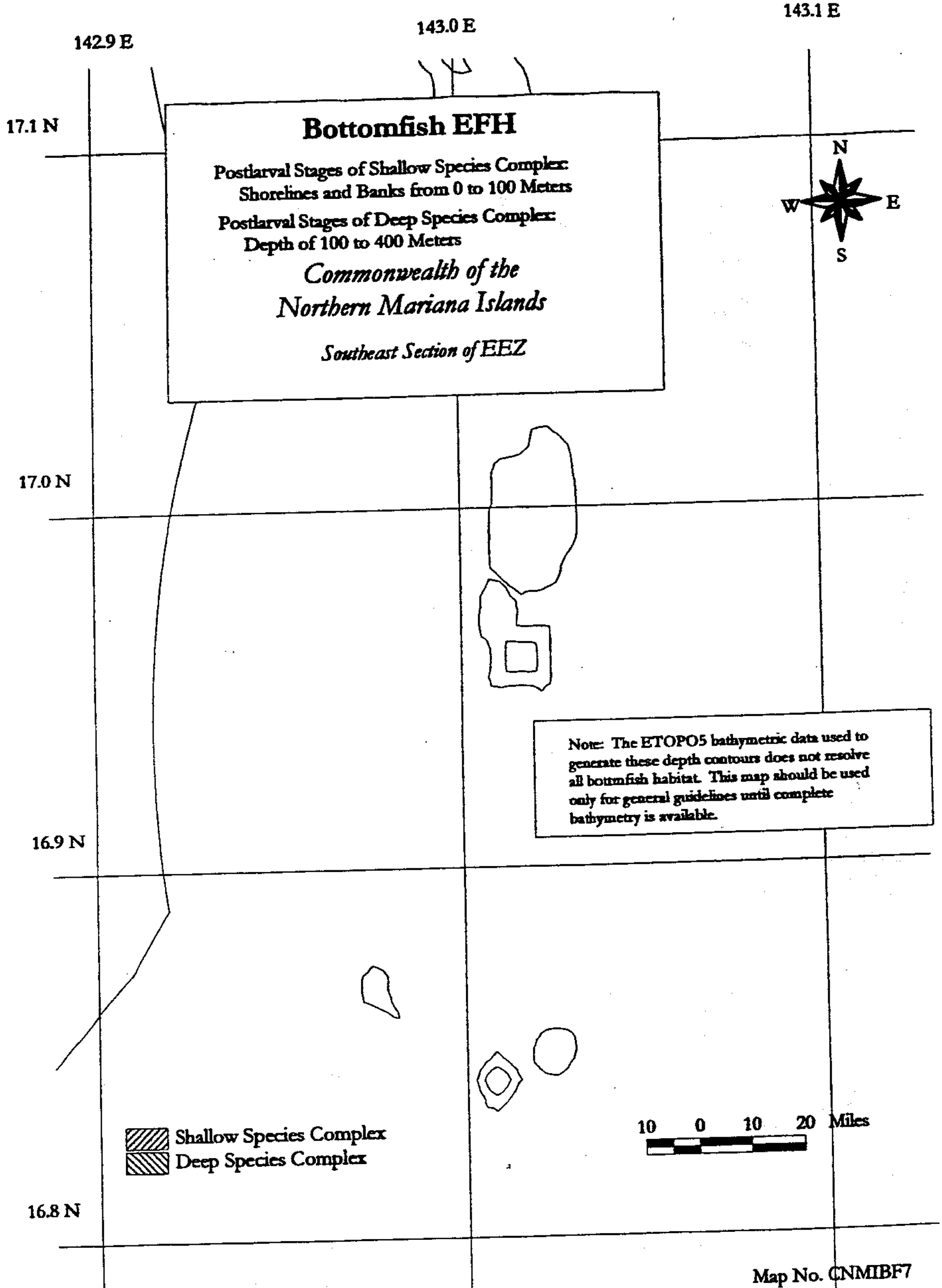
Map No. CNMIBF3


145.9 E
146.0 E
Bottomfish EFH
Postlarval Stages of Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex:
Depth of 100 to 400 Meters
Commonwealth of the
Northern Mariana Islands
Farallon de Medinilla to Zealandia Bank
N
W
E
S
16.2 N
Zealandia Bank
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Sarigan
16.1 N
Anatahan
Islands
Shallow Species Complex
Deep Species Complex
Farallon de Medinilla
16.0 N
7 0 7 14 Miles
Map No. CNMIBF4

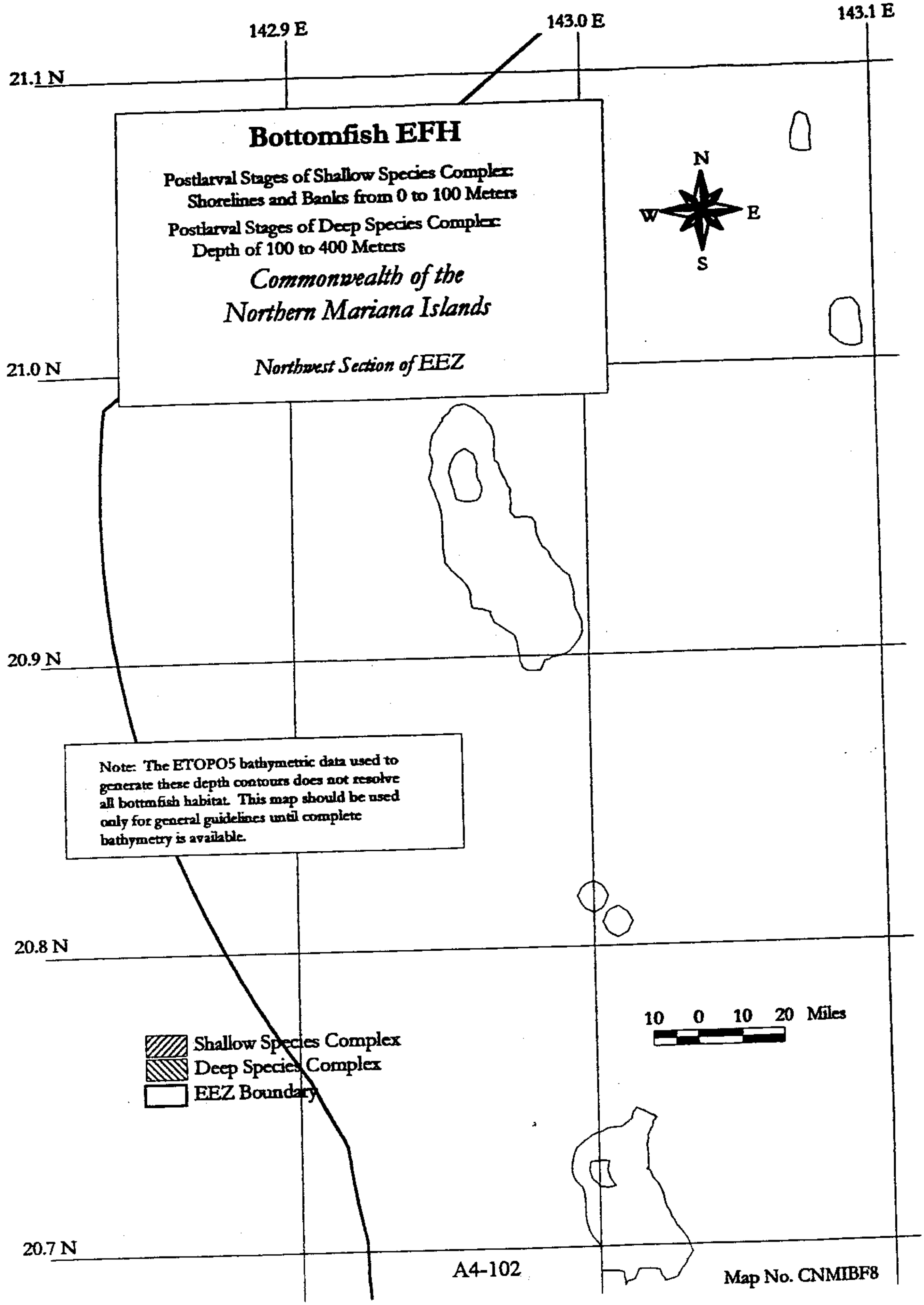

Bottomfish EFH
Postlarval Stages of Shallow Species Complex: Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex: Depth of 100 to 400 Meters
Commonwealth of the Northern Mariana Islands
Guguan to Agrihan
145.8 E
145.9 E
146.0 E
146.1 E
19.1 N
19.0 N
18.9 N
18.8 N
18.7 N
18.6 N
N
W
E
S
Agrihan
Pagan
Alamagan
Guguan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Shallow Species Complex
Deep Species Complex
10
0
10
20
Miles
Map No. CNMIBF5



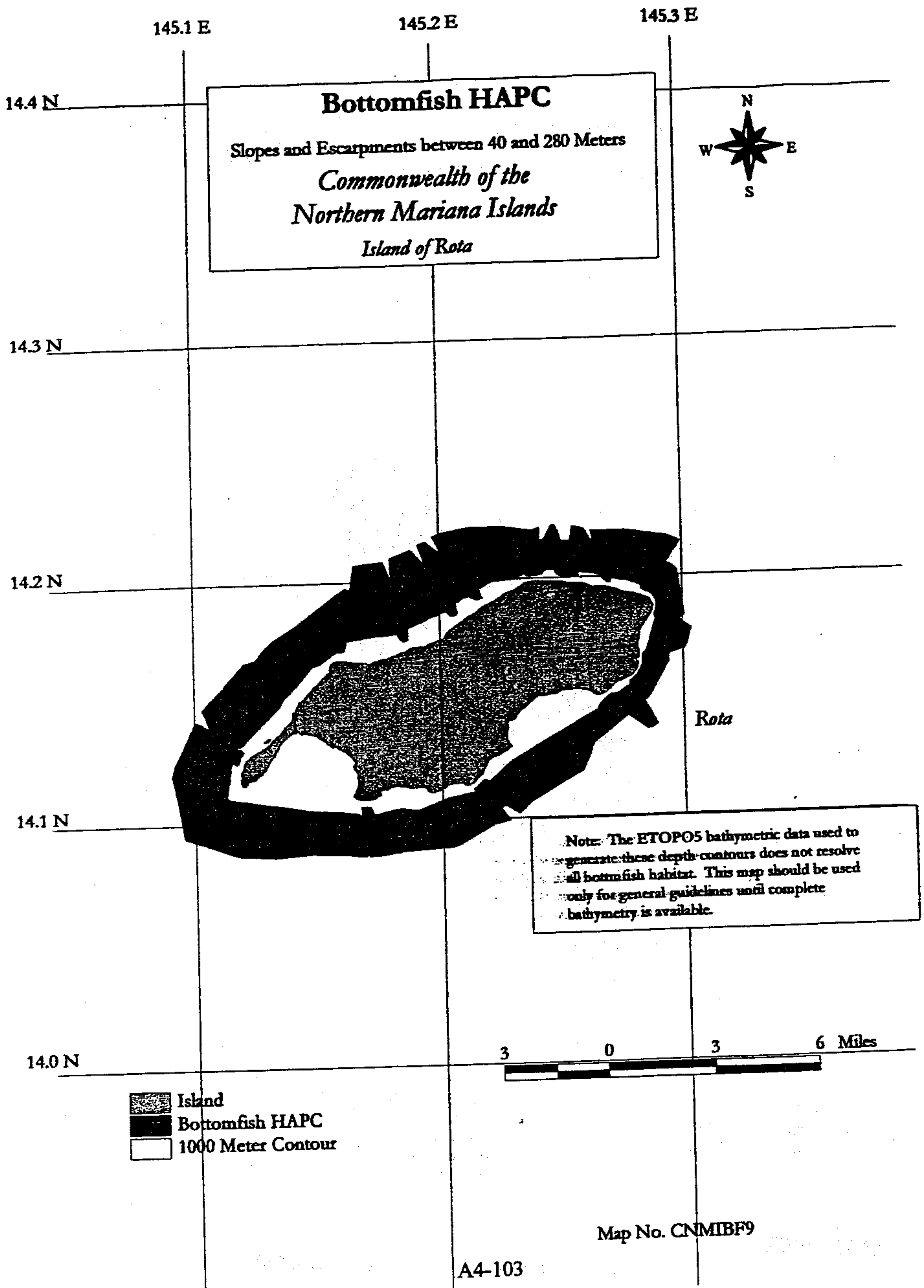
144.9 E
145.0 E
145.1 E
Bottomfish EFH
Postlarval Stages of Shallow Species Complex:
Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex:
Depth of 100 to 400 Meters
Commonwealth of the
Northern Mariana Islands
Asuncion Island to Farallon de Pajaros
20.1 N
N
W
E
S
Farallon de Pajaros
20.0 N
Supply Reef
Maug Islands
19.9 N
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Asuncion Island
10 0 10 20 Miles
19.8 N
Islands
Shallow Species Complex
Deep Species Complex
Map No. CNMIBF6



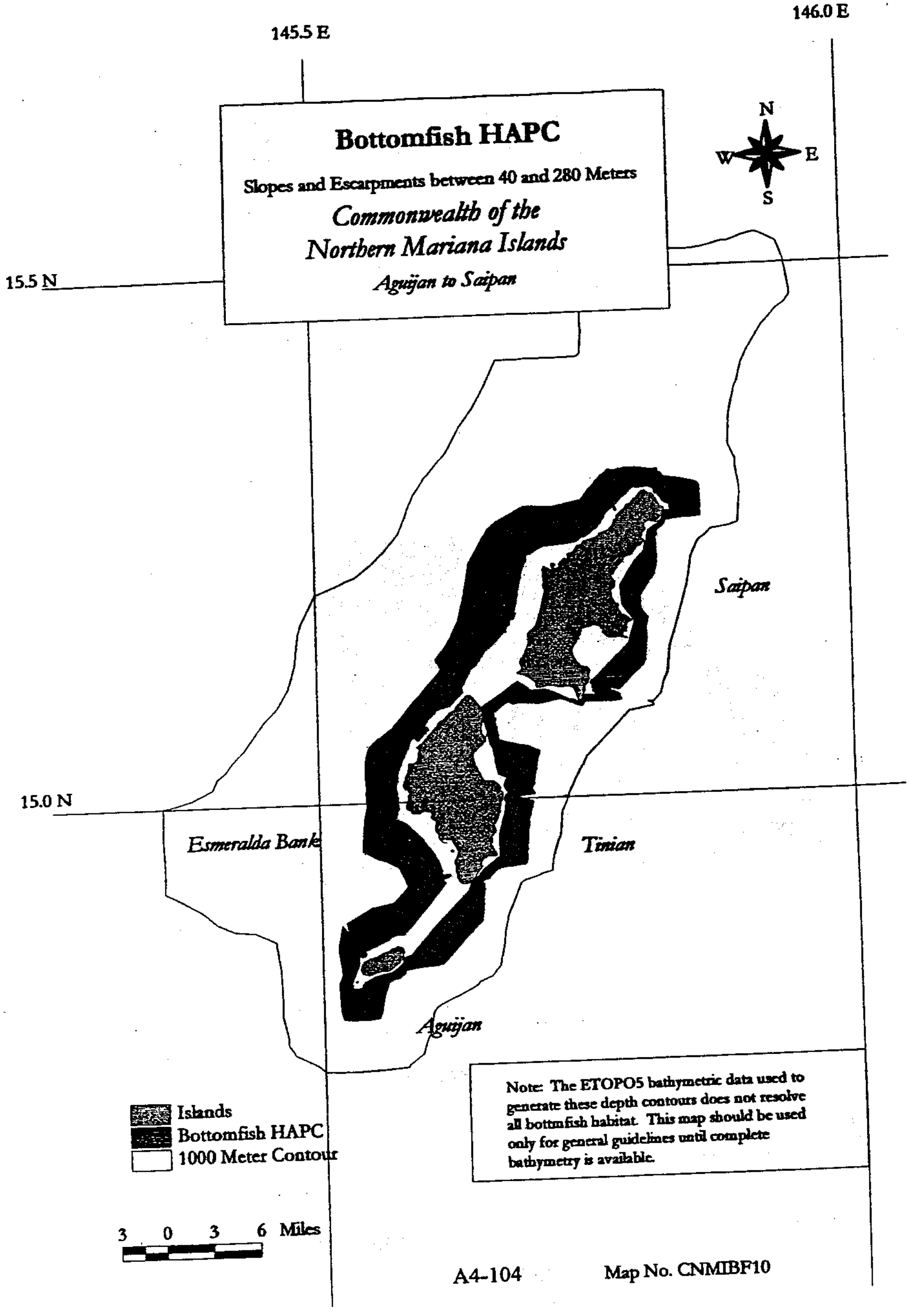
142.9 E
143.0 E
143.1 E
17.1 N
17.0 N
16.9 N
16.8 N
Bottomfish EFH
Postlarval Stages of Shallow Species Complex: Shorelines and Banks from 0 to 100 Meters
Postlarval Stages of Deep Species Complex: Depth of 100 to 400 Meters
Commonwealth of the Northern Mariana Islands
Southeast Section of EEZ
N
W
E
S
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
10 0 10 20 Miles
Shallow Species Complex
Deep Species Complex
Map No. CNMIBF7



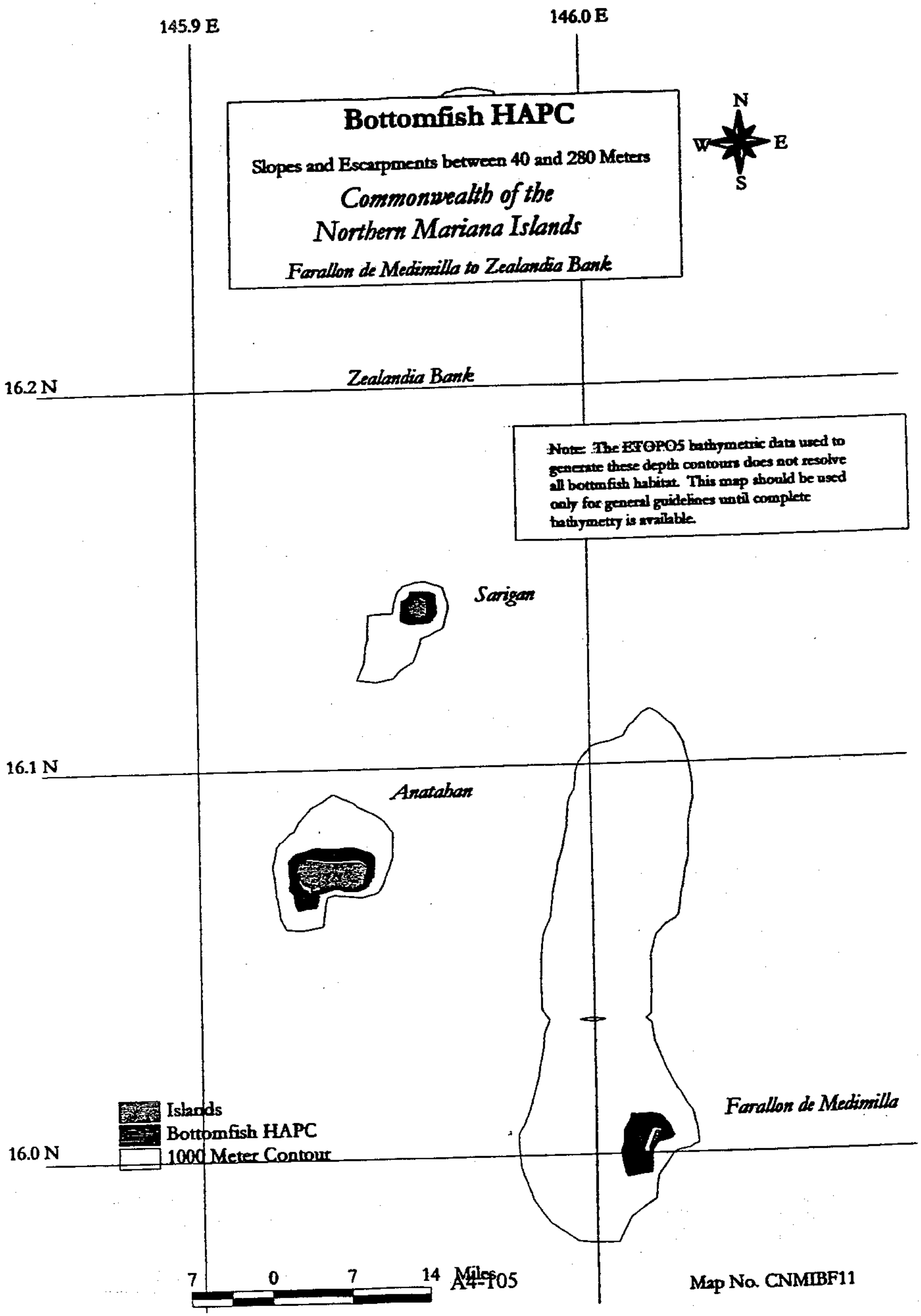
Map No. CNMIBF8

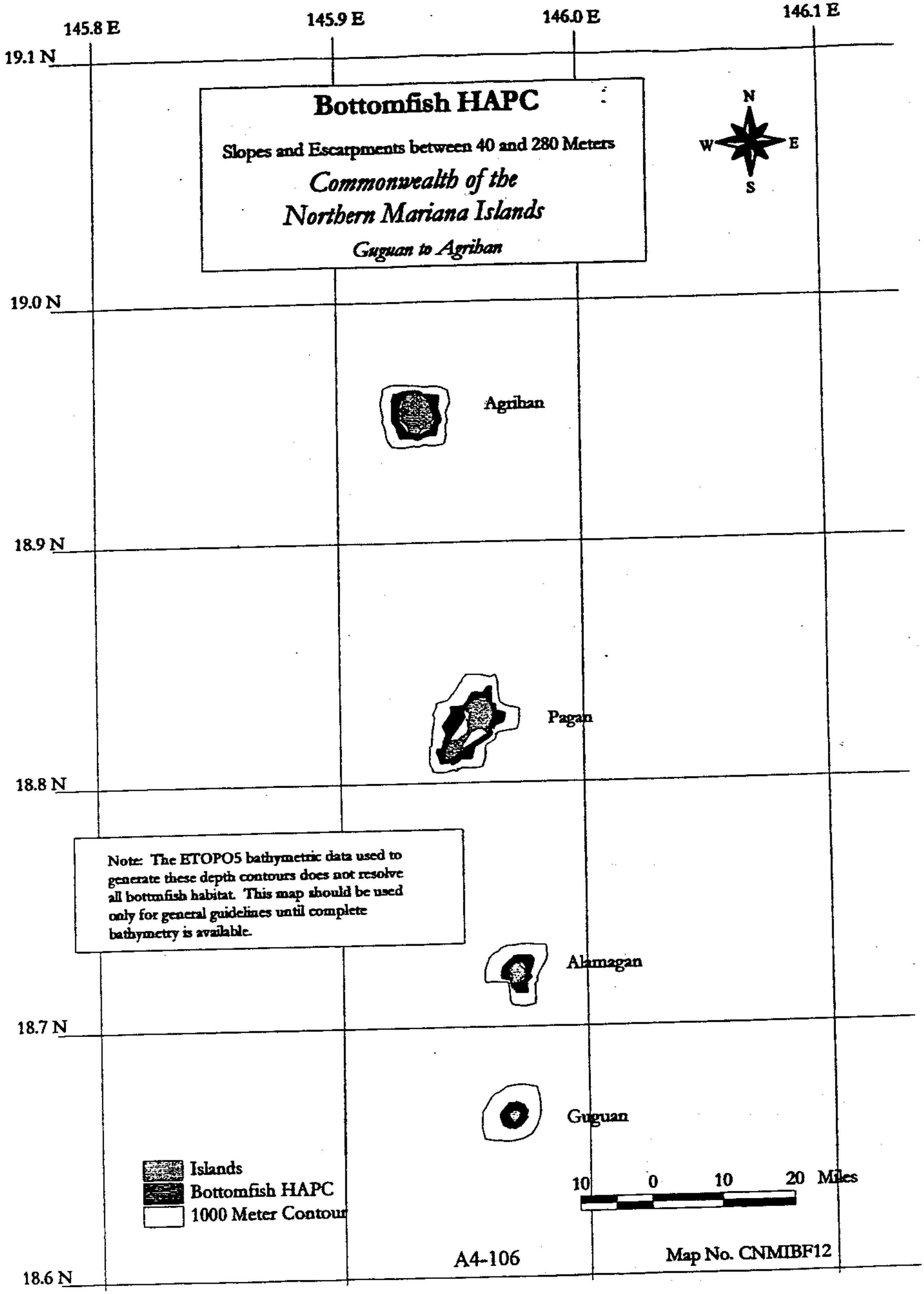


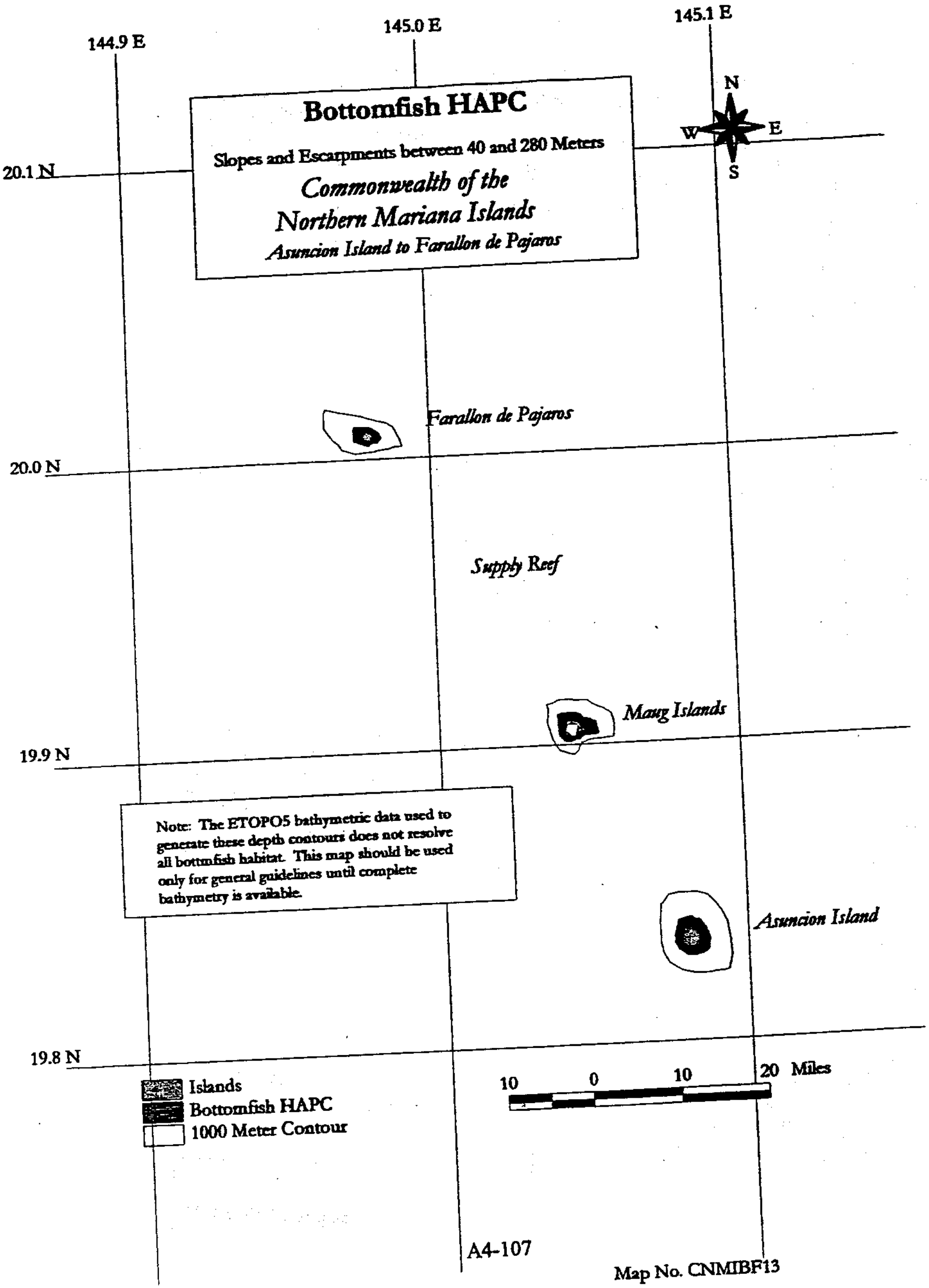
145.1 E
145.2 E
145.3 E
14.4 N
14.3 N
14.2 N
14.1 N
14.0 N
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Island of Rota
N
W
E
S
Rota
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
3
0
3
6 Miles
Island
Bottomfish HAPC
1000 Meter Contour
Map No. CNMIBF9

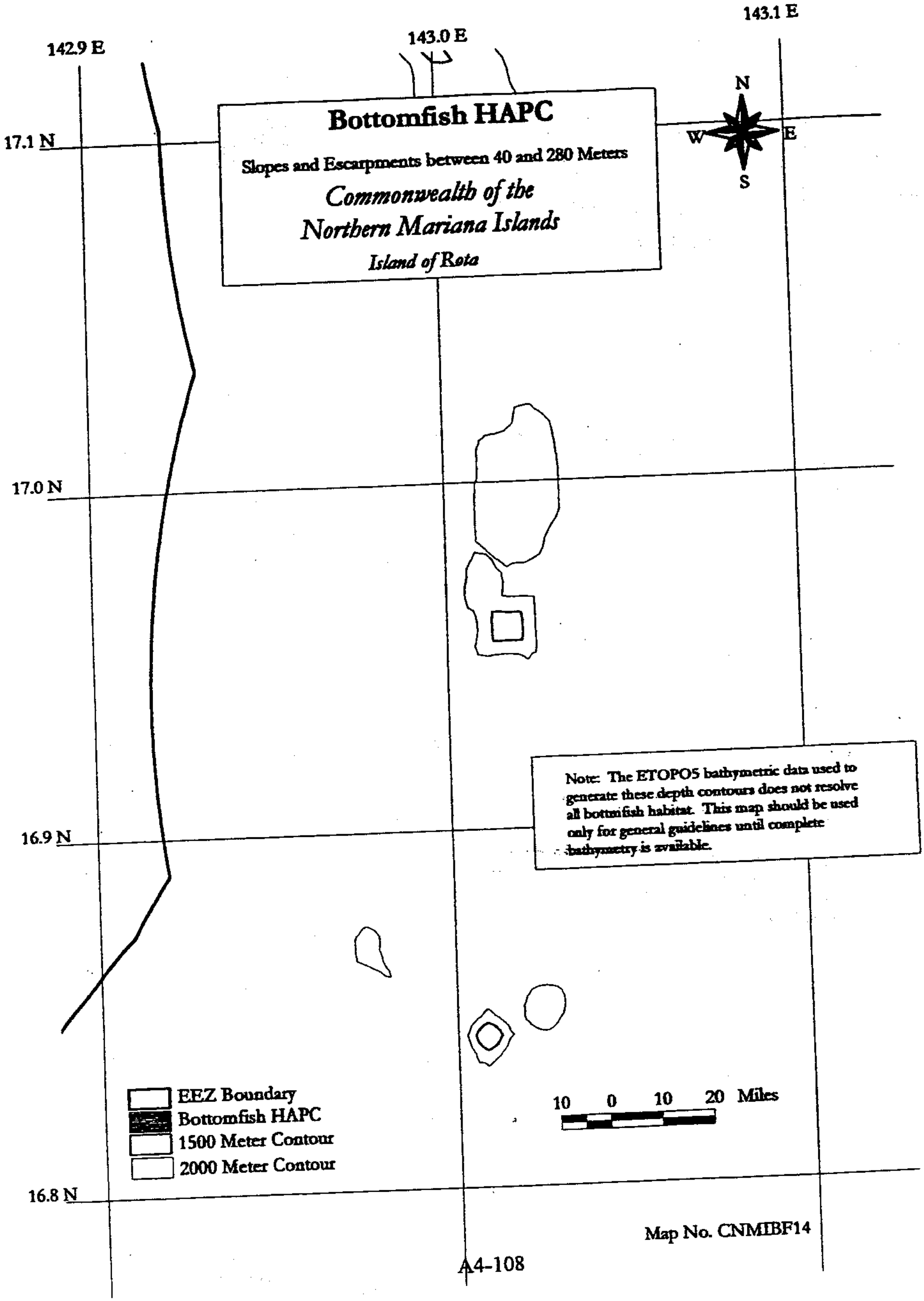


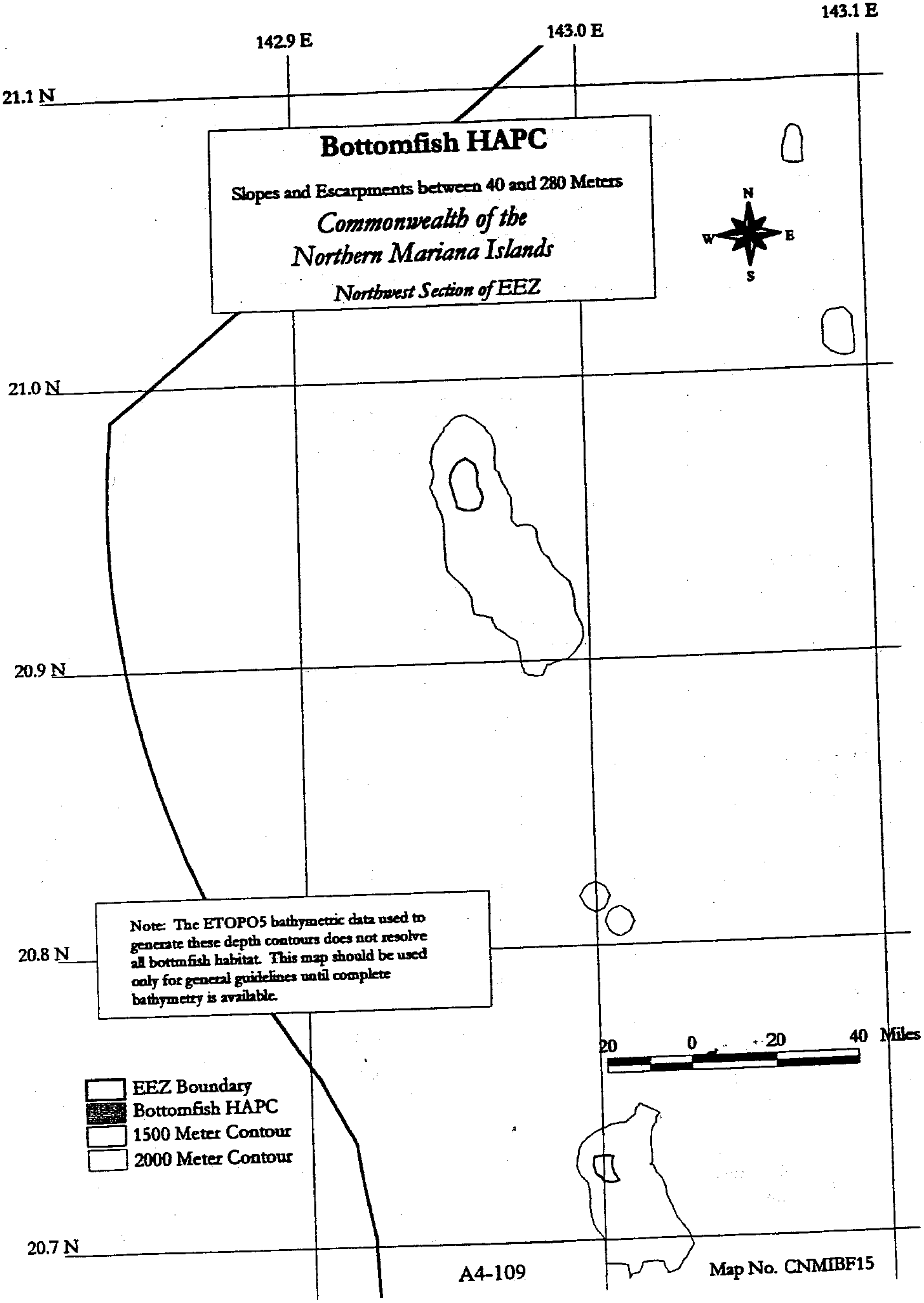
Map No. CNMIBF10

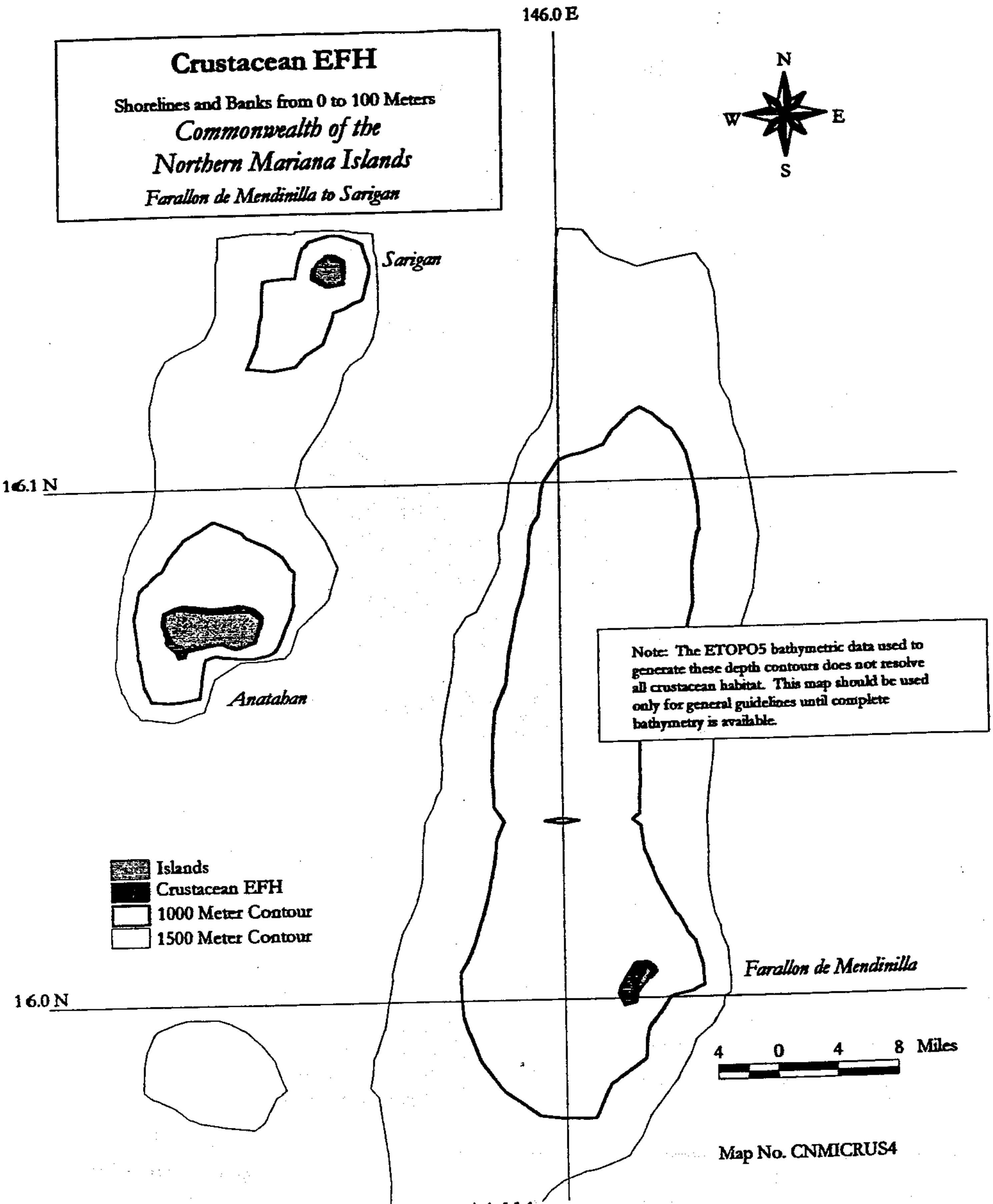

145.9 E
146.0 E
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Farallon de Medimilla to Zealandia Bank
N
W
E
S
16.2 N
Zealandia Bank
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Sarigan
16.1 N
Anatahan
Farallon de Medimilla
Islands
Bottomfish HAPC
1000 Meter Contour
16.0 N
7 0 7 14 Miles
Map No. CNMIBF11


145.8 E
145.9 E
146.0 E
146.1 E
19.1 N
19.0 N
18.9 N
18.8 N
18.7 N
18.6 N
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Guguan to Agrihan
N
W
E
S
Agrihan
Pagan
Alamagan
Guguan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Bottomfish HAPC
1000 Meter Contour
10
0
10
20
Miles
Map No. CNMIBF12

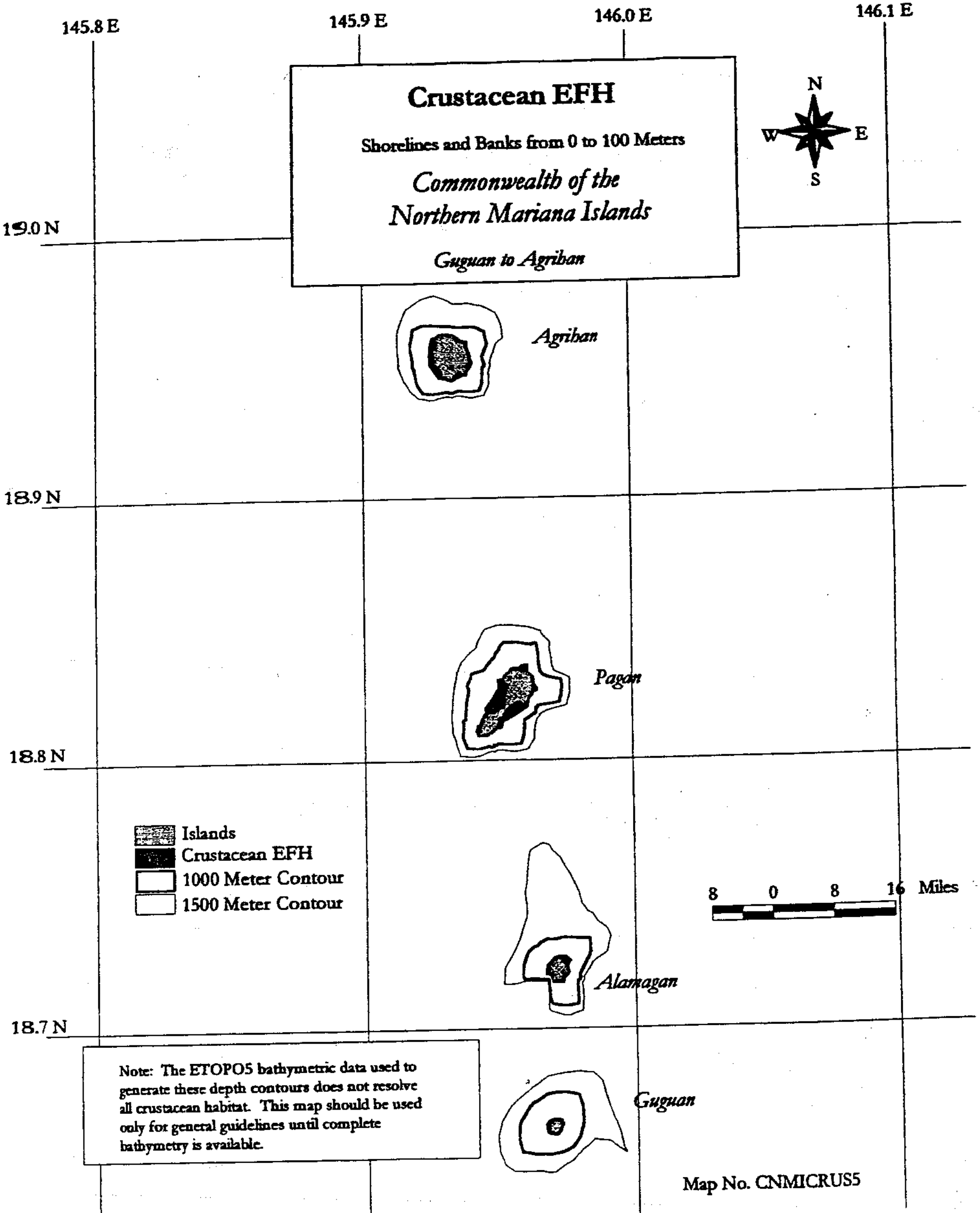

Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Asuncion Island to Farallon de Pajaros
144.9 E
145.0 E
145.1 E
N
W
E
S
20.1 N
20.0 N
19.9 N
19.8 N
Farallon de Pajaros
Supply Reef
Maug Islands
Asuncion Island
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottmfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Bottomfish HAPC
1000 Meter Contour
10
0
10
20
Miles
Map No. CNMIBF13

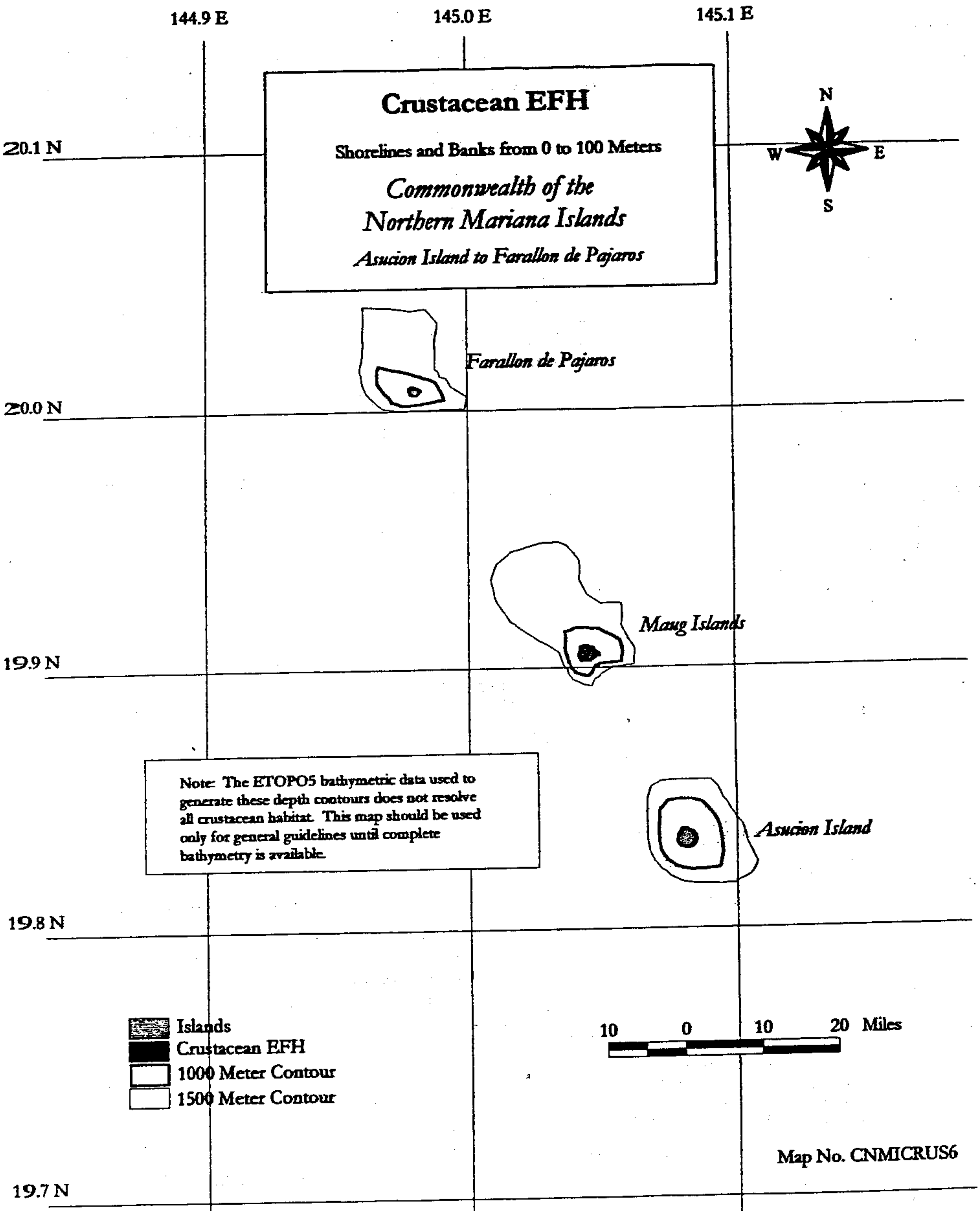

142.9 E
143.0 E
143.1 E
17.1 N
17.0 N
16.9 N
16.8 N
Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Island of Rota
N
W
E
S
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
EEZ Boundary
Bottomfish HAPC
1500 Meter Contour
2000 Meter Contour
10 0 10 20 Miles
Map No. CNMIBF14

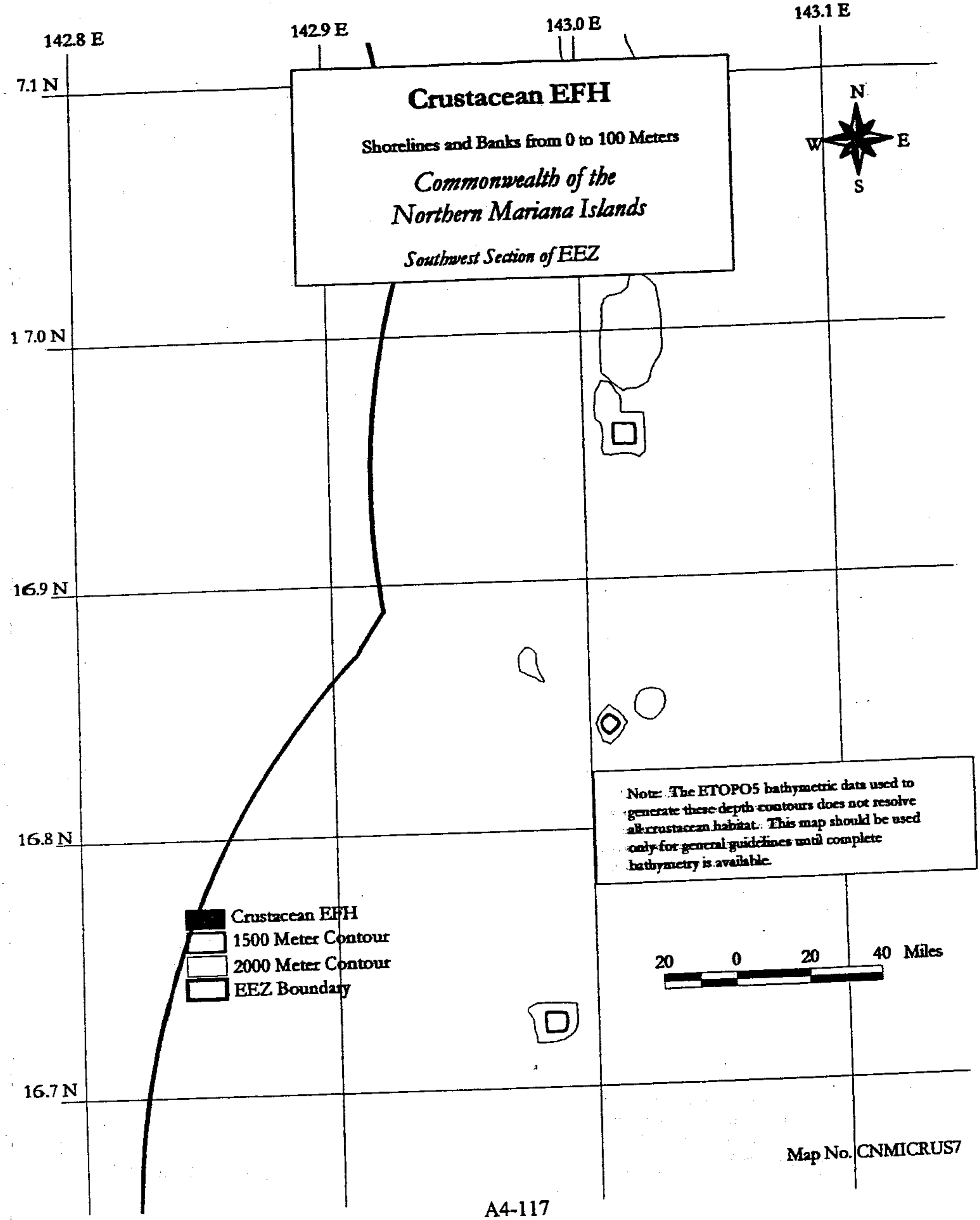

Bottomfish HAPC
Slopes and Escarpments between 40 and 280 Meters
Commonwealth of the
Northern Mariana Islands
Northwest Section of EEZ
142.9 E
143.0 E
143.1 E
21.1 N
21.0 N
20.9 N
20.8 N
20.7 N
N
S
E
W
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all bottomfish habitat. This map should be used only for general guidelines until complete bathymetry is available.
20
0
20
40
Miles
EEZ Boundary
Bottomfish HAPC
1500 Meter Contour
2000 Meter Contour
Map No. CNMIBF15

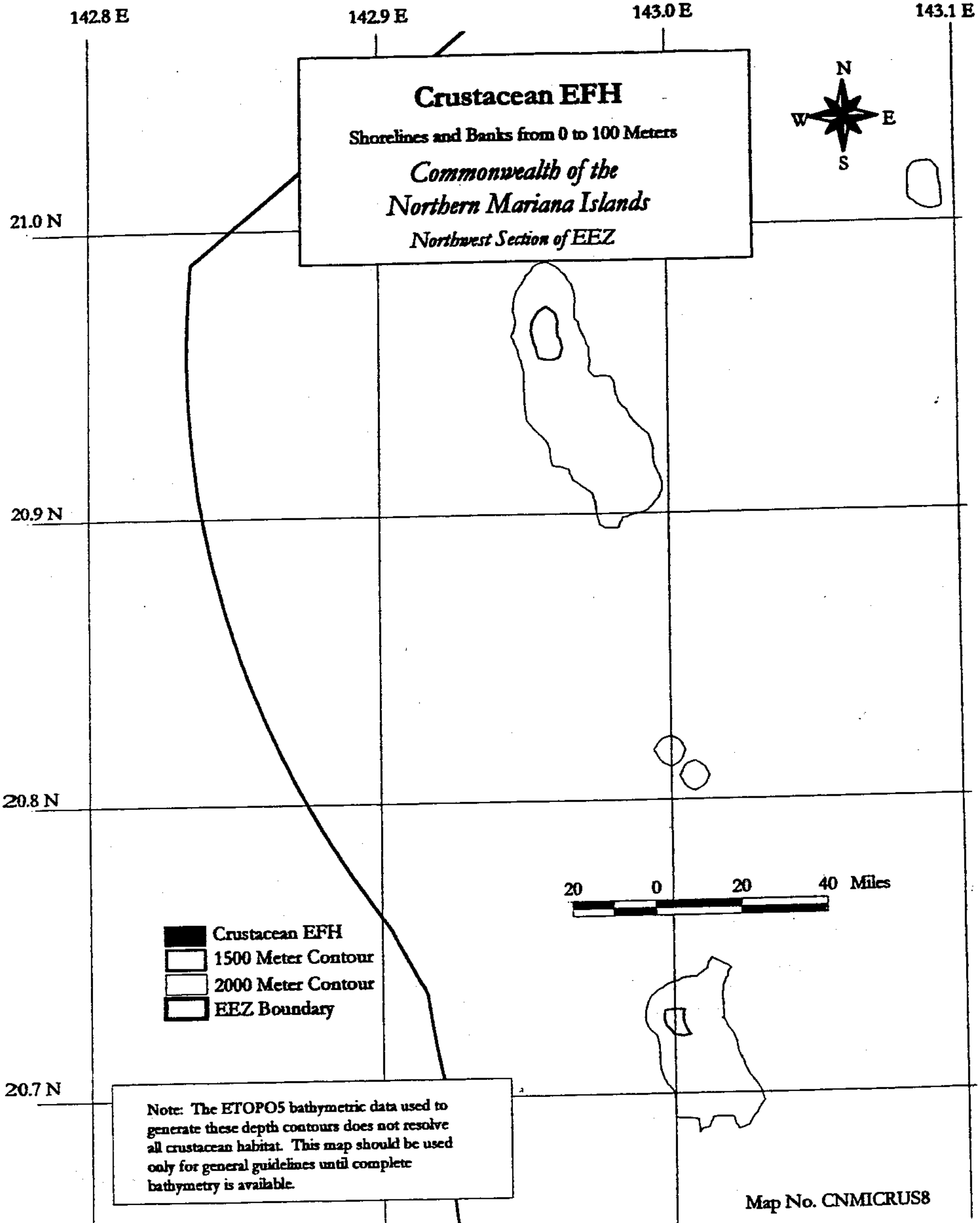


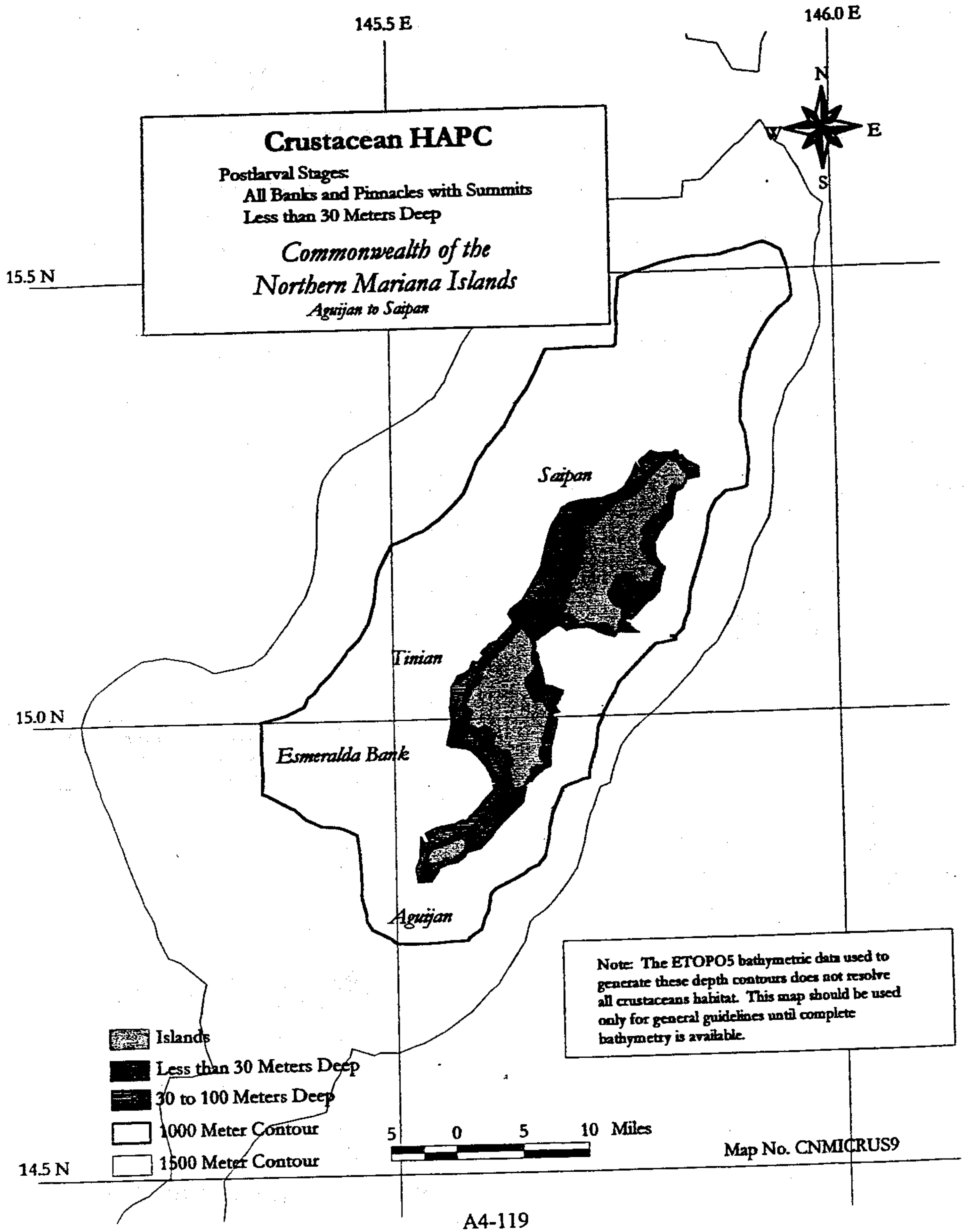
Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Commonwealth of the
Northern Mariana Islands
Farallon de Mendinilla to Sarigan
146.0 E
N
W
E
S
Sarigan
16.1 N
Anatahan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Crustacean EFH
1000 Meter Contour
1500 Meter Contour
Farallon de Mendinilla
16.0 N
4 0 4 8 Miles
Map No. CNMICRUS4

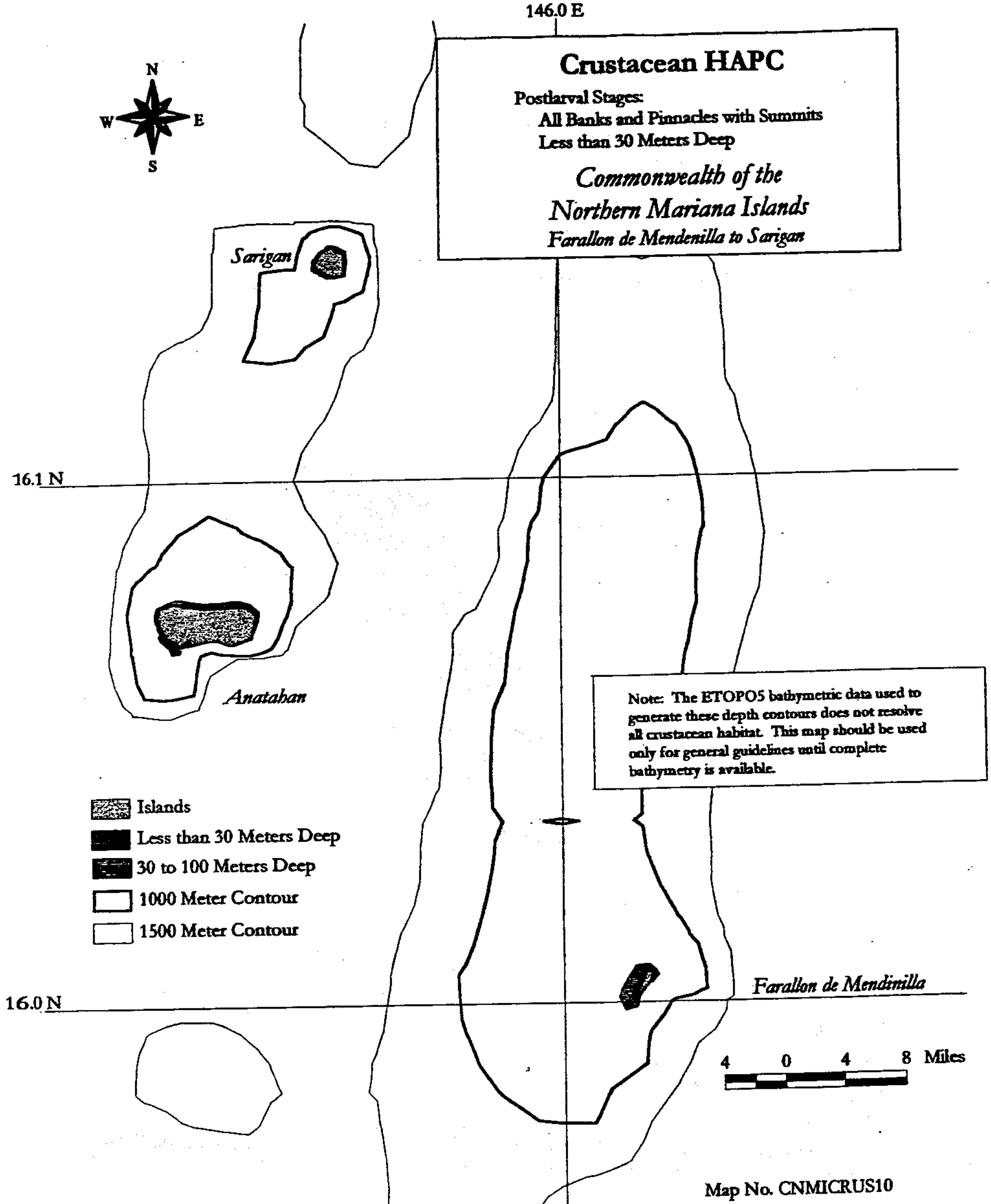

145.8 E
145.9 E
146.0 E
146.1 E
Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Commonwealth of the Northern Mariana Islands
Guguan to Agriban
N
W
E
S
19.0 N
18.9 N
18.8 N
18.7 N
Agriban
Pagan
Alamagan
Guguan
Islands
Crustacean EFH
1000 Meter Contour
1500 Meter Contour
8 0 8 16 Miles
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. CNMICRUS5

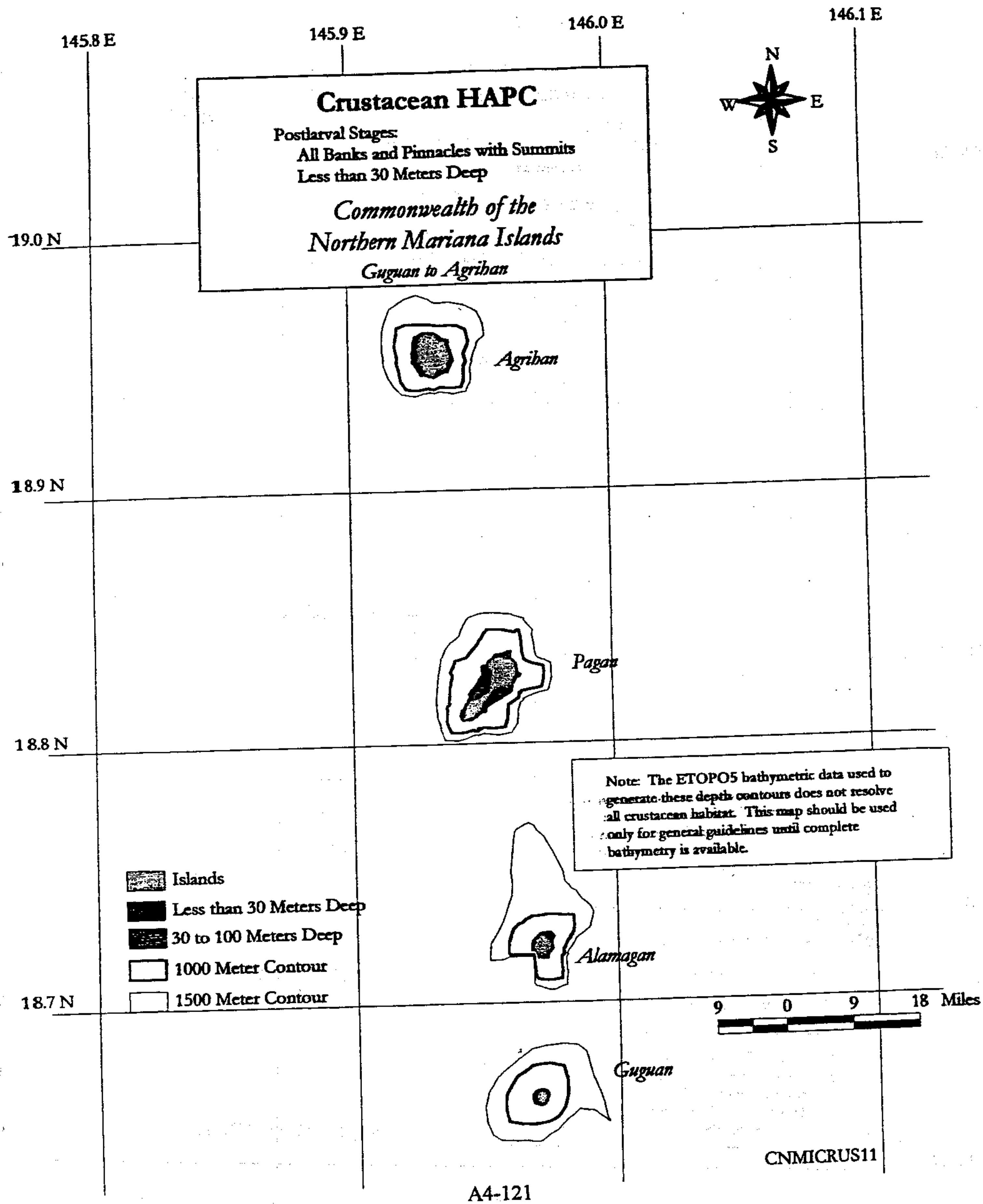

144.9 E
145.0 E
145.1 E
Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Commonwealth of the
Northern Mariana Islands
Asucion Island to Farallon de Pajaros
N
W
E
S
20.1 N
Farallon de Pajaros
20.0 N
Maug Islands
19.9 N
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Asucion Island
19.8 N
Islands
Crustacean EFH
1000 Meter Contour
1500 Meter Contour
10
0
10
20
Miles
Map No. CNMICRUS6
19.7 N

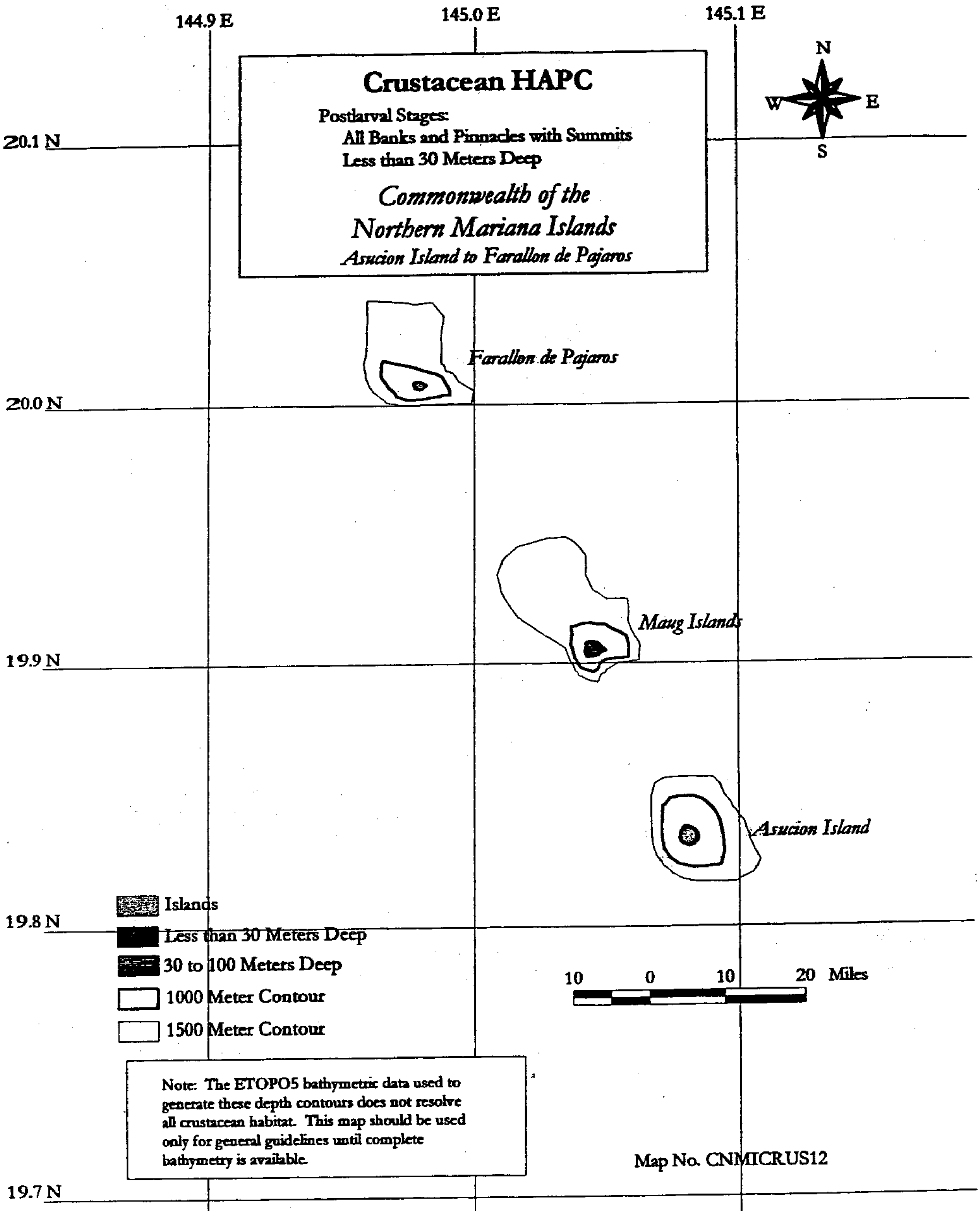

Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Commonwealth of the
Northern Mariana Islands
Southwest Section of EEZ
142.8 E
142.9 E
143.0 E
143.1 E
7.1 N
1 7.0 N
16.9 N
16.8 N
16.7 N
N
W
E
S
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Crustacean EFH
1500 Meter Contour
2000 Meter Contour
EEZ Boundary
20
0
20
40
Miles
Map No. CNMICRUS7

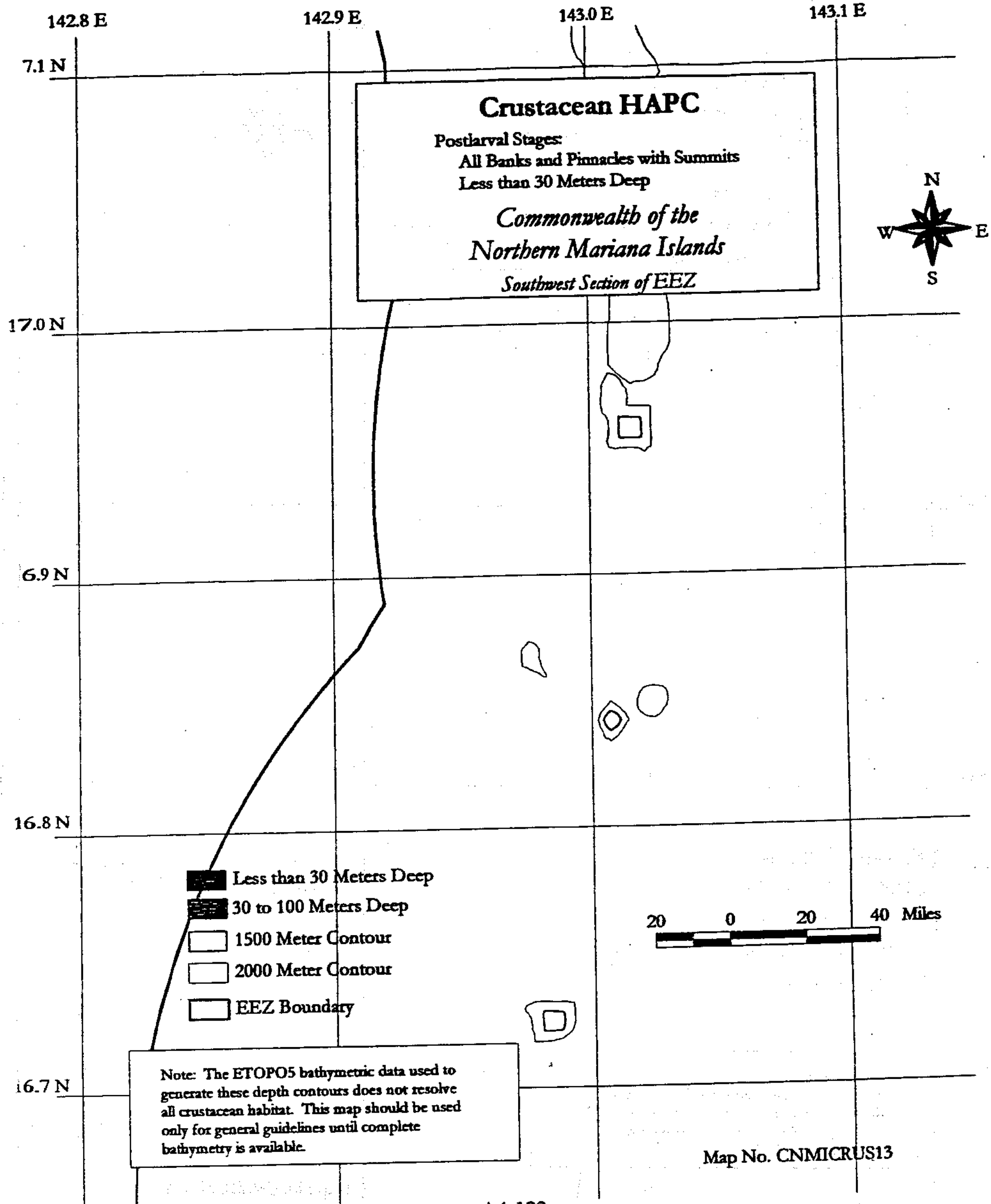

142.8 E
142.9 E
143.0 E
143.1 E
Crustacean EFH
Shorelines and Banks from 0 to 100 Meters
Commonwealth of the
Northern Mariana Islands
Northwest Section of EEZ
N
W
E
S
21.0 N
20.9 N
20.8 N
20.7 N
20
0
20
40
Miles
Crustacean EFH
1500 Meter Contour
2000 Meter Contour
EEZ Boundary
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. CNMICRUS8

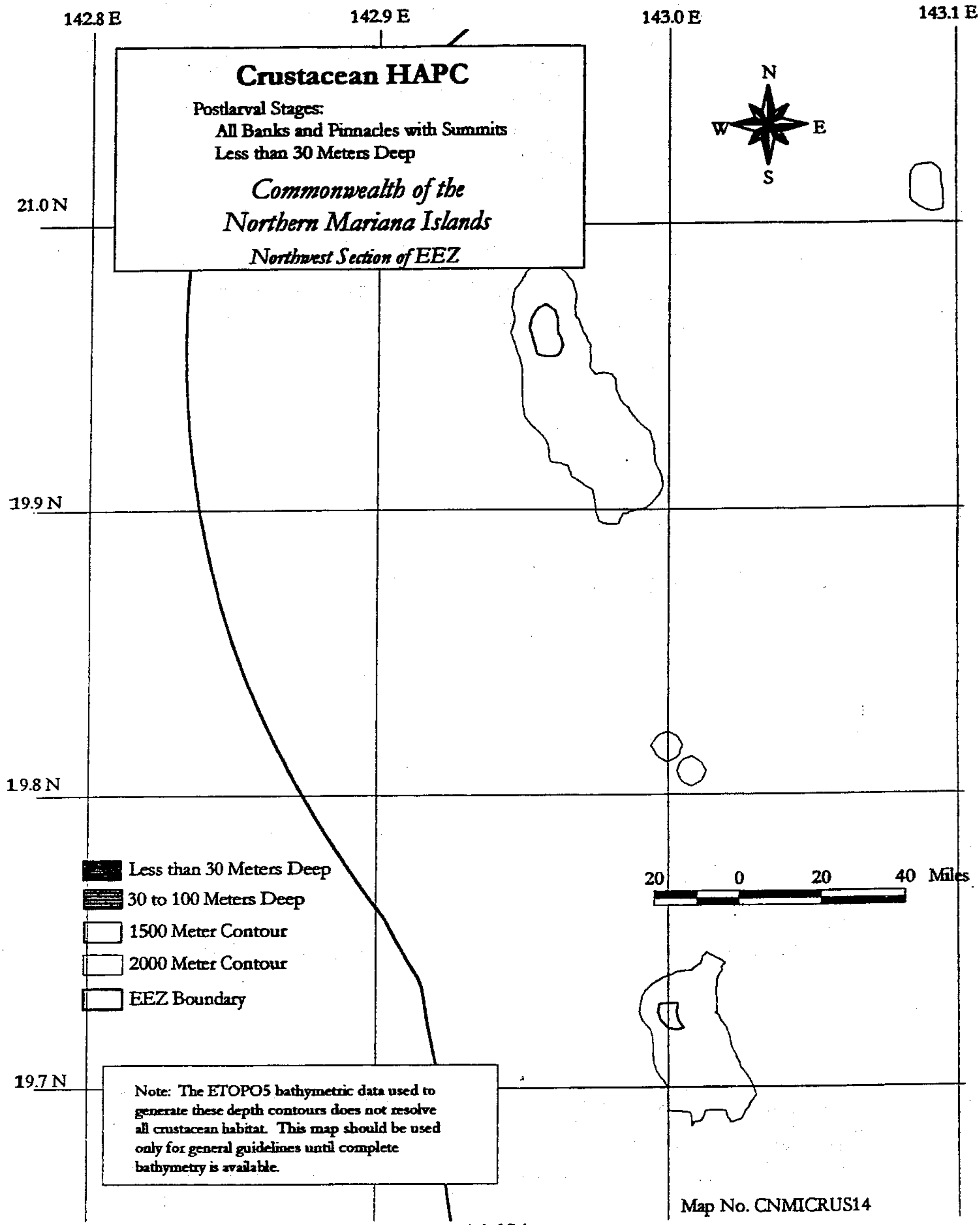

145.5 E
146.0 E
Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Aguijan to Saipan
15.5 N
N
W
E
S
Saipan
Tinian
15.0 N
Esmeralda Bank
Aguijan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustaceans habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Less than 30 Meters Deep
30 to 100 Meters Deep
1000 Meter Contour
1500 Meter Contour
5 0 5 10 Miles
Map No. CNMICRUS9
14.5 N


146.0 E
Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Farallon de Mendenilla to Sarigan
N
W
E
S
Sarigan
16.1 N
Anatahan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Less than 30 Meters Deep
30 to 100 Meters Deep
1000 Meter Contour
1500 Meter Contour
Farallon de Mendinilla
16.0 N
4
0
4
8
Miles
Map No. CNMICRUS10


Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Guguan to Agrihan
145.8 E
145.9 E
146.0 E
146.1 E
19.0 N
18.9 N
18.8 N
18.7 N
N
S
E
W
Agrihan
Pagan
Alamagan
Guguan
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Islands
Less than 30 Meters Deep
30 to 100 Meters Deep
1000 Meter Contour
1500 Meter Contour
9 0 9 18 Miles
CNMICRUS11


Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Asucion Island to Farallon de Pajaros
144.9 E
145.0 E
145.1 E
N
W
E
S
20.1 N
20.0 N
19.9 N
19.8 N
19.7 N
Farallon de Pajaros
Maug Islands
Asucion Island
Islands
Less than 30 Meters Deep
30 to 100 Meters Deep
1000 Meter Contour
1500 Meter Contour
10
0
10
20
Miles
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. CNMICRUS12


142.8 E
142.9 E
143.0 E
143.1 E
7.1 N
17.0 N
6.9 N
16.8 N
16.7 N
Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Southwest Section of EEZ
N
W
E
S
Less than 30 Meters Deep
30 to 100 Meters Deep
1500 Meter Contour
2000 Meter Contour
EEZ Boundary
20
0
20
40
Miles
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. CNMICRUS13


142.8 E
142.9 E
143.0 E
143.1 E
Crustacean HAPC
Postlarval Stages:
All Banks and Pinnacles with Summits
Less than 30 Meters Deep
Commonwealth of the
Northern Mariana Islands
Northwest Section of EEZ
N
W
E
S
21.0 N
19.9 N
19.8 N
19.7 N
Less than 30 Meters Deep
30 to 100 Meters Deep
1500 Meter Contour
2000 Meter Contour
EEZ Boundary
20
0
20
40
Miles
Note: The ETOPO5 bathymetric data used to generate these depth contours does not resolve all crustacean habitat. This map should be used only for general guidelines until complete bathymetry is available.
Map No. CNMICRUS14

Appendix 5
General Description of Non-fishing Impacts to Bottomfish, Crustacean, Pelagic and Precious Coral Habitat in the Western Pacific

1.0 INTRODUCTION

The Magnuson-Stevens Act contains provisions for the description and identification of essential fish habitat (EFH) in fishery management plans (FMPs), including adverse nonfishing impacts on such habitat. To fulfill this goal, the Act requires that all Councils identify activities that have the potential to adversely affect EFH quantity or quality, or both. Section 600.815 (a) (5) of the EFH regulations identifies the following broad categories of non-fishing impacts that can adversely affect EFH: dredging, fill, excavation, mining, impoundment, water diversions, actions that contribute to nonpoint source pollution and sedimentation, thermal discharge, introduction of potentially hazardous materials, introduction of exotic species and the conversion of aquatic habitats that may eliminate, diminish or disrupt the functions of EFH. Other sources of impacts include, but are not limited to, the following: point source pollution, ocean dumping, coastal development, ocean-thermal energy conversion (OTEC), aquaculture, power plants, oil development, sewage outfall, hydrological modifications, volcanic activity, fish enhancement structures, marine debris and shoreline stabilization.

The FMP should describe the EFH most likely to be adversely affected by these or other activities. For each activity, the FMP should describe known and potential adverse impacts to EFH. The descriptions should explain the mechanisms or processes that may cause the adverse effects and how these may affect habitat function. If a proposed activity appears to have the potential to impact EFH, a EFH assessment will need to be undertaken by the action agency to determine whether the activity or activities proposed will impose an adverse impact to the quality and quantity of the habitat.

FMPs must also identify and describe (1) measures to mitigate (avoid, minimize, compensate) adverse impacts on EFH and (2) actions to conserve, enhance or restore EFH. These actions will be used to guide and direct consultations between NMFS and federal agencies that propose activities within areas designated as EFH after October 11, 1998, as required by the Act.

The following is a general description of non-fishing related activities that directly or cumulatively, temporarily or permanently may threaten the physical, chemical and biological properties of the habitat utilized by western Pacific bottomfish, pelagics, crustacean and precious corals management unit species and their prey. The direct result of these threats is that the function of EFH may be eliminated, diminished or disrupted. The list includes common and not
so common activities that all have known or potential impacts to EFH. The list is not prioritized nor is it to be considered as all-inclusive.

The potential impacts addressed in this paper are germane to the EFH of species of western Pacific bottomfish, pelagic fish, crustaceans and precious corals and the prey of these species.

1.1 Dredging

Dredging navigable waters is a re-occurring impact primarily to benthic habitats but also to adjacent habitats in the construction and operation of marinas, harbors and ports. Routine dredging, that is, the excavation of soft bottom substrates, is required to provide or create navigational access to ships and boats at port and mariana docking facilities. Dredging is used to create deep-water navigable channels or to maintain existing channels that periodically fill with sediments from rivers or from movement caused by wind, wave or tidal dynamics. In the process of dredging, excessive quantities and associated qualities of the seafloor are removed, disturbed and re-suspended. Turbidity plumes may arise. Legal mandates covering dredging are the federal Water Pollution Control Act of 1972 (33 U.S.C. 1251 et seq.) and the River and Harbor Act of 1899 (33 U.S.C. 401 et seq.).

Adverse Impacts: Dredging may adversely affect infaunal and bottom-dwelling organisms at the site by removing immobile forms, such as polychaete worms and other prey types, or forcing mobile forms, such as fish, to migrate. Benthic forms present prior to a discharge are unlikely to recolonize if the composition of the deeper layers of sediment is drastically different.

Dredging events can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column. These turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis (e.g., in adjacent seagrass beds); if present for extended periods of times, the plumes may also lower the primary productivity of an aquatic area. If suspended particulates persist, fish may suffer reduced feeding ability and sensitive habitats, such as submerged aquatic vegetation beds, which provide source of food and shelter, may be damaged. The contents of the suspended material may react with the dissolved oxygen in the water and result in short-term oxygen depletion to aquatic resources. Toxic metals and organic substances, pathogens and viruses absorbed or adsorbed to fine-grained particulates in the material may become biologically available to organisms either in the water column or through food chain processes.

Dredging as well as the equipment used, such as pipelines, may damage or destroy spawning, nursery habitat and other sensitive habitats, such as coral reefs. Dredging may also modify current patterns and water circulation of the habitat by changing the direction or velocity of water flow and water circulation or otherwise altering the dimensions of the water body traditionally utilized by fish for food, shelter or reproductive purposes.

1.2 Dredge Material Disposal and Fill

The discharge of dredged materials subsequent to dredging operations or the use of fill material in the construction and development of harbors results in sediments (e.g., dirt, sand, mud) covering or smothering existing submerged substrates.

Adverse Impacts: The disposal of dredged or fill material can result in varying degrees of change in the physical, chemical, and biological characteristics of the substrate. Discharges may adversely affect infaunal and bottom-dwelling organisms at the site by smothering immobile forms (e.g., prey invertebrate species) or forcing mobile forms (e.g., benthic-oriented fish species) to migrate from the area. Infaunal invertebrate forms present prior to a discharge are unlikely to recolonize if the composition of the discharged material is drastically different. Erosion, slumping or lateral displacement of surrounding bottom by such deposits can also adversely affect substrate outside the perimeter of the disposal site by changing or destroying benthic habitat. The bulk and composition of the discharged material and the location, method and timing of discharges may all influence the degree of impact on the substrate.

The discharge of dredged or fill material can result in greatly elevated levels of fine-grained mineral particles, usually smaller than silt, and organic particles in the water column (i.e., turbidity plumes). These suspended particles may reduce light penetration and lower the rate of photosynthesis as well as the primary productivity of an aquatic area if the particles are suspended for lengthy intervals. Subaquatic vegetation, such as seagrass beds, may also be affected. Fish may suffer reduced feeding ability leading to limited growth and lowered resistance to disease if high levels of suspended particles persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion. Toxic metals and organic substances, pathogens and viruses absorbed or adsorbed to fine-grained particles in the material may become biologically available to organisms either in the water column or through food chain processes.

The discharge of dredged or fill material can change the chemistry and the physical characteristics of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form. Changes in the clarity and the addition of unacceptable contaminants can reduce, change or eliminate the suitability of water bodies for populations of fish species and their prey. The introduction of nutrients or organic material to the water column as a result of the discharge can lead to a high biochemical oxygen demand (BOD), which in turn can lead to reduced dissolved oxygen, thereby potentially affecting the survival of many aquatic organisms. Increases in nutrients can favor one group of organisms, such as polychaetes or algae, to the detriment of other types.

The discharge of dredged or fill material can modify current patterns and water circulation by obstructing flow, changing the direction or velocity of water flow and circulation or otherwise altering the dimensions of a water body. As a result, adverse changes can occur in the location, structure and dynamics of aquatic communities; shoreline and substrate erosion and deposition rates; the deposition of suspended particulates; the rate and extent of mixing of dissolved and suspended components of the water body; and water stratification.

Disposal events may lead to the full or partial loss of habitat functions because of the extent of the burial at the site. Loss of habitat function can be temporary or permanent.

1.3 Marine Mining

Mining for sand in coastal waters to support beach nourishment and restoration poses several potential threats to EFH. These include, modification of the substrate, destruction of in infaunal benthic communities, changes in circulation patterns and decreased dissolved oxygen concentrations at excavation sites where flushing is minimal. Sand mining elevates suspended materials at the mining site. The resulting turbidity plume may impact areas up to several km away from the mining site. Suspended sediments may contain contaminants, including pesticides, heavy metals, herbicides and other toxins.

The mining of cobalt-rich manganese crust on the Pacific seamounts located within the EEZ poses a potential threat to EFH. The potential impacts of this proposed activity include the physical destruction of benthic habitat and associated biological communities, discharge of toxic surface plume (which may potentially affect pelagic larvae and eggs), alteration of phytoplankton species composition and of trophic dynamics, increased turbidity in surface layer (which could alter feeding behavior and health of fish in the affected area), changes in circulation patterns and decreased dissolved oxygen concentrations in affected surface layers.

1.4 Water Intake Structures

The withdrawal of ocean water by offshore water intake structures is a common coastwide occurrence. Water may be withdrawn to provide sources of cooling water for coastal power generating stations or sources of potential drinking water, as in the case of desalinization plants. If not properly designed, these structures may create unnatural and vulnerable conditions to many fish at various life stages and their prey. In addition, freshwater withdrawals from riverine systems to support industrial and agricultural operations also occur.

<u>Adverse Impacts</u>: The withdrawal of seawater can create unnatural conditions to the EFH of many species. Water intake operations can affect fish at various life stages by such adverse impacts as entrapment through water withdrawal, impingement on intake screens and entrainment through the heat-exchange systems or discharge plumes of both heated and cooled effluent. High approach velocities along with unscreened intake structures can create an unnatural current making it difficult for fish species and their prey to escape. These structures may withdraw most larval and postlarval marine fishery organisms and some proportion of organisms at more advanced life stages. Periods of low light (e.g., turbid waters, nocturnal periods) may also entrap adult and sub-adult species many of which are either commercially or recreationally utilized or serve as the prey of these species.

Freshwater withdrawal also reduces the volume and perhaps timing of freshwater reaching estuarine environments and thereby potentially alters circulation patterns, salinity and the upstream migration of the saltwater wedge.

1.5 Aquaculture

The culture of estuarine, marine and freshwater species in coastal areas can reduce or degrade habitats used by native stocks. The location and operation of these facilities will determine the level of impact on the marine environment.

Adverse Impacts: A major concern of aquaculture operations is the discharge of organic waste from the farms. Wastes are composed primarily of feces and excess feed, and the buildup of waste products into the receiving waters will depend on water depths and circulation patterns. The release of these wastes may introduce nutrients or organic materials into the surrounding water body and lead to a high biochemical oxygen demand (BOD), which may reduce dissolved oxygen, thereby potentially affecting the survival of many aquatic organisms in the area. Nutrient overloads at the discharge site can also favor one group of organisms to the detriment of other more desirable prey types, such as polychaete worms.

In the case of cage mariculture operations for grow-out operations, impacts to the seafloor below the cages or pens may occur. The composition and diversity of the bottom-dwelling community (e.g., prey organisms) due to the buildup of organic materials on the seafloor may be impacted. Shading effects may inhibit growth of submerged aquatic vegetation, which may provide shelter and nursery habitat for a number of fish species and their prey.

Mariculture operations also have the potential to release high levels of antibiotics as well as allow cultured organisms to escape into the environment. Both events have unknown but potential adverse impacts on fish habitat.

1.6 Wastewater Discharge

The discharge of point and nonpoint source wastewater from commercial activities including municipal wastewater treatment plants, power generating stations, industrial plants and storm drains into open ocean waters, bay or estuarine waters can introduce chemical constituents or salinities potentially detrimental to estuarine and marine habitats. These constituents include pathogens, nutrients, sediments, heavy metals, and oxygen demanding substances, hydrocarbons and toxicants. Historically, wastewater discharges have been one of the largest sources of contaminants into coastal waters. Outfall-related changes in community structure, function, health and abundance may result. Many of these changes can be long lasting.

Adverse Impacts: It is generally assumed that wastewater effluent affects the growth and condition of fish and their prey associated with wastewater outfalls as a result of high contaminant levels (e.g., chlorinated hydrocarbons, trace metals, polynuclear aromatic hydrocarbons). For fish, assimilation of contaminants into fish tissues can be manifested in such ways as impaired reproduction. Many of these contaminant effects result from the consumption of animals living on the sediments that have elevated concentrations of contaminants. Outfall sediments may alter the composition and abundance of benthic community invertebrates living in or on the sediments. Due to bioturbation, diffusion and other upward transport mechanisms that move buried contaminants to the surface layers and eventually to the water column, pelagic and nektonic biota may also be exposed through mobilization into the water column.

The use of biocides (e.g., chlorine, heat treatments) to prevent biofouling can reduce or eliminate the suitability of water bodies for populations of fish species and their prey in the general vicinity of the discharge pipe. These compounds may change the chemistry and the physical characteristics of the receiving water at the disposal site by introducing chemical constituents in suspended or dissolved form.

Extreme discharge velocities of the effluent may also cause scouring at the discharge point as well as entrain particulates and thereby create turbidity plumes. These turbidity plumes of suspended particulates may reduce light penetration and lower the rate of photosynthesis (e.g., in the case of coral reefs and algae beds) and the primary productivity of an aquatic area if suspension persists. Fish may suffer reduced feeding ability especially if suspended particulates persist. The contents of the suspended material may react with the dissolved oxygen in the water and result in oxygen depletion.

Mass emissions of suspended solids, contaminants and nutrient overloading from these outfalls may also affect nearshore marine ecosystems, such as corals reefs and submerged aquatic vegetation sites. These ecosystems are frequently utilized by fish species for shelter and protection from predators and for food by consuming organisms associated with these habitats. Storm-water runoff, which can include both urban and agricultural runoff, is also a large source of particular contaminants to the marine environment affecting both water column and benthic habitats. These contaminants find their way into the food web through benthic infaunal communities and subsequently bio-accumulate in numerous fish species.

1.7 Discharge of Oil or Release of Hazardous Substances

Accidental spills of oil or the release of a hazardous substance into estuarine and marine habitats can create significant pollution events. These inadvertent releases occur from both facilities and vessels during the production, transportation, refinement and utilization of hazardous materials.

Adverse Impacts: Exposure to petroleum products and hazardous substance can have both acute and chronic effects on fish resources and their prey and also potentially reduce the marketability of target species. Direct physical contact with discharged oil or released hazardous substances (e.g., toxicants, oil dispersants, mercury) or indirect exposure resulting from food chain processes can produce a number of biological responses in fish resources and their prey. These responses can occur in a variety of habitats including the water column, seafloor, bays and estuaries. Depending on the biological pathway involved, these responses may include death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction) or physical deformations of commercially and recreationally important fish.
Other issues related to the category include efforts to cleanup spills or releases that in them can create serious harm to the habitat. For example, the use of potentially toxic dispersants to break up an oil spill may adversely affect the egg and larval stages of most species.

1.8 Fish Enhancement Structures

Fish enhancement structures, or “artificial reefs,” are a popular management tool employed by both state and federal governments and private groups. They have been used for centuries to enhance fishery resources and fishing opportunities and usually entail placing miscellaneous materials in ocean or estuarine environments void of physical or “hard-bottom” relief. Although scientists still debate whether these reefs attract and/or produce fish biomass, their proliferation continues. This popularity is the result of increased demands on fish stocks by both commercial and recreational fishermen and losses of habitat productivity due to development and pollution. The introduction of artificial reef material into the marine or estuarine environment can produce negative impacts.

<u>Adverse Impacts:</u> The use of artificial reefs can impact the aquatic environment in at least two ways. The first deals with the loss of habitat upon which the artificial reef material is placed. Usually, artificial reef materials are set upon flat sand bottoms or “biological deserts,” which end up burying or smothering faunal and bottom-dwelling organisms at the site or even preventing mobile forms (e.g., benthic-oriented fish species) from utilizing the area as habitat as has been shown in Hawaii. In Hawaii, areas of flat featureless bottom have typically been thought of as providing low value fishery habitat. As a result, these areas are often seen as ideal locations to site artificial reefs. Recent research has demonstrated that areas of very low relief bottom habitat are utilized as juvenile nursery grounds by several valuable species of deep-water bottomfish. Another potential impact deals with the use of materials that may be inappropriate for the marine environment (e.g., automobile tires, compressed incinerator ash) and that may serve as potential sources of habitat degradation. For example, automobile tires are potential sources of toxic releases and can cause physical damage to existing habitat when they break free of their anchoring systems.

There is also a long-standing debate as to whether artificial reefs actually increase the standing stock of marine fishes by providing suitable habitat or simply cause fish to aggregate.

1.9 Coastal Development Impacts

Coastal development involves changes in land use by the construction of urban, suburban, commercial and industrial centers and the corresponding infrastructure. Vegetated and open forested areas, including wetlands important for exporting nutrients and energy as well as serving as fish nursery areas, are removed by cut-and-fill activities for enhancing the development potential of the land. Portions of the natural landscape are converted to impervious surfaces, thus increasing runoff volumes. Runoff from these developments include heavy metals, sediments, nutrients and organic substances, including synthetic and petroleum hydrocarbons, yard trimmings, litter, debris and pet droppings. As residential, commercial and industrial growth continues, the demand for water escalates. As groundwater resources become depleted or contaminated, greater demands are placed on surface water through dam and reservoir construction or other methods of freshwater diversion. The consumptive use and redistribution of significant volumes of surface freshwater causes reduced river flows that can affect salinity regimes as saline waters intrude further upstream.

Adverse Impacts: Development activities within watersheds and in coastal marine areas often impact fish habitat on both long-term and short-term scales. Runoff of toxic materials from development sites introduces pesticides, fertilizers, petrochemicals and construction chemicals (e.g., concrete products, seals and paints) to suitable fish habitat and thus reduces their quality and quantity. Sediment runoff can also restrict tidal flows and tidal elevations and thus destroy important fauna and flora (e.g., submerged aquatic vegetation). Shoreline stabilization projects that affect reflective wave energy can impede or accelerate natural movements of sand and thereby impact intertidal and sub-tidal habitats. Reduced freshwater flow into estuaries and wetlands can impact the extent and location of the mixing (or entrapment) zone and thereby reduce productivity and habitat quality for fish.

1.10 Introduction of Exotic Species

Over the past two decades, there has been an increase in the introductions of exotic species into aquatic habitats. Introductions can be intentional (e.g., for the purpose of stock or pest control) or unintentional (e.g., fouling organisms).

Adverse Impacts: Exotic species introductions create five types of negative impacts: (1) habitat alteration, (2) trophic alteration; (3) gene pool alteration, (4) spatial alteration; and, (5) introduction of diseases. Habitat alteration includes the excessive colonization of exotics that preclude endemic organisms. Community structure alterations occur through predation on native species or by population explosions of the introduced species. Although hybridization is rare, gene pool deterioration may occur between native and introduced species. Spatial alteration occurs when territorial introduced species compete with native species and end up displacing the endemic species. One of the most severe threats to a native fish community is the introduction of bacteria, viruses and parasites that reduce the quality of the habitat.

1.11 Agricultural Practices

Through uncontrolled nonpoint source runoff, agricultural operations can introduce animal wastes, sediments, fertilizers, herbicides, insecticides and other chemicals into riverine, estuarine and marine environments. Excessive, uncontrolled or improper irrigation practices often exacerbate contaminant flushing.

Adverse Impacts: The introduction of animal wastes, fertilizers, herbicides, insecticides and other chemicals into the aquatic environment, especially estuaries, can affect the growth of aquatic plants, which in turn affects fish, invertebrates and the general ecological balance of the water body. Pollutants associated with these products include oxygen demanding substances, such as nitrogen, phosphorous and other nutrients; organic solids; bacteria, viruses and other microorganisms; and salts. These pollutants and wastes may reduce the quality of habitats to the point where they are no longer suitable for shelter, feeding or spawning; if conditions become extreme, fish will die.

2.0 CONSERVATION MEASURES FOR NONFISHING IMPACTS TO WESTERN PACIFIC BOTTOMFISH, CRUSTACEAN, PRECIOUS CORALS AND PELAGIC HABITATS

The FMP must describe options to avoid, minimize or compensate for the adverse effects to and promote the conservation and enhancement of EFH. Generally, non-water dependent actions should not be located in EFH if such actions may have adverse impacts on EFH. Activities that may result in significant adverse affects on EFH should be avoided where less environmentally harmful alternatives are available. If there are no alternatives, the impacts of these actions should be minimized. Environmentally sound engineering and management practices should be employed for all actions that may adversely affect EFH. Disposal or spillage of any material (dredge material, sludge, industrial waste, or other potentially harmful materials) that would destroy or degrade EFH should be avoided. If avoidance or minimization is not possible, or will not adequately protect EFH, compensatory mitigation to conserve and enhance EFH should be recommended. FMPs may recommend proactive measures to conserve or enhance EFH. When developing proactive measures, Councils may develop a priority ranking of the recommendations to assist federal and state agencies undertaking such measures. FMPs should provide a variety of options to conserve or enhance EFH, which may include, but are not limited to:

Enhancement of rivers, streams, and coastal areas. Initiation of federal, state or local government planning processes to restore watersheds associated with such rivers, streams or coastal areas may be recommended.

Water quality and quantity. This category of options may include use of best land management practices for ensuring compliance with water quality standards at state and federal levels, improved treatment of sewage, proper disposal of waste materials and appropriate in-stream flow to prevent adverse effects to estuarine areas.

Habitat restoration or creation. Under appropriate conditions, habitat creation (converting non-EFH to EFH) may be considered as a means of replacing lost or degraded EFH. However, habitat conversion at the expense of other naturally functioning systems must be justified within an ecosystem context.

2.1 Background

From a broad perspective, fish habitat is the geographic area where the species occurs at any time during its life. This area can be described in terms of ecological characteristics, location and time. Ecologically, essential habitat includes waters and substrate that focus distribution (e.g., coral reefs) and other characteristics that are less distinct (e.g., turbidity zones, salinity gradients). Spatially, habitats and their use may shift over time due to climatic change, human activities and impacts. The type of habitat available, its attributes and its functions are important to species productivity, diversity, health and survival.

The final rule for EFH (Federal Register 62, No. 244 December 19,1997) requires that Management Councils, through Fishery Management Plans, identify non-fishing impacts to EFH and provide general conservation measures.

2.2 Measures

Established policies and procedures of the WPRFMC and NMFS provide the framework for conserving and enhancing EFH. Components of this framework include adverse impact avoidance and minimization; provision of compensatory mitigation whenever the impact is significant and unavoidable; and incorporation of enhancement. New and expanded responsibilities contained in the Magnuson-Stevens Fishery Conservation and Management Act will be met through appropriate application of these policies and principles. In assessing the potential impacts of proposed projects, the WPRFMC and the NMFS are guided by the following general considerations:

- The extent to which the activity would directly and indirectly affect the occurrence, abundance, health and continued existence of fishery resources;

- The extent to which the potential for cumulative impacts exists;

- The extent to which adverse impacts can be avoided through project modification, alternative site selection or other safeguards;

- The extent to which the activity is water dependent if loss or degradation of EFH is involved; and

- The extent to which mitigation may be used to offset unavoidable loss of habitat functions and values.

The following activities have been identified as directly or indirectly affect the habitat utilized by management unit species: dredging, fills/dredge material disposal, marine mining, water intake structures, aquaculture, wastewater discharge, discharge of oil or release of hazardous substances, fish enhancement structures, introduction of exotic species, coastal development, and agricultural practices. The following measures are not all-inclusive, but are good examples of measures that will aid in minimization or avoidance of adverse effects of these non-fishing activities on EFH.

2.2.1 Dredging

1. To the maximum extent practicable, dredging should be avoided. Activities that require dredging (such as placement of piers, docks, marinas, etc.) should be sited in deep-water areas or designed in such a way as to alleviate the need for maintenance dredging. Projects should be permitted only for water-dependent purposes, when no feasible alternatives are available.

2. Dredging in coastal and estuarine waters should be performed during the time frame when management unit species and prey species are least likely to be entrained. Dredging should be avoided in areas with submerged aquatic vegetation.

3. All dredging permits should reference latitude-longitude coordinates of the site so information can be incorporated into Geographic Information Systems (GIS). Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

4. Sediments should be tested for contaminants as per Environmental Protection Agency and US Army Corps of Engineers requirements.

5. The cumulative impacts of past and current dredging operations on EFH should be addressed by federal, state and local resource management and permitting agencies and considered in the permitting process.

6. If dredging needs are caused by excessive sedimentation in the watershed, those causes should be identified and appropriate management agencies contacted to assure action is done to curtail those causes.

7. Pipelines and accessory equipment used in conjunction with dredging operations should, to the maximum extent possible, avoid coral reefs, seagrass beds, estuarine habitats and areas of subaquatic vegetation.

2.2.2 Fills/dredge material disposal

1. To the extent possible, fill materials resulting from dredging operations should be placed on an upland site. Fills should not be allowed in areas with subaquatic vegetation or other areas of high productivity.

2. The cumulative impacts of past and current fill operations on EFH should be addressed by federal, state and local resource management and permitting agencies and considered in the permitting process.

3. The disposal of contaminated dredge material should not be allowed in EFH.

4. When reviewing open-water disposal permits for dredged material, state and federal agencies should identify the direct and indirect impacts such projects may have on EFH. When practicable, benthic productivity should be determined by sampling prior to any discharge of fill material. Sampling design should be developed with input from state and federal resource agencies.

5. The areal extent of the disposal site should be minimized. However, in some cases, thin layer disposal may be less deleterious. All non-avoidable impacts should be mitigated.

6. All spoil disposal permits should reference latitude-longitude coordinates of the site so information can be incorporated into GIS systems. Inclusion of aerial photos may also be required to help geo-reference the site and evaluate impacts over time.

7. Further fills in estuaries and bays for development of commercial enterprises should be curtailed.

2.2.3 Marine mining

1. Mining in areas identified, as juvenile bottomfish habitat should be avoided.

2. Mining in areas of high biological productivity should be avoided.

3. Mitigation should be provided for loss of habitat due to mining.

2.2.4 Water intake structures

1. New facilities that rely on surface waters for cooling should not be located in areas where fishery organisms are concentrated, such as estuaries, inlets, heads of submarine canyons, rock reefs or small coastal embayment's. Discharge points should be located in areas that have low concentrations of living marine resources, or they should incorporate cooling towers that employ sufficient safeguards to ensure against release of blow-down pollutants into the aquatic environment.

2. Intake structures should be designed to prevent entrainment or impingement of MUS larvae and eggs.

3. Discharge temperatures (both heated and cooled effluent) should not exceed the thermal tolerance of the plant and animal species in the receiving body of water.

4. Mitigation should be provided for the loss of essential fish habitat from placement of the intake structure and delivery pipeline.

2.2.5 Aquaculture facilities

1. Facilities should be located in upland areas as often as possible. Tidally influenced wetlands should not be enclosed or impounded for mariculture purposes. This includes hatchery and grow-out operations. Siting of facilities should also take into account the size of the facility, the presence or absence of submerged aquatic vegetation, proximity of wild fish stocks, migratory patterns, competing uses, hydrographic conditions and upstream uses. Benthic productivity should be determined by sampling prior to any operations. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.

2. To the extent practicable, water intakes should be designed to avoid entrainment and impingement of native fauna.

3. Water discharge should be treated to avoid contamination of the receiving water and should be located only in areas having good mixing characteristics.

4. Where cage mariculture operations are undertaken, water depths and circulation patterns should be investigated and should be adequate to preclude the buildup of waste products, excess feed and chemical agents.

5. Non-native, ecologically undesirable species that are reared may pose a risk of escape or accidental release, which could adversely affect the ecological balance of an area. A thorough scientific review and risk assessment should be undertaken before any non-native species are allowed to be introduced.

6. Any net pen structure should have small enough webbing to prevent entanglement by prey species.

7. Mitigation should be provided for the EFH areas impacted by the facility.

2.2.6 Wastewater discharge

1. Outfall structures should be placed sufficiently far enough offshore to prevent discharge water from affecting areas designated as EFH. Discharges should be treated using the best available technology, including implementation of up-to-date methodologies for reducing discharges of biocides (e.g., chlorine) and other toxic substances.

2. Benthic productivity should be determined by sampling prior to any construction activity. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.

3. Mitigation should be provided for the degradation or loss of habitat from placement of the outfall structure and pipeline as well as the treated water plume.

2.2.7 Discharge of oil or release of hazardous substances

1. Containment equipment and sufficient supplies to combat spills should be on-site at all facilities that handle oil or hazardous substances.

2. Each facility should have a "Spill Contingency Plan," and all employees should be trained in how to respond to a spill.

3. To the maximum extent practicable, storage of oil and hazardous substances should be located in an area that would prevent spills from reaching the aquatic environment.

4. Construction of roads and facilities adjacent to aquatic environs should include a storm-water treatment component that would filter out oils and other petroleum products.

2.2.8 Fish enhancement structures

1. Benthic productivity should be determined by sampling prior to any construction activity. Areas of high productivity should be avoided to the maximum extent possible. Sampling design should be developed with input from state and federal resource agencies.

2. Prior to construction, an evaluation of the impact resulting from the change in habitat (sand bottom to rocky reef, etc.) should be performed. The importance of the site as juvenile bottomfish habitat should be evaluated.

2.2.9 Coastal development impacts

1. Prior to installation of any piers or docks, the presence or absence of submerged aquatic vegetation should be determined. Vegetated areas should be avoided. Benthic productivity should also be determined, and areas with high productivity avoided. Sampling design should be developed with input from state and federal resource agencies.

2. The use of dry stack storage is preferable to wet mooring of boats. If that method is not feasible, construction of piers, docks and marinas should be designed to minimize impacts to the substrate and subaquatic vegetation.

3. Bioengineering should be used to protect altered shorelines. The alteration of natural stable shorelines should be avoided.

4. Filling of estuaries and bays for commercial enterprises should be curtailed.

2.2.10 Introduction of exotics

1. Vessels should discharge ballast water far enough out to sea to prevent introduction of non-native species to bays and estuaries.

2. Exotics should not be introduced for aquaculture purposes unless a thorough scientific evaluation and risk assessment are performed (see section on aquaculture).

3. Effluent from public aquaria displays and laboratories and educational institutes using exotic species should be treated prior to discharge.

2.2.11 Agricultural practices

1. The use of pesticides, herbicides and fertilizers in areas that would allow for their entry into the aquatic environment should be avoided.

2. The best land management practices should be used to control topsoil erosion and sedimentation.

Activity	Impacts	Conservation Measures
1. Dredging	· Infaunal and bottom-dwelling organisms · Turbidity plumes · Bioavailability of toxic substances · Damage to sensitive habitats · Water circulation modification	· Curtail/minimize dredging activities as practicable · Take actions to prevent impacts to flora/fauna · Geo-reference all dredge sites · Assay contaminants · Reference past/current dredging operations · Curtail sources of excessive sedimentation · Maintain seafloor contours as practicable · Curtail sloughing events · Avoid impacts of accessory equipment · Minimize turbidity · Provide compensatory mitigation
2. Dredge Material Disposal/Fills	· Infaunal and bottom-dwelling organisms · Turbidity plumes · Biological availablility of toxic substances · Damage to sensitive habitats · Current patterns/ water circulation modfication · Loss of habitat function	· Place dredge spoils upland if possible; avoid fills in productive areas · Address cumulative impacts · Don't dispose contaminated dredge material in EFH · Identify direct and indirect impacts on EFH · Minimize areal extent of the disposal site · Geo-reference the site · Explore beneficial use of clean dredged material
3. Marine Mining	· Resuspension of fine-grained mineral particles · Composition of the substrate altered •Loss of habitat function •Turbidity plumes	· Avoid juvenile bottomfish habitat · Avoid areas of high productivity · Provide mitigation
ACTIVITY	**IMPACTS**	**CONSERVATION MEASURES**
4. Water Intake Structures	· Entrapment, impingement, and entrainment · Loss of prey species	· Locate facilities away from productive areas · Prevent entrainment or impingement of prey

		species. · Contain discharge temperatures · Mitigate habitat/fishery losses
5. Aquaculture	· Discharge of organic waste from the farms · Impacts to the seafloor below the cages or pens	· Minimize water/habitat quality impacts · Avoid entrainment and impingement losses · Treat and mix water discharges · Preclude waste product buildups · Undertake risk assessment prior to introducing non-native species · Prevent entanglement of prey species. · Mitigate impacts
6. Wastewater Discharge	· Wastewater effluent with high contaminant levels · High nutrient levels downcurrent of these outfalls · Biocides to prevent biofouling · Thermal effects · Turbidity plumes · Affected submerged aquatic vegetation sites · Storm-water runoff	· Avoid areas of high productivity · Mitigate as required for water quality/habitat losses · Treat storm-water
7. Oil Discharge/ Hazardous Substances Release	· Direct physical contact · Indirect exposure resulting · Cleanup	· Maintain on-site containment equipment and supplies · Have on-site "Spill Contingency Plan" · Prevent spills from reaching the aquatic environment.
8. Fish Enhancement Structures	· Loss of habitat · Inappropriate materials · Aggregation vs. production	· Avoid areas of high productivity · Evaluate impacts to existing habitat · Determine productivity of structures after construction
ACTIVITY	**IMPACTS**	**CONSERVATION MEASURES**
9. Coastal Development Impacts	· Contaminant runoff · Sediment runoff	· Avoid shoreline construction in productive areas · Use dry stack storage over wet mooring

	· Shoreline stabilization projects	· Curtail fills in estuaries, wetlands and bays
10. Introduction of Exotic Species	· Habitat alteration · Trophic alteration · Gene pool alteration · Spatial alteration · Introduction of disease	· Take precautions to prevent non-native species introductions by vessels · Undertake risk assessment prior to introducing non-native species for aquacultural purposes · Treat effluents prior to discharge · Avoid livestock grazing in areas with invasive, non-indigenous vegetation
11. Agricultural Practices	· Introduction of chemicals · Introduction of animal wastes · Increased sedimentation	· Avoid migration of pesticides, herbicides and fertilizers into aquatic environments · Avoid livestock impacts to tidal wetland areas

Table 1

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Appendix 6
EFH Scientific Data Needs

NMFS guidelines state that the quality of available data should be rated using the following four level systems:

- Level 1: All that is known is where a species occurs based on distribution data for all or part of the geographic range of the species.
- Level 2: Data on habitat-related densities or relative abundance of the species are available.
- Level 3: Data on growth, reproduction, or survival rates within habitats are available.
- Level 4: Production rates by habitat are available.

The Council adopted a fifth level, denoted Level 0, for situations in which there is no information available about the geographic extent of a particular managed species' life stage.

The Council conducted an initial inventory of available environmental and fisheries data sources relevant to the EFH of each managed fishery. Based on this inventory a series of tables were created which indicated the existing level of data for individual MUS in each fishery. These tables are presented on p.A6-2 to A6-5.

Habitat Matrix Table for Bottomfish Management Unit Species

Life History Stage	**Eggs**	**Larvae**	**Juvenile**	**Adult**
Bottomfish: (scientific/english common)				
Aphareus rutilans (red snapper/silvermouth)	0	0	0	2
Aprion virescens (gray snapper/jobfish)	0	0	1	2
Caranx ignoblis (giant trevally/jack)	0	0	1	2
C lugubris (black trevally/jack)	0	0	0	2
Epinephelus faciatus (blacktip grouper)	0	0	0	1
E quernus (sea bass)	0	0	1	2
Etelis carbunculus (red snapper)	0	0	1	2
E coruscans (red snapper)	0	0	1	2
Lethrinus amboinensis (ambon emperor)	0	0	0	1
L rubrioperculatus (redgill emperor)	0	0	0	1
Lutjanus kasmira (blueline snapper)	0	0	1	1
Pristipomoides auricilla (yellowtail snapper)	0	0	0	2
P filamentosus (pink snapper)	0	0	1	2
P flavipinnis (yelloweye snapper)	0	0	0	2
P seiboldi (pink snapper)	0	0	1	2
P zonatus (snapper)	0	0	0	2
Pseudocaranx dentex (thicklip trevally)	0	0	1	2
Seriola dumerili (amberjack)	0	0	0	2
Variola louti (lunartail grouper)	0	0	0	2
Seamount Groundfish:				
Beryx splendens (alfonsin)	0	1	2	2
Hyperoglyphe japonica (ratfish/butterfish)	0	0	0	1
Pseudopentaceros richardsoni (armorhead)	0	1	1	3

Habitat Matrix for Pelagic Management Unit Species

Life History Stage	**Egg**	**Larvae**	**Juvenile**	**Adult**
Pelagics Management Unit Species:(english common/scientific name)				
Mahimahi (dolphinfish) - *Coryphaena* spp	1	2	1	2
Indo-Pacific blue marlin - *Makaira mazara*	1	2	0-1	2-3
Black marlin - *Makaira indica*	1	2	0-1	2-3
Striped marlin - *Tetrapterus audax*	1	2	0-1	2-3
Shortbill spearfish - *Tetrapterus angustirostris*	0	2	0	2
Sailfish - *Istiophorus platypterus*	0	2	0	2
Wahoo - *Acanthocybium solandri*	1	2	0	1-2
Swordfish - *Xiphias gladius*	1	2	0	2-3
Moonfish - *Lampris* spp	0	2	0-1	1
Oilfishes - *Ruvettus pretiosus; Lepidocybium flavobrunneum*	0	2	0	1
Pomfret - Bromidae	0-1	2	0	1-2
Oceanic sharks - Alopiidae; Carcharinidae; Lamnidae; Sphyrnidae	N/A	N/A	0-1	1-2
Albacore - *Thunnus alalunga*	1	2	0-1	2-3
Bigeye tuna - *T obesus*	1	2	2	2-3
Yellowfin tuna - *T albacares*	1	2	1-2	2-3
Northern bluefin tuna - *T thynnus*	1	2	1-2	2-3
Skipjack tuna - *Katsuwonus pelamis*	1	2	2	2-3
Kawakawa - *Euthynnus affinis*	0	2	0-1	2
Dogtooth tuna - *Gymnosarda unicolor*	0	2	0	1
Other tuna relatives - *Auxis* spp; *Scomber* spp; *Allothunnus* spp	0-1	2	1-2	1-2

Habitat Matrix Table for Crustacean Management Unit Species

Life History Stage	Eggs	Larvae	Juvenile	Adult
Crustaceans: (english common\scientific)				
Spiny lobster (*Panulirus marginatus*)	2	1	1-2	2-3
Spiny lobster (*Panulirus pencillatus*)	1	1	1	2
Common slipper lobster (*Scyllarides squammosus*)	2	1	1	2-3
Ridgeback slipper lobster (*Scyllarides haanii*)	2	0	1	2-3
Chinese slipper lobster (*Parribacus antarcticus*)	2	0	1	2-3
Kona crab (*Ranina ranina*)	1	0	1	1-2

Habitat Matrix Table for Precious Corals Management Unit Species

Species	Pelagic phase (larval stage)	Benthic phase
Pink Coral		
Corallium secundum	0	4
C. regale	0	2
C. laauense	0	2
Gold Coral		
Gerardia spp	0	2
Callogorgia gilberti	0	2
Narella spp.	0	2
Bamboo Coral		
Lepidisis olapa	0	2
Acanella spp.	0	2
Black Coral		
Antipathes dichotoma	0	4
A. grandis	0	4
A. ulex	0	2

Based, in part, on the information provided in the tables above the Council identified the following scientific data that are needed to more effectively address the EFH provision:

All FMP Fisheries

- Distribution of early life history stages (eggs and larvae) of management unit species by habitat
- Juvenile habitat (including physical, chemical, and biological features that determine suitable juvenile habitat)
- Food habits (feeding depth, major prey species etc.)
- Habitat-related densities for all MUS life history stages
- Habitat utilization patterns for different life history stages and species for BMUS
- Growth, reproduction and survival rates for MUS within habitats

Bottomfish Fishery

- Inventory of marine habitats in the EEZ of the Western Pacific region
- Data to obtain a better SPR estimate for American Samoa's bottomfish complex
- Baseline (virgin stock) parameters (CPUE, percent immature) for the Guam/NMI deep-water and shallow-water bottomfish complexes
- High-resolution maps of bottom topography/currents/water masses/primary productivity

Pelagics Fishery

- Distribution of juvenile tuna and billfish
- Relationships between chemical, physical, and biological factors and habitat suitability for all life history stages of PMUS throughout the Western Pacific Region throughout the species range (i.e., salinity gradients, temperature gradients, currents, spawning sites, upwelling's, seamounts etc.) Areas of particular interest would include convergence zones such as the North Pacific Transition Zone
- Important spawning sites
- Role of currents in larval distribution patterns

Crustaceans Fishery

- Identification of post-larval settlement habitat of all CMUS

- Identification of "source/sink" relationships in the NWHI and other regions (ie, relationships between spawning sites settlement using circulation models, genetic techniques, etc)

- Establish baseline parameters (CPUE) for the Guam/Northern Marinas crustacean populations

- Research to determine habitat related densities for all CMUS life history stages in American Samoa, Guam, Hawaii and NMI

- High resolution mapping of bottom topography, bathymetry, currents, substrate types, algal beds, habitat relief

Precious Corals Fishery

- Distribution, abundance and status of precious corals in the Western Pacific region