WESTERN
PACIFIC
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MANAGEMENT
COUNCIL

Amendment 15 to the Pelagics Fisheries Management Plan

Measures to Monitor and Manage Domestic Pacific Harvests of Pelagic Squid Including an Environmental Assessment

July 31, 2008

Western Pacific Regional Fishery Management Council
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Measures to Monitor and Manage Domestic Pacific Harvests of Pelagic Squid
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Abstract

There are two small near-shore squid fisheries operating out of Kauai and the Island of Hawaii that target *Sthenoteuthis oualaniensis* and an international large-scale squid jigging fishery on the Pacific high seas which has included U.S.-flagged and foreign fishing vessels. The U.S. squid jiggers have targeted *Ommastrephes bartramii* in the North Pacific high seas waters and could move into U.S. Exclusive Economic Zone (EEZ) waters in the Western Pacific Region. Although no resource concerns have arisen to date, current monitoring systems are sub-optimal and there are no mechanisms in place to implement management measures should they become necessary. This amendment to the Pelagics Fishery Management Plan addresses these issues.

The Western Pacific Fishery Management Council (Council) recommends improving data on U.S. squid fisheries through new permitting, monitoring and reporting requirements, and by establishing domestic mechanisms for management. Amendment 15 includes:

Adding the following pelagic squid species as Pelagic Management Unit Species (MUS): *Ommastrephes bartramii*, *Thysanoteuthis rhombus*, and *Sthenoteuthis oualaniensis*, and require

U.S. vessels greater than 50 ft in length overall that fish for pelagic squid in U.S. EEZ of the western Pacific to obtain Federal permits under the Pelagics Fishery Management Plan, to carry Federal observers if requested by NMFS, and to report any Pacific pelagic squid catch and effort either in Federal logbooks or via existing local reporting systems. The minimum vessel length of 50 feet was selected because this is the approximate lower size limit for commercial squid vessels that fish in the U.S. EEZ and on the high seas, and the smallest size that could readily accommodate observers. Smaller vessels may conduct commercial squid fishing nearer to shore in Hawaii, and their commercial catch is already reported on State commercial catch reports. In other areas, local creel census or commercial sales invoices provide information on the squid catch by smaller vessels.

Under this alternative, NMFS would replace previously-used HSFCA logbooks with logbooks specifically designed for squid fishing. Vessels that only fish on the high seas would be required to report their catch and effort using the revised HSFCA logbooks.

Squid fishery data would be centralized into a fishery database easily available to resource scientists and managers.

These measures, if implemented, would provide additional data and provisions to enable the Council and NMFS to better monitor and manage the U.S. domestic pelagic squid fisheries in the future.

Amendment 15 includes an environmental assessment (EA) that describes the existing squid fishery management and environment, and describes the potential environmental impacts of implementing Alternative 3a. This EA tiers off of a previous Final Environmental Impact Statement (FEIS) that was made available to the public in 2005 (70 FR 24038; May 6, 2005) and incorporates by reference the previous environmental impact analysis of five of the alternatives for Amendment 15. New information about future fishery management policies became available after the Final EIS was completed and the additional alternative considered here addresses the new policy information.

Summary

Pelagic squid are targeted by food and bait fisheries throughout the Pacific and are considered by many to be a 'keystone' species. Squid are active predators and targeted prey items for many species of fish, mammals, birds and sea turtles. The Council reviewed current data collection systems and found them insufficient. Current data collection is considered insufficient by the Western Pacific Regional Fishery Management Council (Council), which recommedned an amendment to the Pelagics Fishery Management Plan (FMP). The purpose of this amendment is to provide for improved squid fisheries data and establish the framework for future management measures that may be needed to manage squid fisheries within the U.S. Exclusive Economic Zone (EEZ).

An international, large-scale squid jigging fishery (multi-species) exists on the Pacific high seas. This includes both foreign and a few domestic (U.S. flagged) fishing vessels. The Japanese jigging fleet was dominant in the North Pacific, but is rivaled now by a rapidly growing Chinese fleet. The fishery is seasonal with most vessels switching to the Southern hemisphere during the antipodean summer (October – February). Three domestic squid jig vessels fished for squid in the North Pacific for a month or less in the summer of 2003, catching *O. bartramii*, (red flying squid) on the high seas and offloading it in Japan. Following a disappointing season they transferred to New Zealand's waters for the 2003 summer/autumn squid season. Fishing for squid was reportedly excellent in the southern hemisphere season in 2004. To date these domestic jigging vessels have fished on the high seas or in the waters of other nations, but the operator anticipates a potential transfer of fishing activity, possibly including to U.S. Exclusive Economic Zone waters (EEZ) around Hawaii, in association with a shift in oceanic conditions.

In addition, a small near-shore squid jigging fishery operating out of Kauai targets *S. oualaniensis* (purpleback squid**).** This fishery provides food and some bait squid. A tuna handline fishery operating primarily from the island of Hawaii (referred to as the Big Island) also catches *S. oualaniensis* on jigs; these squid are then used as bait to target yellowfin tuna. Although significant in the 1970s and 1980s, current participation in this fishery is now estimated to consist of one to three vessels.

Pelagic squid are widely dispersed and short-lived with relatively high fecundity rates. Populations recover very quickly following declines and are very difficult to overfish by relatively inefficient methods such as jigging (in the past drift gillnets were used but these have been illegal since 1992). For example, stock abundance of *O. bartramii* in the Central North Pacific was extremely low in 1993, probably due to high fishing rates derived from the driftnet fishery (Yatsu et al., 1999). When the fishery ended in 1992, the *O. bartramii* stock quickly recovered and abundance was high during 1994-96. Stock abundance was again depressed in 1997, the most prominent El Niño year in this century, but was high in 1998. There is currently no evidence of overfishing of pelagic squid stocks on the high seas or in Hawaii's waters.

However, squid are a major component of the pelagic ecosystem, with large species preying on a variety of fish and invertebrate species and smaller species providing important forage components for species such as swordfish and pilot whales. The keystone role of squid in the forage base of a wide variety of pelagic fish and marine mammals means that they may be an

important indicator of ecosystem dynamics. Although U.S. fisheries in the northern waters of the Western Pacific catch a tiny fraction of the total international squid production, data provided by monitoring of these fisheries is, as yet, the only indicator available of squid stock status.

Fishing by most domestic vessels is managed under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), which in 1976 established a system of regional fishery management Councils. These Councils develop fishery management plans establishing mechanisms to monitor and manage their "management unit species" (those species managed under each fishery management plan). Annual reports are prepared for each fishery management plan which present and analyze catch and effort data, as well as stock status and other indicators for each management unit species. Based on this and other information, Councils then make management recommendations to the National Marine Fisheries Service (NMFS) which, if approved, are promulgated through the publication of proposed and final rules in the Federal Register and their implementing regulations are then codified in the Code of Federal Regulations. Under the MSA the Western Pacific Regional Fishery Management Council consists of the States of Hawaii, American Samoa, Guam, and the Northern Mariana Islands and has authority over the fisheries in the Pacific Ocean seaward of such States and of the Commonwealths, territories, and possessions of the United States in the Pacific Ocean area.

Further as articulated in NMFS' guidelines for the MSA's National Standard 3 (Section 301(a)(3), Councils are required to manage stocks to the extent possible throughout their ranges, not only in EEZ waters. This is also important for consistency with National Standard 1 with respect to MSY (Section 301 (a)(1)), since there is currently little information on the population biology of these species with which to develop stock determination criteria. Currently, the natural mortality rate (M) is unknown, as is the ratio of current biomass to the biomass at MSY (B/Bmsy), and concomitant current fishing mortality to fishing mortality at MSY (F/Fmsy). Thus there is a need to ensure that at a minimum, U.S. catches of squid in the Western Pacific by fisheries in federally regulated waters are recorded accurately in order to determine M.

Fisheries in international waters are managed through international convention, treaties and agreements. In May of 1996 the High Seas Fishing Compliance Act (HSFCA) was established to implement the International Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas. This agreement requires that all fishing vessels of participating nations are authorized to operate on the high seas, that vessels are identified, that vessel operators submit logbooks, and that they do not violate conservation and management measures that have been adopted through international treaties, conventions or agreements. The U.S. implemented the authorization requirement by requiring that all domestic vessels fishing commercially on the high seas first obtain a HSFCA permit (this permit is currently a general permit, meaning that these are not separate permits according to target species or gear types). In January of 1999, vessel identification and reporting requirements were promulgated by NMFS for vessels permitted under the HSFCA. Affected vessels (those that fish on the high seas) must have vessel identification numbers clearly marked on their hull, and vessel operators must complete and submit logbooks of their high seas fishing effort and catches to NMFS . However because there has been no specific HSFCA logbook for squid fishing, vessel operators have been recording different information in a variety of logbooks. For example, some report squid catches by species while others do not. The HSFCA logbooks are not collated and analyzed and their data is not routinely entered into a database system nor is it readily available to scientists or resource managers.

“Historically, a permit issued under the HSFCA has listed the international living marine resource agreements recognized by the U.S. and noted that holders of HSFCA permits must act in compliance with the listed agreements, including any international conservation and management measures implemented under the agreements. The only restrictions on such HSFCA permit holders were to abide by such international conservation and management measures and any measures that might apply under a Magnuson-Stevens Fishery Conservation and Management Act fishery management plan” (letter from W.T. Hogarth, Asst. Admin. for Fisheries, National Marine Fisheries Service to HSFCA permit holders, February 23, 2004). As a result of a 2003 decision by the U.S. Court of Appeals for the Ninth Circuit, this policy changed. The Court ruled that NMFS has the legal obligation to consult, pursuant to section 7 of the ESA [Endangered Species Act], on the issuance of HSFCA permits, and that permits may be conditioned as necessary to protect or benefit listed species. For vessels currently fishing under a valid HSFCA permit, this ruling did not affect their operations for the remainder of the five-year term of their permit. However, as of February 23, 2004, applications for permit renewals or for new permits became subject to new requirements. Permits “will no longer authorize permit holders to fish with any gear anywhere on the high seas they chose for any target species they chose. Only specific high seas fishing activities will be authorized by HSFCA permits in the future. Activities not specifically authorized are prohibited” (letter from W.T. Hogarth, Asst. Admin. for Fisheries, National Marine Fisheries Service to HSFCA permit holders, Feb. 23, 2004).

Commercial landings of squid and other species offloaded in Hawaii (regardless of where caught) are required to be reported on Hawaii state catch reports. Recreational catches landed in Hawaii are not subject to any reporting requirements; however with respect to squid, these harvests are believed to be very small and are not a concern to resource managers. With the exception of the PRIA, creel surveys in the other island areas under the Council’s jurisdiction are conducted to collect information on both commercial and recreational fishing vessels. However, because pelagic squid are not included as management unit species under any of the Council’s fishery management plans, neither the locally collected squid data nor the squid data in the HSFCA logbooks are collated or analyzed in the annual reports prepared under each plan. Implementation and improvement of data collection mechanisms are consistent with MSA section 303(a)(8).

In addition to a need for better data, a second issue regarding the domestic squid jigging fishery is that there is no management mechanism to implement fishery regulatory controls should concerns arise regarding squid stocks or other aspects of the fishery. The appropriate management mechanism is through the inclusion of Pacific pelagic squid in a fishery management plan, which would allow the Council to develop regulations for them. In addition to providing the framework for future squid fisheries management actions, including squid as MUS species in the Pelagics FMP would also allow fisheries regulations to be implemented and enforced under international agreements regarding squid fisheries, in accordance with the HFSCA.

The objective of this action is to establish appropriate monitoring and management mechanisms for the domestic harvest of Pacific pelagic squid. Due to the health of the resources and the small size of the current domestic Pacific pelagic squid fishery, as well as the lack of any reports of interactions with protected species or significant levels of bycatch, specific management measures (such as time or area closures, or effort or landing limits) are not being considered at this time. Also not under current consideration is the use of vessel monitoring systems. These systems monitor the location of fishing vessels and are only appropriate (by Council policy) for fisheries where there are spatial or temporal aspects to management measures. However, the establishment of mechanisms to implement specific fishing management measures will allow for these or other regulatory controls to be quickly put in place should the data collected indicate a need for management measures regulating harvest.

Objective: To establish appropriate mechanisms for the monitoring and management of Pacific pelagic squid harvests by domestic vessels.

The following was recommended as the preferred alternative by the Council at their 124th meeting in October 2004:

Alternative 3: Improve mandatory monitoring and establish mechanisms for management by including the following pelagic squid species, *O. bartramii, Thysanoteuthis rhombus* (Troschel 1875) and *S. oualaniensis,* in the Council's existing Pelagics Fishery Management Plan. Require that vessels greater than 50 ft in length overall that harvest pelagic squid in EEZ waters be subject to federal permit and reporting requirements and require these vessels to carry observers if requested by NMFS. Centralize this data into a database easily available to resource managers.

Subsequently, however, the Council was notified by NMFS of impending changes to the HSFCA which would include a requirement for U.S. vessels to have an FMP permit in order to qualify for an HSFCA permit. As such, the Council did not transmit the above recommendation to NMFS and instead will consider recommending new Alternative 3a (below) at its 140th meeting in March 2008.

Alternative 3a: Improve mandatory monitoring and establish mechanisms for management by including the following pelagic squid species, *O. bartramii, Thysanoteuthis rhombus* (Troschel 1875) and *S. oualaniensis,* as Pelagic Management Unit Species. Replace HSFCA logbooks currently used with logbooks specifically designed for squid fishing. [Note: although HSFCA logbooks are not managed under the MSA, in response to the Council's concerns NMFS began revising these logbooks in March 2007]. Require U.S. vessels greater than 50 ft in length overall that fish for pelagic squid in U.S. Pacific EEZ waters to obtain federal permits under the Pelagics FMP to carry observers if requested by NMFS and to report their high sea catch and effort using Pelagics FMP logbooks. Require these vessels to also report any U.S. Pacific EEZ pelagic squid catch and effort either in federal Pelagics Fishery Management Plan logbooks or to via existing local reporting systems. The minimum vessel length of 50 feet was selected because this is the approximate lower size limit for commercial squid vessels that fish in the U.S. EEZ and on the high seas, and the smallest size that could readily accommodate observers. Centralize the data into a database easily available to resource scientists and managers.

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Chapter 1. Background Information

1.1 Introduction

The Western Pacific Regional Fishery Management Council (WPRFMC or Council) has become aware of a domestic squid jigging operation comprised of three fishing vessels and a mother ship fishing sporadically around the Western Pacific region. In addition, a small near-shore squid jigging fishery operating out of Kauai, Hawaii, targets *S. oualaniensis* (purpleback squid). This fishery provides food and some bait squid. A tuna handline fishery operating primarily from the island of Hawaii (referred to as the Big Island) also catches *S. oualaniensis* using jigs, these squid are then used as bait to target yellowfin tuna. Although significant in the 1970s and 1980s, current participation in this fishery is now estimated to consist of one to three vessels.

Although no resource concerns have arisen to date, current monitoring systems for these fisheries are sub-optimal, and there are no mechanisms in place to implement management measures should they become necessary.

1.2 Responsible Agencies

The Council was established by the Magnuson-Stevens Fishery and Conservation Management

Act (MSA) to develop Fishery Management Plans (FMP) for domestic fisheries seaward of state and territorial waters around American Samoa, Guam, Hawaii, the Commonwealth of the Northern Mariana Islands and the Pacific Remote Island Areas[1]. Once an FMP is approved by the Secretary of Commerce, it is implemented by federal regulations which are enforced by the National Marine Fisheries Service and the U.S. Coast Guard, in cooperation with state, territorial and commonwealth agencies. For further information contact:

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1.3 Public Review Process and Schedule

Given the Council's concern regarding the management of Pacific pelagic squid, on October 17, 2003, the Council and National Marine Fisheries Service (NMFS, also known as NOAA

[1] Howland, Baker, Jarvis, Wake and Johnston Islands, Palmyra and Midway Atolls and Kingman Reef.

Fisheries) announced their intent to prepare a Supplemental Environmental Impact Statement under the National Environmental Policy Act (NEPA) to evaluate long-term management measures for the pelagic fishery, potentially including measures for pelagic squid. This notice also provided times and dates for scoping meetings, and requested comments (68 FR 59771). Scoping meetings were held as part of the NEPA process to develop an environmental impact statement, which would inform the Council as they considered management alternatives for a FMP amendment to the Pelagics Fishery Management Plan. Public meetings were held as follows to obtain public comments on the issues discussed here:

October 21, 2003 – Honolulu, Oahu.
October 27, 2003 – Lihue, Kauai
October 28, 2003 – Kahului, Maui
October 29, 2003 – Hilo, Hawaii
October 30, 2003 – Kona, Hawaii
November 6, 2003 – Pago Pago, American Samoa
December 3, 2003 – Saipan, Northern Marianas Islands
December 4, 2003 – Hagatna, Guam

On April 28, 2004, an overview of this topic was presented and discussed at a public meeting of the Council's Pelagics Plan Team in Honolulu. A publicly available background paper containing a range of potential alternatives was subsequently reviewed and discussed at a public meeting of the Council's Scientific and Statistical Committee (SSC) meeting on June 8, 2004 in Honolulu. This meeting included a public comment period.

The Council then reviewed and discussed a publicly available draft of this FMP amendment to the Pelagics Fishery Management Plan and the related recommendations of the Plan Team and the SSC at its 123rd meeting held June 21-24, 2004 in Honolulu. This meeting included several public comment periods, following which the Council took initial action to recommend a preliminarily preferred alternative.

The Council's SSC reviewed and discussed a revised draft of this document at a public meeting held October 5 – 7, 2004 in Honolulu. They also discussed the Council's initial action and made recommendations regarding final action on the alternatives under consideration.

At its 124th meeting in Honolulu (October 12-15, 2004) the Council reviewed these recommendations as well as the comments received on the Draft Environmental Impact Statement prepared for this action. Following a public hearing, the Council took final action to recommend Alternatives A3 (management of EEZ fishing under the MSA) and B4 (management of high seas fishing under the HSFCA) for implementation by NMFS and directed Council staff to finalize this FMP amendment and transmit it to NMFS for approval and implementation.

A Final EIS on this topic was published in April 2005 and notice of availability published in May 2005 (70 FR 24038 May 6, 2005). The EIS included analyses of a second objective and range of alternatives related to the management of domestic high seas squid fishing under the High Seas Fishing Compliance Act (HSFCA) which were were included in the FEIS following an August 21, 2003 court decision (TIRN vs. NMFS) which ruled that NMFS has the legal obligation to consult, pursuant to section 7 of the Endangered Species Act on the issuance of new (or the renewal of existing) permits issued to domestic vessels fishing on the high seas, under the HSFCA. Following this ruling, NMFS also determined that it was necessary to analyze the potential impacts of domestic high seas fisheries under the National Environmental Policy Act as well as the Marine Mammal Protection Act (MMPA) prior to issuing any new (or renewing existing) HSFCA permits. The NEPA analysis for that action, was completed via the preparation and circulation of the 2005 FEIS. The FEIS alternatives that would have applied to vessels fishing solely on the high seas under the HSFCA are not included in this document as the Council does not have jurisdiction over these vessels

In July 2007, NMFS notified the Council of impending changes to the HSFCA. Among the planned changes is a requirement for all U.S. vessels to have an FMP permit in order to qualify for HSFCA permits. Given this information, analysis of a new preferred alternative (Alternative 3a) was added for consideration by the Council and public at the Council's 141st Council meeting (April 14, 2008) At that meeting, Alternative 3a was adopted as the preferred alternative and the public was given an opportunity to comment on this new alternative.

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1.5 Purpose and Need for Action

Pelagic squid are targeted by food and bait fisheries throughout the Pacific and are considered by many to be a 'keystone' species - an active predator and a targeted prey item for many species of fish, mammals, birds and reptiles.

An international, large-scale squid jigging fishery (multi-species) exists on the Pacific high seas. This includes both foreign and, until recently, a few domestic (U.S. flagged) fishing vessels. The fishery is seasonal with most vessels switching to the Southern hemisphere during the antipodean summer (October – February). The three U.S. flagged squid jiggers (which were registered to High Seas Fishing Compliance Act permits and fished in conjunction with a domestic mother ship), fished for squid in the North Pacific for a month or less in the summer of 2003, catching *O. bartramii*, (red flying squid). Following a disappointing season they transferred to New Zealand waters for the 2003 summer/autumn squid season. Fishing for squid was reportedly excellent in the southern hemisphere season in 2004. To date these domestic jigging vessels have fished on the high seas or in the waters of other nations, but the operator anticipates a potential transfer of fishing activity, possibly including to the U.S. Exclusive Economic Zone (EEZ) around Hawaii, in association with a shift in oceanic conditions.

In addition, a small near-shore squid jigging fishery operating out of Kauai targets *S. oualaniensis* (purpleback squid**).** This fishery provides food and some bait squid. A tuna handline fishery operating primarily from the island of Hawaii (referred to as the Big Island) also catches *S. oualaniensis*, these squid are then used as bait to target yellowfin tuna. Although significant in the 1970s and 1980s, current participation in this fishery is now estimated to consist of one to three vessels.

Fishing by most domestic vessels is managed under the Magnuson-Stevens Fishery Conservation and Management Act which in 1976 established a system of regional fishery management Councils. These Councils develop fishery management plans establishing mechanisms to monitor and manage their "management unit species" (those species managed under each fishery management plan). Annual reports are prepared for each fishery management plan which present and analyze catch and effort data, as well as stock status and other indicators for each management unit species. Based on this and other information, Councils then make management recommendations to NMFS which, if approved, are promulgated through the publication of proposed and final rules in the Federal Register and their implementing regulations are then codified in the Code of Federal Regulations.

In May of 1996 the HSFCA was established to implement the International Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas. This agreement requires that all fishing vessels of participating nations are authorized to operate on the high seas, that vessels are identified, that vessel operators submit logbooks, and that they do not violate conservation and management measures that have been adopted through international treaties, conventions or agreements. The U.S. implemented the authorization requirement by requiring that all domestic vessels fishing commercially on the high seas first obtain a HSFCA permit (this permit is currently a general permit, meaning that these are not separate permits according to target species or gear types). In January of 1999, vessel identification and reporting requirements were promulgated by NMFS for vessels permitted under the HSFCA. Affected vessels (those that fish on the high seas) must have vessel identification numbers clearly marked on their hull, and vessel operators must complete and submit logbooks of their high seas fishing effort and catches to the National Marine Fisheries Service. However, because there have been no specific HSFCA logbook for squid fishing, vessel operators have used a variety of logbooks and recorded a variety of information. For example, some report squid catches by species while others do not. The HSFCA logbooks were not collated and analyzed and their data was not routinely entered into a database system nor is it readily available to scientists or resource managers. According to a

May 27, 2007 letter sent to the Council from NMFS's Pacific Islands Regional Administrator, NMFS is revising the HSFCA permit applications and logbooks to include squid jigging and to require the use of specific HSFCA squid fishing logbooks to record high seas catches.

"Historically, a permit issued under the HSFCA has listed the international living marine resource agreements recognized by the U.S. and noted that holders of HSFCA permits must act in compliance with the listed agreements, including any international conservation and management measures implemented under the agreements. The only restrictions on such HSFCA permit holders were to abide by such international conservation and management measures and any measures that might apply under a Magnuson-Stevens Fishery Conservation and Management Act fishery management plan" (letter from W.T. Hogarth, Asst. Admin. for Fisheries, National Marine Fisheries Service to HSFCA permit holders, Feb. 23, 2004). As discussed above a result of a 2003 decision by the U.S. Court of Appeals for the Ninth Circuit, this policy changed. For vessels then fishing under a valid HSFCA permit, this ruling did not affect their operations for the remainder of the five-year term of their permit. However, as of February 23, 2004, applications for permit renewals or for new permits became subject to new requirements. Permits "will no longer authorize permit holders to fish with any gear anywhere on the high seas they chose for any target species they chose. Only specific high seas fishing activities will be authorized by HSFCA permits in the future. Activities not specifically authorized are prohibited" (letter from W.T. Hogarth, Asst. Admin. for Fisheries, National Marine Fisheries Service to HSFCA permit holders, Feb. 23, 2004). Future permits will thus be specific to the permitted gear type. As detailed in an August 16, 2006 letter sent to the Council from NMFS' Pacific Islands Regional Administrator, this amendment provides the nexus or trigger for the commencement of the ESA and MMPA analyses required before domestic high seas squid jig fisheries can be authorized under the HSFCA and new (or renewed) HSFCA permits can be issued.

Commercial landings of squid and other species offloaded in Hawaii (regardless of where caught) are required to be reported on Hawaii state catch reports. Recreational catches landed in Hawaii are not subject to any reporting requirements; however with respect to squid, these harvests are believed to be very small and are not a concern to resource managers. With the exception of the PRIA, creel surveys in the other island areas under the Council's jurisdiction are conducted to collect information on both commercial and recreational fishing vessels. However, because pelagic squid are not included as management unit species under any of the Council's fishery management plans neither the locally collected squid data nor the squid data in the HSFCA logbooks are collated or analyzed in the annual reports prepared under each plan.

A second issue regarding the domestic squid fishery is the lack of management mechanisms in place to implement regulatory controls should concerns arise regarding squid stocks or other aspects of the fishery. The appropriate management mechanism for domestic vessels fishing exclusively in U.S. Pacific EEZ waters is through the inclusion of Pacific pelagic squid in a fishery management plan. There is no management mechanism for domestic squid jigging vessels currently fishing exclusively on the high seas as there are currently no international agreements on Pacific pelagic squid with the exception of the United Nations ban on the use of drift gillnets on the high seas. Alternatively, if an international agreement was made, it could be implemented and enforced through the HSFCA.

1.6 Management Objective

The objective of this action is to establish appropriate monitoring and management mechanisms for the domestic harvest of Pacific pelagic squid.

This objective is consistent with the following findings and policy of the Magnuson-Stevens Fishery Conservation and Management Act:

Findings

101-627
.....(8) The collection of reliable data is essential to the effective conservation, management, and scientific understanding of the fishery resources of the United States

Policy

101-627, 104-297
...... (3) to assure that the national fishery conservation and management program utilizes, and is based upon, the best scientific information available; involves, and is responsive to the needs of, interested and affected States and citizens; considers efficiency; draws upon federal, State, and academic capabilities in carrying out research, administration, management, and enforcement; considers the effects of fishing on immature fish and encourages development of practical measures that minimize bycatch and avoid unnecessary waste of fish; and is workable and effective;

Due to the health of the resources and the small size of the current domestic Pacific pelagic squid fishery, as well as the lack of any reports of interactions with protected species or significant levels of bycatch, specific management measures (such as time or area closures, or effort or landing limits) are not being considered at this time. Also not under current consideration is the use of vessel monitoring systems. These systems monitor the location of fishing vessels and are only appropriate (by Council policy) where there are spatial or temporal aspects to management measures, which are not being considered at this time. However the establishment of mechanisms to implement specific fishing management measures will allow for these or other regulatory controls to be promulgated should resource concerns arise.

1.7 Initial Actions

To date the Council has focused its management of pelagic stocks on finfish as these constitute the vast majority of domestic landings of pelagic species. The prospect of a growing domestic squid jigging fishery has led the Council to consider including Pacific pelagic squid as a management unit species in its Pelagics FMP so as to improve monitoring of domestic harvests and establish mechanisms for further management of these operations should it become necessary. Moreover as articulated in MSA National Standard 3 (Section 301(a)(3), Councils are required to manage stocks to the extent possible throughout their ranges, and are not limited to the EEZ.

Further, the Council has begun moving towards ecosystem approaches to management and because squid are an important prey base for many pelagic species (e.g. tunas and billfish) as well as for some marine mammals and seabirds it is appropriate that their status and domestic harvest (however small) be monitored.

Chapter 2. Alternatives Considered

Chapter 2 presents the alternatives considered for management of the U.S. Pacific squid jigging fishery. Where alternatives have been eliminated from detailed analyses, the reason for their elimination is discussed. Chapter 3 presents a discussion of the affected environment and Chapter 4 analyses the expected impacts of the alternatives on the environment.

2.1 Alternatives Considered in Detail

Six alternatives including the no-action alternative, were developed by the Council and NMFS, with input by and review from the Council's Scientific and Statistical Committee, other interested agencies, and members of the public. Alternatives 1-4 are described and their environmental impacts were previously analyzed and in the 2005 FEIS (NMFS 2005x). New Alternative 3a responds to NMFS' July 2007 announcement of pending changes to the HSFCA as discussed in Section 1.5.

Alternative 1: No Action.

Alternative 2: Improve voluntary monitoring by the optional use of logbooks designed specifically for use by domestic pelagic squid vessels, and by the voluntary placement of federal observers on these vessels. (The Council has reached a preliminary agreement with the above domestic high seas squid jiggers to voluntarily participate in a pilot program under which they would use modified logbooks and carry federal observers, this alternative would continue these efforts). Centralize this data into a database easily available to resource managers.

Alternative 3. Improve mandatory monitoring and establish a framework for management by including pelagic squid in the Council's existing Pelagics FMP. Replace HSFCA logbooks currently used with logbooks specifically designed for squid harvesting and require operators of squid vessels permitted under the HSFCA to also include any EEZ fishing in this logbook. Require vessels that harvest pelagic squid solely in EEZ waters to either use this logbook or to participate in local reporting systems. Centralize this data into a database easily available to resource managers.

Alternative 3a: Improve mandatory monitoring and establish mechanisms for management by including the following pelagic squid species, *O. bartramii, Thysanoteuthis rhombus* (Troschel 1875) and *S. oualaniensis,* as Pelagic Management Unit Species. Replace HSFCA logbooks currently used with logbooks specifically designed for squid fishing. [Note: although HSFCA logbooks are not managed under the MSA, in response to the Council's concerns NMFS began revising these logbooks in March 2007]. Require U.S. vessels greater than 50 ft in length overall that fish for pelagic squid in U.S. Pacific EEZ waters to obtain federal permits under the Pelagics FMP to carry observers if requested by NMFS and to report their high sea catch and effort using Pelagics FMP logbooks. Require these vessels to also report any U.S. Pacific EEZ pelagic squid catch and effort either in federal Pelagics Fishery Management Plan logbooks or to via existing local reporting systems. Centralize this data into a database easily available to resource scientists and managers (**preferred**).

Alternative 4: Improve mandatory monitoring and establish mechanisms for management by developing a new Squid Fishery Management Plan for pelagic squid. Require vessels that harvest pelagic squid solely in EEZ waters to participate in local reporting systems. Centralize this data into a database easily available to resource managers.

Alternative 5: Improve mandatory international monitoring and establish mechanisms for both domestic and international management by pursuing and participating in international management agreements for Pacific pelagic squid.

2.2 Alternatives Not Considered in Detail

At the present time, U.S. participation in the Pacific high seas fishery is extremely small, with no more than four domestic vessels participating in the past four years. Hundreds of foreign vessels participate in this fishery. Our current knowledge of the status of the stocks, fishing mortality and bycatch in this fishery is limited, however the stocks appear healthy and bycatch does not appear to be a problem. There is no data to indicate interactions in this fishery with protected species. Consequently there does not appear to be any reason at this time to consider alternatives that would limit fishing mortality or reduce bycatch (such as time or area closures, or effort or landing limits).

Also not under current consideration is the use of vessel monitoring systems. These systems monitor the location of fishing vessels and are only appropriate for fisheries that are subject to area closures. However the establishment of mechanisms to implement specific fishing management measures would allow for regulatory controls to be quickly put in place should resource concerns arise.

Chapter 3. Affected Environment

3.1 Introduction

Chapter 3 describes the environment likely to be affected by the alternatives considered here, and Chapter 4 analyzes the expected impacts of the alternatives on the environment. The information presented here builds upon the information presented in the 2001 Pelagics FEIS (NMFS, 2001), and the 2004 Pelagics SEIS (WPRFMC, 2004b), supplemented by recent Biological Opinions (BiOps) prepared by NMFS and the USFWS, and Council preliminary action documents. The information about the Japanese squid jigging fishery was obtained from a Council-funded project to translate and summarize recent Japanese reports and scientific papers (Bower, 2004).

3.2 Oceanographic Environment

The following summary of the oceanography of the tropical and sub-tropical Pacific Ocean is taken from a Final Environmental Impact Statement (FEIS) for the Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region published by NMFS in 2001 (NMFS, 2001), which is believed to be an accurate account of that ecosystem.

The Hawaiian Archipelago and the Marianas Archipelago, which includes Guam and CNMI, lie in the North Pacific subtropical gyre while American Samoa lies in the South Pacific subtropical gyre. These subtropical gyres rotate clockwise in the Northern Hemisphere and counter clockwise in the Southern Hemisphere in response to tradewind and westerly wind forcing. Hence the Main Hawaiian Islands (MHI), Guam and CNMI, and American Samoa experience weak mean currents flowing from east to west, while the northern portion of the Hawaiian Archipelago experiences a weak mean current flowing from west to east. Imbedded in this mean flow are an abundance of mesoscale eddies created from wind and current interactions with bathymetry. These eddies, which can rotate either clockwise or counter clockwise, have important biological impacts. Eddies create vertical fluxes, with regions of divergence (upwelling) where the thermocline shoals and deep nutrients are pumped into surface waters enhancing phytoplankton production, and also regions of convergence (downwelling) where the thermocline deepens. North and south of the islands are frontal zones that also provide important habitat for pelagic fish and thus are targeted by fishers. To the north of the Hawaiian and Marianas Archipelagoes, and also to the south of American Samoa, lie the subtropical frontal zones consisting of several convergent fronts located along latitudes 25°-40° N. and S. often referred to as the Transition Zones. To the south of the Hawaiian and Marianas Archipelagoes, and to the north of American Samoa, spanning latitudes 15° N.-15° S. lies the equatorial current system consisting of alternating east and west zonal flows with adjacent fronts.

A significant source of interannual physical and biological variation is the El Niño and La Niña events. During an El Niño the normal easterly trade winds weaken, resulting in a weakening of the westward equatorial surface current and a deepening of the thermocline in the central and eastern equatorial Pacific. Water in the central and eastern equatorial Pacific becomes warmer and more vertically stratified with a substantial drop in surface chlorophyll. A La Niña event exhibits the opposite conditions. During an El Niño the purse seine fishery for skipjack tuna shifts over 1,000 km from the western to the central equatorial Pacific in response to physical and biological impacts (Lehodey et al., 1997).

Physical and biological oceanographic changes have also been observed on decadal time scales. These low frequency changes, termed regime shifts, can impact the entire ocean basin. Recent regime shifts in the North Pacific have occurred in 1976 and 1989, with both physical and biological (including fishery) impacts (Polovina, 1996; Polovina et al., 1995).

Pelagic species are closely associated with their physical and chemical environment. Suitable physical environment for these species depends on gradients in temperature, oxygen or salinity, all of which are influenced by oceanic conditions on various scales. In the pelagic environment, physical conditions such as isotherm and isohaline boundaries often determine whether or not the surrounding water mass is suitable for pelagic fish, and many of the species are associated with specific isothermic regions. Additionally, areas of high trophic transfer as found in fronts and eddies are important habitat for foraging, migration, and reproduction for many species (Bakun, 1996).

Oceanic pelagic fish such as skipjack and yellowfin tuna, and blue marlin prefer warm surface layers, where the water is well mixed by surface winds and is relatively uniform in temperature and salinity. 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 and maturity of pelagic fish, and adults usually have a wider temperature tolerance than sub-adults. Thus, during spawning, adults of many pelagic species usually move to warmer waters, the preferred habitat of their larval and juvenile stages. Large-scale oceanographic events (such as El Niño) 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 are commonly most concentrated near islands and seamounts that create divergences and convergences which concentrate forage species, also near upwelling zones along ocean current boundaries, and along gradients in temperature, oxygen and salinity. Swordfish and numerous other pelagic species tend to concentrate along food-rich temperature fronts between cold, upwelled water and warmer oceanic water masses.

These fronts represent sharp boundaries in a variety of physical parameters including temperature, salinity, chlorophyll, and sea surface height (geostrophic flow) (Niiler and Reynolds, 1984; Roden, 1980; Seki et al., in press). Biologically, these convergent fronts appear to represent zones of enhanced trophic transfer (Bakun, 1996; Olsen et al., 1994). The dense cooler phytoplankton-rich water sinks below the warmer water creating a convergence of phytoplankton (Roden, 1980; Polovina et al., in review). Buoyant organisms, such as jellyfish as well as vertically swimming zooplankton, can maintain their vertical position in the weak down-welling, and aggregate in the front to graze on the down-welled phytoplankton (Bakun, 1996;

Olsen et al., 1994). The increased level of biological productivity in these zones attracts higher trophic-level predators such as swordfish, tunas, seabirds, and sea turtles, and ultimately a complete pelagic food web is assembled.

Near Hawai‘i, there are two prominent frontal zones. These frontal zones are associated with two isotherms (17° C and 20° C), and they are climatologically located at latitudes 32°-34° N. (the Subtropical Front or STF) and latitudes 28°-30° N. (the South Subtropical Front or SSTF) (Seki et al., in press). Both the STF and SSTF represent important habitats for swordfish, tunas, seabirds and sea turtles. Variations in their position play a key role in catch rates of swordfish and albacore tuna, and distribution patterns of Pacific pomfret, flying squid, loggerhead turtles (Seki et al., in press), and seabirds. Hawai‘i-based longline vessels targeting swordfish set their lines where the fish are believed to be moving south through the fronts following squid, the primary prey of swordfish (Seki et al., in press). Squid is also the primary prey item for albatross (Harrison et al., 1983), hence the albatross and longline vessels targeting swordfish are often present at the same time in the same area of biological productivity.

These frontal zones have also been found to be likely migratory pathways across the Pacific for loggerhead turtles (Polovina et al., 2000). Loggerhead turtles are opportunistic omnivores that feed on floating prey such as the pelagic cnidarian Vellela vellela (“by the wind sailor”), and the pelagic gastropod Janthia sp., both of which are likely to be concentrated by the weak downwelling associated with frontal zones (Polovina et al., 2000). Data from on-board observers in the Hawai‘i-based longline fishery indicate that incidental catch of loggerheads occurs along the 17° C front (STF) during the first quarter of the year and along the 20° C front (SSTF) in the second quarter of the year. The interaction rate is, however, substantially greater along the 17° C front (Polovina et al., 2000).

Since the publication of the 2001 FEIS there has been an increasing awareness within the scientific community of the occurrence and importance of long-term (decadal-scale) oceanographic cycles (Chavez et al., 2003; SCBT 15, inter alia) and of their relationship to cycles in the population sizes of some species of fish such as California sardines and North Atlantic bluefin tuna. These naturally occurring cycles can either mitigate or accentuate the impact of fishing mortality on target species and, in general, the scientific community is becoming more aware of the need to recognize the possibility of large natural swings in the populations of exploited species and to incorporate this dynamism into management models. Meso-scale events such as El Nino and shorter term phenomena such as cyclonic eddies near the Hawaiian Islands (PFRP Newsletter 8(1), 2003) also impact the recruitment and fishing vulnerability of species managed under the Pelagics FMP.

3.3 Pelagic Management Unit Species

The Pelagics FMP manages a suite of “pelagic management unit species” (PMUS, see Table 1). These species have been assigned to species assemblages based upon the ecological relationships between species and their preferred habitat. The species complex designations for the PMUS are marketable species, non-marketable species and sharks. 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 as adults including swordfish, bigeye tuna, bluefin tuna, albacore tuna, striped marlin and pomfret. The tropical species complex includes all other tunas and billfish as well as *mahimahi*, wahoo and *opah*.

Species of oceanic pelagic fish live in tropical and temperate waters throughout the world's oceans, and 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. 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 (e.g., yellowfin, skipjack, bigeye, which appear to roam extensively within a broad expanse of the Pacific centered on the equator.

Table 1. Pelagic Management Unit Species.

English or Common Name	Scientific Name
Mahimahi (dolphinfishes)	Coryphaena spp.
Wahoo	Acanthocybium solandri
Indo-Pacific blue marlin: Black marlin	Makaira mazara: M. indica
Striped marlin	Tetrapturus audax
Shortbill spearfish	T. angustirostris
Swordfish	Xiphias gladius
Sailfish	Istiophorus platypterus
Pelagic thresher shark	Alopias pelagicus
Bigeye thresher shark	Alopias superciliosus
Common thresher shark	Alopias vulpinus
Silky shark	Charcharinus falciformis
Oceanic whitetip shark	Carcharhinus longimanus
Blue shark	Prionace glauca
Shortfin mako shark	Isurus oxyrinchus
Longfin mako shark	Isurus paucus
Salmon shark	Lamna ditropis
Albacore	Thunnus alalunga
Bigeye tuna	T. obesus
Yellowfin tuna	T. albacares
Northern bluefin tuna	T. thynnus
Skipjack tuna	Katsuwonus pelamis
Kawakawa	Euthynnus affinis
Dogtooth tuna	Gymnosarda unicolor
Moonfish	Lampris spp
Oilfish family	Gempylidae

English or Common Name	Scientific Name
Pomfret	family Bramidae
Other tuna relatives	Auxis spp, Scomber spp; Allothunus spp

None of the PMUS stocks in the Pacific are known to be overfished, although concern has been expressed for several species and data are unavailable for others. Concise definitions of the various criteria used in the Pelagics FMP to analyze current levels of harvest exploitation and the status of PMUS stocks can be found in a publication by Boggs et al. (2000). That document and the NMFS Report to the U.S. Congress both contain estimates of the status of PMUS stocks. Those two publications and the most recent report of the Standing Committee on Tuna and Billfish (SCTB) are the main sources for the following sections regarding the current status of PMUS stocks. There is currently little information on the population biology of the squid species considered within this amendment with which to develop stock determination criteria. Currently, the natural mortality rate (M) is unknown, as is the ratio of current biomass to the biomass at MSY (B/Bmsy), and concomitant current fishing mortality to fishing mortality at MSY (F/Fmsy). Thus there is a need to ensure that at a minimum, U.S. catches of squid in the Western Pacific by fisheries in federally regulated waters are recorded accurately in order to determine M.

Of particular pertinence are results from ongoing studies of feeding habits of yellowfin and bigeye tuna in Hawaiian waters. Squid of the family Omnastrephidae are the second most common group of cephalopods found in the stomachs of these fish but cephalopods as a whole comprise less than 10percent of the food taken by these tuna species (Holland, pers. comm.).

3.4 Pacific Pelagic Squid

Synopses of the biology and ecology of the three species of pelagic squids with commercial value that are found in the Western Pacific Region being considered for inclusion as Pelagic Management Unit Species are presented in this section. There follows a brief summary of other cephalopods commonly encountered in the region, and rationale for their exclusion from consideration as PMUS.

3.4.1 Neon Flying Squid (*O. bartramii* Lesueur, 1821)

General Description

O. bartramii, commonly known as akaika, red squid, red ocean squid, red flying squid, flying squid, neon flying squid and Bartram's squid (among many other names), is the most broadly distributed species in the family *Ommastrephidae* with a circumglobal subtropical to temperate distribution (Murata, 1990). The possibility of genetic interchange between disjunct populations in different hemispheres and oceans, apparently, has not been reported. Russian researchers (Dunning, 1998), however, consider the North Pacific and North Atlantic populations to represent separate subspecies and the southern hemisphere populations to represent a third subspecies. The southern-hemisphere population, however, is discontinuous at the tip of South America and at the southeastern tip of Australia which suggests to Dunning (1998) that the South Pacific population is reproductively separate from the South Atlantic-Indian Ocean population. The northern limit of the population in the South Pacific is approximately 25°N latitude (Dunning, 1998). This review is restricted to the North Pacific population where the species primarily occupies waters between 20° and 50°N latitude from near Japan to near the west coast of North America with highest population densities along the Subarctic Frontal Zone from July-December (Murata, 1990; Murata and Hayase, 1993). In the North Pacific, *O. bartramii* is common as indicated by commercial catches that have reached over 300,000 mt/year. During summer and fall, *O. bartramii* is fished primarily between 36° and 46°N latitude and in winter most squid are thought to migrate south to the subtropics between about 25° and 35°N latitude where spawning occurs (Yatsu, et al., 1998; Ichii, et al., 2004). Within a few months of hatching the new generation, apparently, begins migrating northward (Seki, 1993).

Maximum size reported by Murata (1990) for North Pacific *O. bartramii* is 40.6 cm ML (mantle length) (1680 g) for males and 56.2 cm ML (5,790 g) for females. Although females grow to a much larger size than males, the length-weight relationships are indistinguishable and are given by the formula: $W= (1.2799 \times 10^{-5})L^{3.1437}$ with L (length) in mm and W (weight) in g (Murata, 1990). Mature males are found between 21-44 cm ML with most males larger than 30 cm ML mature and mature females between 37-57 cm ML with "a considerable number" mature between 40 and 50 cm ML and most mature larger than 50 cm ML (Yatsu et al., 1998). The life span of *O. bartramii* is estimated to be about one year.

Eggs and Paralarvae

Most squids do not have a true larval stage but exhibit direct development and the term "paralarva" is used, therefore, to distinguish young in the near-surface plankton (Young and Harman, 1988). The end of this stage is determined by both morphological and habitat changes. Where known, nearly all squids spawn eggs in egg masses. Egg masses for *O. bartramii* have never been observed. In two other ommastrephids (*Illex illecebrosus* and *Todarodes pacificus*) egg masses are gelatinous, nearly neutrally-bouyant spheres, about 50-80 cm in diameter and contain up to 20×10^5 eggs distributed throughout the egg mass (O'Dor and Balch, 1985; Bower and Sakurai, 1996). Presumably *O. bartramii* produces similar egg masses. Eggs of *O. bartramii* measure about 0.9 x 1.1 mm in size (Sakurai, et al., 1995). The depths at which spawning occurs and the depths at which egg masses float and embryos develop are unknown for *O. bartramii*.

The distribution of paralarvae suggests that spawning does not occur in near-shore waters (Bower, 1996; Yatsu et al., 1998; Bower, et al., 1999). Spawning period, based on hatching dates determined by retrospective analysis of statoliths (calcareous structures in the balance organ, comparable to otoliths in fish) of subadult and adult squid, is from September to August (Yatsu et al., 1998). Spawning, therefore, occurs virtually all year long, but judging from the seasonal abundance of subadults (squid of commercial size are most abundant during June-September: Murata and Nakamura, 1998), peaks in spawning exist. Hatchlings measure about

1.1 mm ML (Yatsu and Mori, 2000).

Paralarvae appear to occur mostly in the upper 25 m during the day and night. Young and Hirota (1990) caught numerous *O. bartramii* paralarvae in surface plankton tows during the day and night. They also examined the vertical distribution of the paralarvae with a small opening-closing net. The latter series sampled the upper 200 m and caught 13 *O. bartramii* at 0-40 m during the day and 0-20 m at night. Saito and Kubodera (1993) caught small numbers of paralarvae in simultaneously towed vertical series of closing nets with the highest catch rates at 0-25 m but incidental catches at 50-75 m and 75-100 m.

Paralarvae have been captured over a broad stretch of the North Pacific from 140°E to 130°W between 25° and 35°N with a possible break in distribution at 170°E - 180° (Yatsu, et al., 1998; Ichii, et al., in press). In the region of the Hawaiian Archipelago, Bower (1994) caught paralarvae during February where SSTs (sea surface temperatures) were between 21°-24°C with peak abundance at 22.0°-22.5°C. All captures occurred south of the subtropical front at latitudes of about 21°-28°N. Young et al. (2000) confirmed the absence of paralarvae north of the subtropical front at latitudes in the Hawaiian region during February and the dominance of catches at SSTs around 22°C. In 2000 they found just hatched paralarvae as far south as 20°N off the windward side of the Island of Hawaii at SSTs of 23.4°-23.9°C. The following year *O. bartramii* paralarvae were virtually absent from these latter waters (personal observation, R. Young). The subtropical front meanders greatly during the winter and is ill-defined in the summer (Seki, 2003). As a result, the possible relationship between the subtropical front and the spawning habitat is difficult to confirm and unknown for most regions and most seasons. Paralarvae are present in Hawaiian waters or immediately northward in October-June (Young and Hirota, 1990; Bower, 1994; Yatsu, et al., 1998; Ichii, et al., in press). Distribution of paralarvae indicates that spawning habitat shifts seasonally with the SST. Ichii et al., in press, found paralarval distributions approximately confined to the 21°-26°C isotherms from October to May although the isotherms shifted latitudinally about 5° during this period. While the general geographic areas of the nursery grounds for paralarvae and SST-correlates are known for much of the year, the specific physical and biological conditions triggering spawning and favoring survival of paralarvae are unknown.

In the case of one ommastrephid, *I. illecebrosus*, however, O'Dor and Balch (1985) suggest physical parameters that might be necessary for spawning and embryonic development. They found that the egg mass was slightly negatively buoyant. An egg mass slowly sinking in the open ocean would encounter decreasing water temperatures (which increases water density), and would stop sinking when temperature equilibrium between the egg mass and the water is reached; but temperature equilibrium can occur quickly. Increasing water salinity (which would increase water density) encountered with depth also would stop sinking but it would take far longer (over two orders of magnitude longer) to reach equilibrium. A mid-depth salinity maximum could stop or slow the descent of an egg mass until hatching occurs. In Hawaiian waters a shallow salinity maximum, formed at the subtropical front, slowly submerges as it moves south (Roden, 1991). This salinity maximum could retain an egg mass, spawned in lower salinity, near-surface water, within a relative warm-water environment (important for rapid egg development) that allows relatively easy access for hatchlings to surface waters. The shallow salinity maximum is present during the winter but is not apparent during summer.

Temperature is another physical factor that may be critical to paralarval growth and survival. Yatsu et al. (2000), noting that the El Niño years of 1993 and 1997 coincided with low stock abundance, suggest that negative SST anomalies recorded during these years may have affected both the feeding and nursery grounds in their study area. Forsythe (1993) noted that cephalopods are poikilotherms with a Type 4 adaptation (i.e., metabolic rate varies with temperature with little or no compensation) and modeled the effect of temperature during the paralarval exponential growth phase on the loliginid squid, *Loligo forbesi*, and found that a 1°C increase in temperature during this critical period (90 days in this species) would result in a subadult twice as heavy and a 2°C change results in a 5 fold increase in subadult weight.

Ommastrephid squids have a peculiar paralarval stage in which the tentacles are fused together in an elongate "proboscis" that eventually splits apart to form normal tentacles. The presence of a proboscis suggests that these paralarvae have a unique, although unknown, method of feeding. Bigelow and Landgraf (1993) determined a growth curve for *O. bartramii* paralarvae, captured in February, based on statolith increment counts using both light and scanning electron microscopy (SEM). The curve they found was exponential and of the form $ML=0.331e^{0.103x}$ (ML in mm and x in days). They suggested that this growth curve applied to at least 12.1 mm ML at an age of 35 days. They found proboscis separation complete by 9.5-12.0 mm ML. They also estimated a size at hatching of 0.33 µm from the growth curve as they lacked paralarvae less than 18 days old. This hatching size subsequently proved (as the authors expected) to be much too small. A study by Bower (1996) using similar methods but without SEM found a growth curve of $ML=0.95e^{0.067x}$ for paralarvae captured in February. Yatsu and Mori (2000) re-examined paralarval growth rates using similar methods without SEM but for paralarvae captured in October and they were able to include hatchlings grown from artificial fertilization. The growth curve determined by Yatsu and Mori (2000) is $ML=1.139e^{0.063x}$. They note proboscis separation was reported by Wormuth et al. (1992) to occur at 7 mm ML and that this size appears to coincide with a change from exponential to linear growth. They suggest that feeding habits must change at this point with the presence of functional tentacles. After separation, however, the tentacles are undeveloped and very small (L. Shea, personal communication with R. Young) indicating that considerable growth of the tentacles is necessary before they can participate in feeding. In addition, the more accurate measurements of Bigelow and Landgraf show tentacle separation occurred at a larger size. A change in feeding, if it does occur at 7 mm ML, may involve the replacement of the proboscis by the arms as the primary tool in food capture. The growth curve of all three studies gives a size of about 7 mm at 30 days of age in spite of the different capture seasons. In the absence of more complete data, the apparent change in growth rate at 7 mm ML can be considered the end of the paralarval stage.

Juvenile

Juvenile squid are virtually absent from net, jigging or driftnet collections. Very little is known about the distribution of small squid between about 10 and 100 mm or virtually any other aspect of their ecology or biology. Yatsu and Mori (2000) reported the capture of 14 squid (52 - 164 mm ML) by dipnet at 28°-32°N. Harrison et al. (1983) commonly found unidentified ommastrephid squid, mostly smaller than 100 mm ML, in the diet of many seabirds in the NWHI. Presumably many of these were *O. bartramii.* Seki and Harrison (1989) were able to identify *O. bartramii* as a minor component of the diet of the red-footed booby at French Frigate Shoals in the NWHI. Both studies suggest that juveniles occur in the region of the NWHI (ca. 23-28°N) in near-surface waters, presumably during the daytime. Judging from this limited data, the habitat of squid in this size range may not differ much, if any, from that of paralarvae.

Yatsu and Mori (1998) provide size at age data for squids about 30, 50 and 100 days old. A straight line drawn by eye through this data (i.e., their Fig. 4A) yields a growth rate of 1.8 mm/day. Using this growth rate, the growth rate jumps from 6.5 percent of the ML/day at 30 mm ML at the end of the exponential growth phase to 19.5 percent/day at 31 mm ML at the beginning of linear growth. Such a sudden jump is, of course, unrealistic. Nevertheless, as growth continues at 1.8 mm ML/day the daily rate of increase drops to about 8 percent within a week, and 5 percent in two weeks (45 days of age and about 33 mm ML) and 3 percent in four weeks (59 days of age and approaching 60 mm ML). This exercise suggests that during a 10 day period (corresponding roughly to juveniles of 7-25 mm ML) the relative linear growth rate of early juveniles exceeds the relative exponential growth rate of paralarvae. If true, then environmental conditions during this period may be especially important. Clearly more age data for juveniles is needed.

The size and age at the end of the juvenile period are unknown. Changes in the statolith occur at about the size and age that could mark this point in the life cycle. The width of statolith daily increments abruptly decreases from 5-7μ at about increment 80-100 from the nucleus and is followed by a short zone (20-30μ) of indistinct increments then small increments, 1-2μ to the edge of the statolith (Yatsu, et al., 1997). Yatsu et al. (1997) suggest that this transition probably corresponds to major changes in the ecology of the squid and Yatsu et al. (1999) suggest the juvenile period ends here. Yatsu et al. (1999) found that the end of the juvenile period for squid caught in 1995-1997 had mean ages from 87.4-92.9 days with a range of 70-113 days. Without considering a different growth rate for the paralarval stage, Yatsu et al. (1997) calculate that this short zone corresponds to mantle lengths of 96-220 mm by apparently using growth rates of 1.1 to 2.2 mm/day (see below). By including the paralarval period and using a single growth rate of 1.8 mm/day for post-paralarval growth and juvenile ages of 80-100 days, we calculate a range of 97 mm ML [(80 increments-days minus 30 paralarval days times 1.8 mm/day) plus 7 mm at end of paralarval growth] to 151 mm ML [(100 - 30 days + 10 days of transition) x 1.8) +7] for size at the end of the juvenile stage. Therefore, a tentative working range for squid size corresponding to the short zone on the statocyst may be about 100-150 mm ML. Other than these possible statolith features, no morphological correlates are presently recognized that can mark the end of the juvenile stage.

Subadult and Adult

The life history stages of squids include several terms not generally applied to other organisms.

Because many squids are terminal spawners that spawn and die shortly after reaching maturity, the adult phase is often very short and most of the life span occurs in the normal juvenile stage. As a result the juvenile stage is generally divided into two steps, juvenile and subadult (Young and Harman, 1988). The subadult stage extends from the end of the juvenile period (i.e., the size/age when most morphological characteristics of the species are attained) until maturity. Maturity is defined as the presence of eggs in the oviducts or spermatophores in Needham's sac.

Age and Growth

Females attain larger sizes and grow faster than males (Yatsu, 2000). Growth rates of squids are strongly affected by food availability and ambient temperature (Forsythe, et al., 2001). Because of high growth plasticity, Yatsu (2000) recommends that data in age and growth studies not be fitted to *a priori* growth curves. Overall growth rates determined by dividing the squid length at capture by the hatching date derived from statolith data indicate rates of 1.1 to 2.5 mm per day (Yatsu et al., 1997). This use of linear growth rates is not as risky as it might seem. Growth is exponential up to a size of around 7 mm ML, beyond that it appears to be linear (Yatsu and Mori, 2000) at least until sexual maturity is reached. Tag and recapture rates for squid recaptured after 2 months or more give similar growth rates (1.85 - 2.44 mm/day; N=3) (Yatsu et al., 1997). Kasahara (1985) followed size modes of an apparently isolated population in the Sea of Japan and found essentially linear growth of about 1.9 mm/day from about 140 mm ML to about 420 mm ML (Murata, 1990; Yatsu et al., 1997). While the variability in average growth rates found by Yatsu et al. (1997) is high, we must assume that the variability is even greater if one looks at daily or short-term growth rates rather than rates averaged over the life of the squid. For example, shorter average rates given by Arata (1983) for tag and release data show one squid recaptured five weeks after release appeared (size measurements were not exact) to exhibit no growth while a second released within two days of the first and recaptured after 11.6 weeks exhibited a growth rate of about 2.4 mm/day. Estimates of growth rates based on modal length data gave low rates of 1.1 mm per day and are considered less accurate due to complications in correctly tracking size modes in migrating squid (Yatsu, et al., 1997).

The fact that the linear growth data do not show evidence of slowing growth in mature *O. bartramii* may simply reflect an insufficient sample size of mature female squid. Obtaining adequate data will be especially difficult if the adult period is short. Linear growth means that relative growth slows as each growth increment, which is a constant, progressively becomes a smaller proportion of the increasing squid size. Therefore a mature *O. bartramii* could maintain linear growth while still providing energy for reproduction. Chen and Chiu (2003), however, based on back-calculated growth curves derived from statoliths, found that growth in a population of squid from the northeast Pacific that contained a few mature females did show a tapering of growth at larger sizes. They suggest that the slower growth could be due to reallocation of energy for maturation although they found a similar pattern in another population that lacked mature females.

Yatsu, et al. (1997) found that growth rates with hatch dates from January to August increased with the season although summer data were lacking for males. Murata (1990) summarizing results from modal length data, also concluded that growth was more rapid in summer-autumn than in winter-spring. Seasonal growth trends were most apparent in squid from 143°-146°E. Not surprisingly, growth rates of loliginid squid in culture have been shown to be strongly affected by temperature (Forsythe and Hanlon, 1989).

The beginning of the adult stage for males, assuming the size at maturity for most males is 300 mm ML and the growth rate is 1.6 mm/day (midpoint between the range of male growth rates of 1.1 and 2.1 mm/day reported by Yatsu, et al., 1997), would be 188 days. The beginning of the adult stage for females, assuming the average size at maturity for females is 475 mm ML and the growth rate is 1.8 mm/day (midpoint between the range of female growth rates of 1.1 and 2.5 mm/day reported by Yatsu, et al., 1997), would be about 264 days. These data suggest that males mature at a younger age than females. Age determination from statoliths suggest a one-year life-span as mature males have been aged at 188-308 days (N=10) and mature females at 212-324 days (N=10) (Yatsu et al., 1998). If the maximum lifespan is 365 days for both sexes, then males would be in the adult phase of their life cycle for a much longer period than would females.

Population structure

The population structure of *O. bartramii* has been extremely difficult to unravel because this squid is distributed over a large area, spawns virtually throughout the year and undergoes strong horizontal migration. Compounding this is a short one-year life-span and differential growth rates between males and females. Catches from driftnet fishers were usually processed on-board making biological data difficult to obtain (Murata et al., 1988). Catch data are also affected by weather, moonlight, and predators, and size data can often be biased by the type and size of fishing gear.

At any locality north of the subtropical region where the squid are common, often more than one size mode is present. Murata (1990) attempted to quantify four possible groups of females and three of males that had long been recognized (at least from the work of Murakami et al., 1981). The groups are known as SS (extra-small), S (small) and L (large) for males and females and LL (extra large) for large females which attain a much larger size than the largest males (a counterpart for the LL group in males cannot be recognized: Murata, 1990). Murata identified each group by size and month which enabled following monthly progressions of size modes, although his classification was incomplete for some months and some sizes. Murata (1990) and Murata and Hayase (1993) noted that the SS, S and L groups might represent a common cohort with different peaks of hatching during winter and spring. A division of the population into subpopulations at approximately 160-170°E had been generally recognized since the work of Murakami et al. (1981) mostly due to low catches in this region and differences between the size composition of the catch to the east and west (Murata, 1990). The subpopulation on the eastern side was thought to develop in the autumn and that of the western side in the spring (Murata, 1990; Fig. 1 in Murata and Nakamura, 1998).

Yatsu, et al. (1997), using statolith data to determine hatching dates of adult and subadult squid, cast doubt on the validity of the alphabetical classes by noting that spawning occurred virtually throughout the year and growth rates were faster than those determined from the alphabetical size modes. Yatsu et al., (1998) revised the view of the population structure mostly on the basis of data from research cruises and with statolith-determined squid ages. They recognized two seasonal cohorts: one an autumn cohort (comprising the LL group) with a hatching period from September to February and a winter-spring cohort with a hatching period primarily from January to May but extending to August. That a male counterpart to the autumn cohort has not yet been recognized from statolith data (Yatsu, et al., 1998) is unfortunate but not surprising; LL males and females probably do not occupy the same waters much of the time, so absence of LL males in the statolith data could be due to chance. Chen and Chiu (2003), however, also failed to distinguish LL males although males sampled hatched between September and March.

The division by Yatsu et al. into two seasonal cohorts appears to be supported by their finding of two modes in the size of mature squids: mature females collected during the autumn-winter period (between September and February) were larger (mode ca. 53 mm ML) than those collected in the spring-summer period (between March and August)(mode ca. 43 mm ML). Also, they were able to recognize the autumn cohort by the monthly progression of its mantle-length modes. Yatsu, et al., (1998) found the autumn cohort to be more abundant in the central and eastern Pacific east of 170°E (170°E approximately marks the position of the Emperor Seamounts) but they apparently coexist throughout the North Pacific. Squid of the autumn cohort taken from the same waters as the squid of the winter-spring cohort have different abundances of various nematode and cestode parasites, a finding which supports the presence of different cohorts (Yatsu, et al., 1998).

Indeed, Nagasawa et al., (1998) and Yatsu, et al. (1998) divide the North Pacific into three zones based partly on the occurrence of these parasites in *O. bartramii*: a western region bounded by the 170°E longitude, a central region between the 170°E and 160°W longitudes and an eastern region east of 160°W. The winter-spring cohort has one stock in the western region and one in the combined central-eastern region. The autumn cohort has one stock in the eastern region and one in the central region; this cohort is rare in the western region and has an uncertain relationship to the central stock. Yatsu, et al. (1998) suggest that the stocks are not genetically separated due to the overlapping hatching dates. In addition, they suggest that male-female size differences, which could affect mating, are mitigated by the large variability in growth rates. Chen and Chiu (2003), however, based on back-calculated growth-curves derived from statoliths and statolith radius to mantle length relationships, recognized the two seasonal cohorts, and also suggest that females (as well as males) of the winter-spring cohort represent separate populations in the central-eastern and western regions. In addition, they examined large females (autumn cohort) from the western region but found no differences between these and their counterparts in the central-eastern region. They suggest that large females of the western region are spawned in the central-eastern region. Katugin (2002) also suggests genetic differences using protein electrophoresis. Subsequent studies by Katugin and a co-worker (per. comm. from J. Bower to R. Young) based on alloenzyme differentiation found no significant differences between eastern and western regions and no differences between size groups in the

Northwest Pacific Ocean. Japanese scientists at the National Research Institute of Fisheries Science are presently using mitochondrial DNA sequencing to separate Pacific and Atlantic populations and hope, eventually, to identify local stocks with this technique (Bower, 2004).

The mechanism responsible for the larger size of the autumn cohort (i.e., maximum > 55 mm ML vs. 46 mm ML (Bower, 2004)) is unknown (Yatsu, et al., 1998). Ichii et al. (in press) suggest that paralarvae of both seasonal cohorts exhibit similar conditions of low environmental productivity. However, by the time the squid of the autumn cohort are juveniles, a Transition Zone Chlorophyll Front has moved south through their habitat bringing higher food availability and allowing higher growth rates than in the case of juveniles of the Winter-Spring cohort which remain in low-productivity waters. The advantage of higher productivity waters for the autumn cohort remains throughout much of the subadult stage as well. The result is the distinct size separation between the cohorts. Chen and Chiu (2003), however, found that the two size cohorts (LL and S) in their study in the eastern region had peak hatching periods separated by only two months (October and December) and with broad overlap in time of hatching of all squid examined. The latter study suggests that if the productivity hypothesis of Ichii et al. is correct, the spatial and temporal differences that lead to a size advantage may occur on rather small scales. The size modes within the winter-spring cohort, as indicated by Murata (1990), may relate to variation in success of young during different (and presumably variable) periods of the spawning season and/or to subsequent differences in growth rate.

Horizontal Migration

There are two aspects to the north-south migrations of *O. bartramii*. First is a seasonal geographic shift of the major squid concentrations at their northern-most locations which are assumed to be major feeding grounds. In June the major concentrations (as determined by commercial fishing) are at 35°-40°N; during August-October they shift northward to 40°-45°N (i.e., about 2° latitude/month), then during November-December they shift gradually southward (Murata and Nakamura, 1998). An example of a latitudinal peak in squid concentrations is seen in the following example. Chen and Chiu (1999) using data from an experimental fishing cruise that ran latitudinal and longitudinal transects from about 38°N to 44°N and 150°-170°W during July and August of 1997, found the CPUE averaged about 5-8 kg/hr between 38° and 42°N. The CPUE began increasing at 43°N and peaked at 100 kg/hr at 44°N which lay in the northern part of the Subarctic Frontal Zone.

Second, and superimposed on the first movement, is an ontogenetic migration. *O. bartramii* migrates northward, as it grows, from a subtropical hatching site to the feeding grounds of the subadults near or within the Subarctic Frontal Zone and then returns to subtropical waters for mating and spawning (Seki, 1993). The two population movements are not the same as spawning occurs virtually throughout the year. Even during the major spawning season evidence of the two migrations can be detected. If one calculates the growth rate of *O. bartramii* from the seasonal and northward progression of its different size modes, an erroneously slow growth rate is obtained (Yatsu, et al., 1998); therefore the northward movement of individuals is somewhat different than the northward movement of modes.

Presumably squid migrate north toward the feeding grounds as they grow but the location of the feeding grounds shifts with the changing season and squid adjust accordingly. The distribution patterns are further complicated by some size and sex segregation.

Because the ontogenetic migration occurs during a one year life-span, a gradation of increasing squid size should be encountered with increasing latitude as the ontogenetic migration progresses northward. Superimposed on this gradient are the southward migration of large squid to the spawning grounds and the shifting location of the subadult feeding grounds. Because the northward migration should generally take longer due to the small size of the squid and the population should be more numerous at these sizes, the north-moving squid should generally (all else being equal) dominate the catches. This simple model is complicated by, among other effects, seasonal and local cohorts of differing abundance and areal affects of size segregation. Nevertheless, increases in squid size with increasing latitude are usually found (Araya, 1983). To site one example, Murata, et al. (1988) reported catches in July from research driftnets, with a range of mesh sizes, and jigging between 160°E and 172°W and 37°- 41.5°N. This latitudinal range included the Transition Zone, the Subarctic Boundary and the Subarctic Frontal Zone with surface temperatures ranging from 24° to 12°C. At 37°N squid ranged from 14-19 cm ML (modes at 14, 17 and 18 cm). At 38°30'N the range was 17-27 cm ML (modes at 18 and 21 cm); at 40°N the range was 20 - 25 cm (modes at 20 and 24 cm); at 41°30'N the range was 27-42 (modes at 27, 38 and 41 cm).

In general, according to Murata and Nakamura (1998), the winter-spring cohort is distributed mainly within the Subarctic Boundary and Subarctic Frontal Zone during summer and fall. Females tend to move into this region before males and southward migration is thought to occur mostly in October to November for males and November to December for females. The females of the autumn cohort are found largely in the Subarctic Frontal Zone in the spring to summer and males are found further south. Males apparently start migrating south in July and females in September. Males never seem to occur in the high abundance of females in the northern-most areas (e.g., Figs. of Yatsu, et al., 1998). Therefore, the northern, seasonally shifting population abundance peak appears to be composed mostly of females. Murata et al. (1988) obtained samples from the driftnet fishery taken mostly from 39°-46°N, 170°E-145°W, which presumably follows the abundance peak, from June-December during 1983-85. The catch was mostly females with a 3-year average of 2.4 percent males. Males and females clearly show some different spatiotemporal distribution patterns. As another example, a research cruise in 1988 (170°E - 180°), found females dominating the catch in the northern area of the Subarctic Frontal Zone (ca. 41-43°N), males dominating in the southern area of this zone (ca 40°N) and males only in catches at 35°N (Murata and Nakamura, 1998). More information is needed on the relative distribution of the sexes and on causes of size and sex segregation. Do large squids just migrate further or do they exclude smaller squids from the same region? Do the squid school by size and sex? These and other problems (e.g., fishing-gear selection) of real or apparent sex segregation make determining sex ratios difficult.

Yatsu, et al. (1998) found mature females as far as 42°N and mature males as far as 45°N. Mature females were commonly present at stations south of 35°N and males were commonly present at stations south of 43°N. While the occurrence of mature squid is broad, their relative abundance peaks south of 35°N (Murakami, et al., 1981).

Swimming Speed

Average swimming speeds were measured using ultrasonic transmitters attached to free-swimming squid by Nakamura (1993) for squids apparently on the spawning grounds (26°-28°N). Swimming speeds ranged between 19 and 25 cm/s over the entire tracking period (three squid, 9, 23 and 36 hrs.) for squids of 44-46 cm ML but swimming was not always in one direction. Yoshida et al. (1990) tracked three females that swam consistently in a southeasterly direction from about 35°N and were apparently migrating. Their average speeds varied from 25-30 cm/sec or 54-74 percent of their ML (squids were females of 38-42 cm ML). At 30 cm/sec a squid would require about two months to travel directly south from the feeding grounds (ca. 45°N) to the spawning grounds (ca. 30°N) disregarding possible effects of currents. The paper by Murata and Nakamura (1998) on ultrasonic tracking did not provide data on swimming speed.

The tag and release study of Murata and Hayase (1993) reported 11 migrating squids that had been released in May-June and recaptured mostly between one and three months after release. These squid traveled in various directions between NNW and ENE at a combined average speed of 11.8 km/day (14 cm/sec). Two of these squid traveled (one ENE and the other NE) for an average distance of 594 miles at an average speed of 23.1 km/day (27 cm/sec). The sizes of these squid at release are not known but, based on the time of release and direction of movement, presumably the squid were considerably smaller than those tracked by ultrasonic transmitters.

Spawning

Many details of spawning that are critical to understanding the population dynamics of *O. bartramii* are unknown. Cephalopods exhibit five spawning patterns (Rocha, et al., 2001). Among ommastrephid squids the best understood strategy is that of *T. pacificus* which have a "spawning once" strategy (terminal spawning) (Ikeda, et al., 1993). Squid with this strategy have: synchronous ovulation, no ovulation during the spawning period, monocyclic maturation of oocytes (i.e., a single cycle of ovarian development) and spawning during a short period near the end of life (i.e., no growth occurs) (Rocha, et al., 2001). A closer relative of *O. bartramii*, *S. oualaniensis*, appears to be a "continuous spawner" (Rocha et al., 2001) with the following characteristics: continuous asynchronous ovulation, ovulation during the spawning period, monocyclic maturation of oocytes, spawning over an extended period with intermittent spawning events (i.e., as the oviducts fill, they are emptied) and somatic growth during the period of spawning. *O. bartramii* probably utilizes this latter strategy. However, the evidence is not conclusive and is reviewed here. The size-frequency of oocytes in the ovary of mature *O. bartramii* shows an exponential decrease in numbers from small to large oocytes (Young, et al., 1997). This indicates continuous asynchronous ovulation. Mature female *O. bartramii* exhibit great variation in the state of fullness of the oviducts and this shows no relationship to mantle length (Young, et al., 1997; Yatsu, et al., 1998). In addition, the weight of the nidamental glands of mature females varies with the weight of the oviduct rather than the mantle length, suggesting that the nidamental glands which form much of the jelly for the egg mass, fluctuate in size as the oviducts are filled and emptied (Young, et al., 1997). These two latter features both suggest monocyclic maturation of oocytes and continuous spawning. Finally, great variation exists in the size of mature females suggesting that growth occurs during the period of spawning. These data are not conclusive due to ambiguities created by variation in the size of females reaching maturity and possible unknown variation in the rates of ova production (Young, et al., 1997).

Assuming that *O. bartramii* is a continuous spawner, the length of the spawning period and the number of spawning episodes must be known in order to determine total fecundity. Neither of these is known. The batch fecundity (number of ova in both oviducts) is known to reach at least $1.4x10^6$ eggs in a female of 590 mm ML and $1.3x10^6$ in a 545 mm ML female (Young et al., 1997).

Vertical distribution

Judging from the methods used in commercial fisheries (jigging-usually upper 50 m, driftnets-upper 10 m) *O. bartramii* commonly occupies depths of 0 to 50 m at night at the subarctic boundary (Murata, 1990). At 37°N latitude from 160°E to 172°W small *O. bartramii*, estimated at 140-180 mm ML in numbers up to several hundred at a time, have been observed gliding above the surface of the water during nighttime and daytime suggesting the habitat for squid in this size range is in near-surface waters during the day and night (Murata, 1988). The "flying" portion of the name "neon flying squid" came from previous observations of this sort (see Clarke, 1966).

A few squid have been tracked by ultrasonic telemetry. Murata and Nakamura (1998) acoustically tracked 10 apparently female squid in the region of the Subartic Frontal Zone (ca. 42°-45°N). At night the squid swam at depths of 0- 40 m within the mixed layer. During the day the two longest records appear the most reliable: the first squid (48 hrs) swam at depths of 150-200 m during the daytime (10°-6°C) and the second squid (22 hrs) swam at depths of 160-300 m during the daytime (7°-4°C). A few squid stayed near the surface during the daytime.

Nakamura (1993) acoustically followed three mature females in subtropical waters (ca. 26°-28°N). One stayed at depths between 400 and 700 m in the day and mostly at 40-70 m at night with occasional excursions to the surface. The temperature at 600 m was 9°C. The second squid didn’t provide much useful information and was lost after about 8 hrs. The third squid spent the day at depths greater than 680m (limit of the working range of the transmitter). The actual records show the squid between about 700 and 900 m but are unreliable. The squid migrated up to depths mostly between 50 and 70 m at night then in the late night and early morning the behavior became erratic and the squid was lost. The greater daytime swimming depths of squid in subtropical waters presumably is related to the greater clarity of these waters, which requires that the squid swim much deeper to reach the same light levels (Murata and Nakamura, 1998).

Young et al. (1997) found a predominance of mature males over mature females in Hawaiian waters during February and suggested that this may be due to greater swimming depths of females making them less susceptible to jig fishing. This suggestion is supported by the tracking data of Murata and Nakamura (1998) and submersible observations on a related squid, *S. oualaniensis*, in the Arabian Sea. In the latter case medium-sized females were found in the 0-100 m depth range at night while large females (in the size range of mature *O. bartramii* females) were seen at depths of 50-500m (Bizikov, 1995).

Presumably *O. bartramii* can on occasion descend to much greater depths than recorded above. Clarke (1966) reported that *O. bartramii* in the North Atlantic had tentacles caught in reversing thermometers as deep as 1490 m. Submersible observations in the North Atlantic found *O. bartramii* at 540-1,050 m by day and mostly in surface waters at night with a few individuals to 300 m depth; in the South Atlantic *O. bartramii* was found at 530-950 m, but mostly at 750-850 m by day and near the surface at night (squid ranged from 15-45 cm ML)(Moiseev, 1991).

Prey and Predators

Prey

Seki (1992) examined stomach contents of *O. bartramii* (N= 174, mean length 322 mm ML, SD = 98.1, all immature, about 70 percent female) caught by gillnet within the Subarctic Frontal Zone during the summer. He found many squid with empty stomachs (nearly 80 percent) and a high incidence of apparent cannibalism. The prey consisted about equally of cephalopods and fish whether considering weight or frequency of occurrence. Most fishes were not identifiable but those that were consisted largely of mesopelagic myctophids and stomiiforms and the epipelagic saury, *Cololabis saira*. About a third of the cephalopod prey were unidentifiable but nearly 60 percent of the identifiable squid consisted of *O. bartramii*; but Seki suggested that the cannibalism could be an artifact of the sampling technique. Seki (1993) found remains of partially cannibalized *O. bartramii* entangled in driftnets and suggested that free-swimming squids were attacking those caught in nets. If the *O. bartramii* are eliminated from the samples, squid then would comprise 32 percent of the diet by weight.

Seki (1993) also examined 42 mature females captured in February by driftnets in the general vicinity of 30°N latitude (ca. 25°-34°N), in the general region of the subtropical front. About 30 percent had empty stomachs. The diet consisted of predominately fish and squid. If *O. bartramii* and unidentified ommastrephids are eliminated from the data, squids comprise 44 percent of the diet. These two studies found no significant regional differences in the diets of the squid when using the categories fishes, squid, and cannibalized *O. bartramii* (Seki, 1992).

The most detailed study of feeding in the Transition Zone (TZ) and the Subarctic Frontal Zone (SAFZ) was by Watanabe et al. (2004). They examined both the autumn and winter-spring cohorts in May and July. In May the Winter-Spring cohort was in the TZ, mostly between 15-19 cm ML, and fed mostly on planktonic crustaceans (euphausiids and amphipods) but in July this cohort was still in the TZ and fed mostly on fishes (especially *Maurolicus imperatorius* a mesopelagic boundary species that is especially abundant in the region around the Emperor seamounts and the Shatsky Rise area which were near the study area). The changeover from crustaceans to fish occurred around a size of 20 mm ML. The autumn cohort in May in the TZ fed mostly on fishes and cephalopods with fishes more common in the diet but with the two groups about equal in weight contribution to the diet. The fishes were mainly myctophids, especially *Symbolophorus californiensis*, and the squids were mainly gonatids and the onychoteuthid, *Onychoteuthis borealijaponicus*. In July most members of the Autumn cohort had left the TZ and those that remained fed on fish, mostly *M. imperatorius*, as the other fish and squid prey had moved northward to the SATZ or beyond. The major portion of the autumn cohort in July was found in the SATZ where they again fed on fishes and squids with fishes more common in the diet but squids comprising more of the biomass. The dominant fish were *S. californiensis* and the subarctic bathylagid, *Bathylagus ochotensis*. The dominant squid was *O. borealijaponicus* and species of *Abraliopsis*. Two of the fishes, *B. ochotensis* and *Protomyctophum thompsoni*, found in diet during this study are non-migrators that remain in deep water (300-600m and 200-400 m respectively) day and night. *O. bartramii*, therefore, feeds at depth (presumably during the day) as well as near the surface at night. Based on estimates of the daily ration needed for *O. bartramii* (6 percent body wt/day), the biomass of this squid in the SAFZ (240-610 mg wet weight/m^2) and the biomass of vertically migrating myctophids (5.2 g wet weight/m^2), the authors conclude that *O. bartramii* consumes 4.9-12.4 percent of the total estimated biomass of vertically migrating myctophids during the summer.

Murata (1990) also found that small, immature squid prey more heavily on crustaceans. In squid 150-190 mm ML stomachs contain 44 percent crustaceans, in squid 200-240 mm ML stomachs contain 21 percent crustaceans and in squid larger than 240 mm ML stomachs contain 4-7 percent crustaceans.

Off Japan Araya (1983) found mostly fishes in *O. bartramii* stomachs with myctophids dominant and followed by sardines, mackerel larvae and sauries. Squids were 18-30 percent but this included a high proportion of cannibalized *O. bartramii*. Crustaceans fluctuated widely between 2-18 percent with the higher percentages in young squid. Naito, et al. (1977) had found very similar results off Japan but noted nearly 40 percent empty stomachs.

Pearcy (1991) in a general study of the biology of the transitional region, noted that *O. bartramii* fed almost exclusively on the gonatid squid, *Berryteuthis anonychus*, at 44°N during a gill net survey along 155°W. At more southerly stations the diet consisted variously of fishes, squids, pteropods, heteropods and crustaceans.

Parry (2003) in a detailed study of feeding of mostly adult *O. bartramii* captured within or south of the subtropical front near Hawaii during winter (February) found the diet consisted almost exclusively of fishes and squids with fishes being much more abundant. Myctophids were the most common fishes in the diet and, among squids, onychoteuthids were the most common but *O. bartramii* took a wide variety of mesopelagic fishes and squids with no one species of fish accounting for more than 10 percent of all fishes eaten. To determine the trophic level of *O. bartramii*, Parry examined the ∂^{15}N content of the mantle muscle. Paralarvae had an average of

6.4‰, squids of 75-100 mm ML had an average of 6.9‰, those of 200-300 mm ML had 11.1‰ and those of 300-570 mm ML had about 12.0‰. This odd logistic shape of the data was supported by retrospective analyses of ∂^{15}N content of eye-lens tissue from single squids. His baseline data from filtered seawater was 2.8‰ and assuming a 3.4‰ increase per trophic level he placed large females at about trophic level 4. He acknowledged that many variables can affect the ∂^{15}N values and that the 3.4‰ change per trophic level was inconsistent in his data. Nevertheless, the data provide a working model of the trophic position of this squid. Different trophic levels were determined for *O. bartramii* by Aydin, et al., (2003) from their trophic model of the Subarctic ecosystem (the Subarctic Frontal Zone included) based on stomach contents. They place *O. bartamii* at a trophic level of 5.3 in the eastern Subarctic region and 5.1 in the western region.

Predators

Many marine mammals prey on squid. There are 47 species of marine mammals in the North Pacific north of 30°N, and over 10 million individuals that consume over 13 million metric tons of prey during the summer (Hunt, et al., 2000). *O. bartramii* is certainly an important prey for many of these species but information is limited. The percent of the diet consisting of *O. bartramii* for the following marine mammals was used for the trophic model of the Subarctic ecosystem by Aydin, et al., (2003) for the eastern Subarctic area: sperm whale (34 percent), toothed whales (4.6 percent), fin whales (2.3 percent), sei whales (2.3 percent), northern fur seals (13.7 percent), elephant seals (18.3 percent), Dalls porpoise (20.6 percent), white sided dolphin (11.4 percent), right whale dolphin (22.9 percent). Values were considerably lower in the western subarctic area. Mori et al. (2001) found *O. bartramii* to be an important prey of the northern fur seal in the Central North Pacific. Gaskin and Cawthorn (1967) quantitatively analyzed the stomachs of nine sperm whales in the Cook Strait region of New Zealand and found a ratio of 1.69:1 of squid to fish by weight. Onychoteuthid squid made up the bulk of stomach contents by number and weight and were identified as *Notodarus sloanei, Histioteuthis cookina, Architeuthis* sp. and *Moroteuthis* sp..

In the North Pacific north of 30°N there are 135 species of seabirds and over 200,000,000 individuals (Hunt, et al., 2000). Many feed on squid. In the PICES tropical zone (30°N to about 45°N) some albatrosses and shearwaters are estimated to consume over 350,000 mt of squid during the summer, with *O. bartramii* the dominant prey (Hunt, et al., 2000).

Swordfish are known to feed heavily on squid, often predominately ommastrephid squids (Toll and Hess, 1981; Stillwell and Kohler, 1985). Ommastrephid squids, especially *O. bartramii*, appear to be important in the diet of swordfish captured near 30°N latitude in February where swordfish may be feeding on concentrations of spawning squid (Seki, 1993).
Seki (1992) found that the diet of blue sharks caught within the Subarctic Frontal Zone by surface longlines during the summer in the size range of 66-155 cm precaudal length, consisted of 55 percent *O. bartramii* by weight.

In general, most large fishes and toothed marine mammals in the subtropical to subarctic regions of the North Pacific are known to feed on squids but the species of squids usually have not been identified (Seki, 1993).

Habitat

The general habitat of *O. bartramii* in the North Pacific appears to be approximately 20-50°N in oceanic waters from Japan to North America with the highest densities of commercial-size squid found along the Subarctic Frontal Zone (Murata and Hayase, 1993). *O. bartramii* rarely occurs off east China or in the Japan, Okhotsk and Bering Seas (Arata, 1983). More precise boundaries are difficult to define. Based on Japanese fishery records, the population has a more northerly distribution east of 170°W and major concentrations occur westward during October-December (Murata and Nakamura, 1998). That is, in December catches east of 160°W decline greatly and are absent west of 180° (Murata and Nakamura, 1998). Kubodera, et al. (1983) suggest that the species does not enter the Subarctic Domain north of the Subarctic Frontal Zone. Murakami, et al. (1981), however, show good catches as far as 49°N, 139°W, well into the Subarctic Domain in 1978-9. In the Western Pacific Murakami shows catches as far as 46°N at 162°E and just over 44°N off the Kuril Islands at about 149°E.

In the central Pacific the most southerly record we are aware of is a mature female taken just south of the Hawaiian Archipelago at 17°S and about 160°W (Young, et al., 1997). In the eastern North Pacific Wormuth (1976) reported a female (122 mm ML) at 27°N, 120°W. Murakami, et al. (1981) report mature females from about 25°N at 142°E and about 24°N at 170°E.

The northern end of *O. bartramii*'s distribution generally does not extend beyond 11°C SST although it is known from SSTs as low as 9°C (Yatsu, 1992; Yatsu and Watanabe, 1996) and good catches have been made at 10°C in November (Yatsu, 1992). For example, fishing effort during 1987 occurred with SSTs ranging from 10°-27°C with 97 percent of the effort at 11°-17°C and 0.1 percent at 8°-9°C (Murata and Hayase, 1993). Low SSTs probably do not directly limit the distribution of the squid as they can enter temperatures of at least 4°C and probably less at depth during the day (Murata and Nakamura, 1998). *O. bartramii* is mostly fished where SSTs lie between 13°-18°C (Yatsu et al., 1993). Temperatures at the southern end of the distribution are less well known. Bower (1994) reported paralarvae at SSTs up to 24.9°C in Hawaiian waters. Hayase (1995) reported paralarvae from about 26°N at 158°E at a SST of 26.6°C. Presumably the habit of *O. bartramii* of descending into deep waters during the day prevents their occurrence in neritic waters.

Status of the Stock

The combined annual catch by the Japanese, Taiwanese and Korean fisheries for 1985-1990 ranged from 248,000-378,000 mt (328,000 mt average.)(Murata and Nakamura, 1998). *O. bartramii* has been fished commercially in the North Pacific since 1974 (Yatsu, et al., 2000). An intense fishery for *O. bartramii* began in 1978 with the introduction of driftnet fishing, and driftnet fishing dominated the fishery until the end of 1992 when a moratorium on large-scale driftnet-fishing was instigated (Yatsu et al., 2000). Catch rates from driftnet fishing greatly exceeded those of jigging when fishing in the same area (1.5 - 3.8 times greater) (Murata, 1990) and driftnet catches represented about 87 percent of the Japanese total catch between 1985-1990 (Murata and Nakamura, 1998). Prior to the moratorium data were insufficient to assess the population size, but there was some indication from declines in the stock size index and the size of individual squid that the population in the eastern region might be declining (Murata, 1990). The CPUE for the Japanese driftnet fishery, however, showed a peak in 1990 and good values in 1991 and 1992 (Yatsu and Watanabe, 1996). The major fishery, before the moratorium, operated primarily from June through December with most fishing occurring in the Subarctic Frontal Zone (Araya, 1983; Murata, 1990; Murata and Hayase, 1993). The current jigging fishing grounds lie at about 40-42°N and 150°-170°E (Yatsu et al., 1997). Research catches using jigging and small-size driftnets starting in 1980 show high catches beginning in 1994 indicating that the population recovered rapidly after the termination of commercial driftnet fishing (Yatsu et al., 2000). In the western region total catches in the jigging fishery ranged from 50 Kt to 80 Kt during 1994-1998 and fell to 30 Kt in 1999 and 2000 (Yatsu, 2003, cited in Bower, 2004). In the central region, beginning in 1996 the Japanese *O. bartramii* jigging fishery showed increasing catches to 1998 then declining catches (1997 - 12 Kt, 1998 - 21 Kt, 1999 - 12 Kt, 2000 - 5 Kt. Numerous Chinese jigging vessels, estimated to be about 400-600 in number with a catch equal to or greater than the Japanese catch), along with Korean and Taiwanese vessels operating in the general area of the Japanese fishing grounds may contribute to the declining catches (Ichii, 2003 and Yatsu, 2003, both cited in Bower 2004).

The total biomass for *O. bartramii* in the North Pacific is uncertain. Aydin, et al., (1993), however, used estimates of 1,678 Kt for the population size of *O. bartramii* for their subarctic gyre models. Ichii (2003, cited in Bower, 2004) estimated, with uncertain reliability the MSY (his “resource”) of the autumn cohort for the year 2000 to be 370 Kt and he roughly estimated its biomass on the driftnet fishing grounds during the driftnet period at 240-610 Kt. Ichii (2003 in Bower, 2004) also noted that the catch of the winter-spring cohort in the central and east region during the drift net period was 10,000 to 60,000 tons, but that the current MSY is not known. Osako and Murata (1983) estimated the sustainable catch for O. bartramii west of 170°E (i.e., for the west stock of the winter-spring cohort) at 80-100 Kt. The reliability of this estimate for the present resource (i.e., over 20 years later) is uncertain (Bower, 2004). Considering the uncertainty of the MSY estimates and the uncertainty of the present fishery yield, the position of the population on the yield curve cannot be determined.

The CPUE has fluctuated greatly since 1995 and this may be due to changing environmental conditions in the North Pacific (Ichii, 2003, cited in Bower, 2004).

3.4.2 Diamondback Squid (*T. rhombus*)

General Description

T. rhombus, commonly called the diamondback squid, diamond-squid, sode-ika, taru-ika, chipirone, and chipilona among others, is the sole member of the family Thysanoteuthidae. *T. rhombus* has a distinctive morphology and its phylogenetic relationships with other squids are unknown. It is found in tropical and warm-temperate waters throughout the world's oceans, but is rarely abundant (Nigmatullin and Arkhipkin, 1998); although it supports small fisheries in the Sea of Japan and in waters around Okinawa. *T. rhombus* is of interest to pelagic fisheries in Hawaii because of its large size and desirable eating qualities which make the capture of low numbers valuable. The usual maximum size is about 850 mm ML for females and 800 mm ML for males with body weight up to 20-24 kg (Nigmatullin and Arkhipkin, 1998). These authors suggest that individuals can reach 1000 mm ML. Kawasake and Kakuma (1998) report a maximum size of 900 mm ML off Okinawa. Miyahara and Gorie, in press (mentioned in Bower, 2004) report a length to weight formula, based on 10, 432 squid of 194-745 mm ML from the Sea of Japan, with mantle length (L) in mm and total weight (W) in grams of $W=(4.008x10^{-5})L^{2.982}$. Nigmatullin and Arkhipkin (1998) present a similar curve based on squid from the Atlantic and Eastern Pacific ($W=0.056L^{2.89}$ with L in cm). Sexual differences in this length/weight relationship were not apparent. Males mature by 450 mm ML and females by 650 mm ML (Nigmatullin and Arkhipkin, 1998).

T. rhombus probably has the thickest mantle of any muscular cephalopod. Mantle thickness reaches 40-50 mm in individuals of 700-800 mm ML and the mantle weight reaches 60-85 percent of the total weight (Nigmatullin and Arkhipkin, 1998). Another unusual feature is the presence of very large fins that extend the full length of the mantle.

Very little is known about the population structure of *T. rhombus*.

Eggs and Paralarvae

Egg masses of *T. rhombus* have been reported floating at the surface of the tropical Atlantic and Pacific oceans on many occasions (e.g., Suzuki et al.,1979; Young and Vecchione, 1996; Nigmatullin and Arkhipkin, 1998; Billings, et al., 2000; Guerra et al, 2002; Bower, 2004). A submersible observation in calm water showed one egg mass floating about 10 cm below the ocean surface (pers. obs., R. Young). The egg mass has a sausage-shape with a length of 600-1800 mm and a diameter of 110-300 mm (Nigmatullin, et al., 1995). Compared to ommastrephid egg masses, the egg mass of *T. rhombus* is tough and resilient. Near the surface of the mass, the eggs are arranged in two adjacent rows that spiral around the entire cylindrical egg mass like a coiled spring. The number of eggs varies from 32,000 to 76,000 (Nigmatullin, et al., 1995), 24,000 to 44,000 (Guerra, et al., 2002) or 180,000 (Billings, et al., 2000). Batch fecundity is estimated to be up to 140,000 eggs (Nigmatullin, et al., 1995). Eggs are 1.6-1.8 mm in diameter (Nigmatullin and Arkhipkin, 1998). Sabirov et al. (1987) state that shortly before hatching occurs the egg mass loses its buoyancy and sinks. Confirmation of sinking is needed by other studies.

Paralarvae have a distinctive appearance and are easily recognized. Nevertheless, little is known about their precise vertical distribution. They presumably leave the egg mass in near-surface waters. Paralarvae of various sizes are captured in the upper 100 m (Bower, et al., 1999).

Around the Hawaiian Archipelago, Bower, et al. (1999) found the paralarvae were part of an "oceanic" assemblage of paralarvae rather than an "island-associated" assemblage. They were ranked 23rd in abundance of the 57 species of paralarvae captured.

The size of paralarvae at hatching was estimated from Clarke (1966) at 1.6 mm ML. Nigmatullin and Arkhipkin (1998) give a hatchling ML of 1.0-1.3 mm. Watanabe et al. (1998) measured hatchlings at 1.4-1.6 mm ML. Growth rates of paralarvae have not been studied. Nigmatullin and Arkhipkin (1998) suggest the end of the paralarval phase occurs at 16-18 mm ML when arms II and III reach 80-115 percent of the ML and the fins reach 80-85 percent of the ML. Wakabayashi, et al. (2003) suggest that the end of the paralarval stage may occur at 6-8 mm ML when development of the beak rostrum, disappearance of cilia on the lips and development of suckers on the distal third of the arms may reflect changes in feeding habits.

The presence of egg masses or paralarvae indicates regions where spawning occurs. Nigmatullin, et al. (1995) report such occurrences from the tropical to subtropical regions of the Western Pacific, equatorial waters of the Indian Ocean near 80°E, off the tip of Brazil in the tropical western South Atlantic, the Mediterranean Sea, in the region of the Antilles in the tropical western North Atlantic, and off the coast of Peru in the tropical Eastern Pacific. To these records we add egg masses from the Atlantic off the southeastern coast of Florida, and the Bahama Islands and in the Pacific off Hawaii. Bower (2004) summarizes numerous records in the Pacific off southern Japan. With the exception of the Mediterranean Sea, spawning grounds appear to be world-wide in tropical waters. Specific patterns, if they exist, within this broad range have yet to be found.

Juvenile

T. rhombus is best known as paralarvae or subadults. Juveniles are rarely caught in standard pelagic trawls. Young (1978) in his work on the vertical distribution of pelagic cephalopods off Hawaii captured no juvenile *T. rhombus* in midwater trawls even though paralarvae are commonly caught in plankton nets (e.g., Bower, et al., 1999) and egg masses are occasionally seen (pers. obs., R. Young). Russian researchers using a variety of trawls up to 24 m mouth-width over a period of 20 years have captured 40 individuals from 10-100 mm ML (Nigmatullin and Arkhipkin, 1998) which is the largest collection of juveniles known. The squid were captured in the upper 100 m but the time of capture was not reported. A 25 mm ML juvenile was caught in a trawl that fished between 55 m depth and the surface during the day (Roper and Young, 1975). Nigmatullin and Arkhipkin (1998) suggest that juveniles between 15-50 mm ML occur at depths greater than 20-30 m during the day and night as they are rarely observed at night-light stations and are virtually absent from the diet of sea birds. Nigmatullin and Arkhipkin (1998) suggest that the juvenile phase ends at 120 mm ML when body shape and arm lengths (except arms III) are similar to subadults and suckers have 10-16 fang-like teeth on the distal margin and obtuse teeth on the proximal margin of the inner rings. See below for juvenile growth rates.

Juveniles, presumably, have the same geographical distribution as paralarvae.

Subadult and Adult

Age and Growth

Nigmatullin, et al. (1995) examined growth in *T. rhombus* based on statolith analysis of 72 individuals on the assumption that statolith increments were deposited daily. Ages ranged from 60 days (25 and 27 mm ML) to 309 days (770 mm ML); the largest squid examined, a mature male of 805 mm ML, had 288 increments. No apparent differences were noticed between male and female growth. Squid reached 90 mm ML at 90 days of age and 590 mm ML at 240 days. In juveniles growth rates were 1.2-1.5 mm per day but at an age of 150-180 days (ca. 275-400 mm ML) growth rates were exceptionally high at 4.6 mm day^{-1} (ca. 140 mm mo^{-1}). Bower (2004) reviewed studies of length-frequency data from the Sea of Japan that indicated growth rates of 80-100 mm mo^{-1} for squid larger than 400 mm ML and he reported a tag-and-release study where one squid grew from 340-480 mm in 45 days (90 mm mo^{-1}). At an age of 300 days, growth had slowed to 0.97 mm per day (ca. 30 mm mo^{-1}) (Nigmatullin, et al., 1995); their combined data set (males, females, juveniles) exhibited a logistic growth-curve when plotting ML or BW (body weight) against age in days. According to their curve of BW vs. age, a squid will reach 10 kg at about 240 days old. Nigmatullin, et al. (1995) suggest that maximum longevity is about 12 months and this is supported by the size-frequency data of Kawasaki and Kakuma (1998).

Kawasaki and Kauma (1998) reported on 13,876 squid caught by research and commercial fisheries around Okinawa from 1990-1994. The squid ranged in size from 300-900 mm ML. The 300-400 mm size group recruited into the fishery each year around June. The size mode increased to 600 mm by November and 700 mm in January and reached 750 mm in March. Growth rates ranged from 50-100 mm mo^{-1} in the summer to 20 mm mo^{-1} in March. These values are very close to those determined by Nigmatullin, et al. (1995). Kato, et al. (2001) suggest that the fast growth rates are related to relatively slow swimming; Kato, et al.'s ultrasonic tracking indicated that the squid did not swim against strong currents. (Undulatory swimming with fins, is a slower, but energetically more efficient means of locomotion, than jet-swimming (Wells and O'Dor, 1991)).

Kato, et al. (2001) found gonad somatic indices (relationships between gonad and body weight) were maximal in March to May in Okinawan waters and egg masses were found in April. From January to May the sex ratio was approximately 1:1 but the percent of females dropped in June to August with a low of about 30 percent female in July. Kawasaki and Kauma (1998) suggest that spawning in Okinawan waters occurs between January and September with a peak in March to May. Dates of hatching based on statolith increment counts from squid captured in the Pacific near the southern tip of Kyushu Japan (ca 5° of latitude north of Okinawa), indicate hatching occurred in all months except August, November and December (data summarized in Bower, 2004) which agrees fairly well with spawning dates suggested by Kawasaki and Kauma. Seasonal trends in hatching, if any, in more tropical waters have not been reported. In the Sea of Japan, Bower (2004) reports a study by Miyahara and Gorie (2003) in which squid that recruit into the fishery beginning in August grow faster than those recruiting after October.

According to Nigmatullin and Arkhipkin (1998) sex can be determined visually at a squid size of 100-120 mm ML and males mature between 390 and 450 mm ML; all males were mature beyond 450 mm ML (ca. 200 days old). Females mature between 520 and 650 mm ML; all females were mature beyond 650 mm ML (ca. 250 days old). Bower (2004) referring to Japanese research in the Sea of Japan quotes values of 470-520 mm ML for mature males and 590-610 mm ML for mature females. *T. rhombus* exhibits unusual sexual dimorphism in the length of arms III which, in immature males, can be twice as long as in females (Nigmatullin and Arkhipkin, 1998). These authors suggest the long third arms aid in sexual recognition during pair formation; however, the bisexual nature of the pairs is questionable (Takeda and Tanada, 1998).

Population Structure

Kitaura et al. (1998) looked for genetic variation, between squid caught in the Sea of Japan, in the Western Pacific near Okinawa and the Ogasawara Islands, and in the Eastern Pacific near the Galapagos Islands, by sequencing DNA of the mitochondrial COI gene. They found no evidence of genetic differentiation among squid from around Japan or between squid on both sides of the Pacific. This study suggests an absence of genetic differentiation but is not conclusive.

Kawasaki and Kauma (1998) found a linkage between catch fluctuations in different regions around Okinawa which suggested to them that the catch represented changes in the local stock size.

Nishimura (1966) reported that fishermen generally found *T. rhombus* as a male/female pair and catch frequency in set nets supported the paired occurrence. Nigmatullin and Arkhipkin (1998) reported that *T. rhombus* observed from ships is usually seen as a pair of squid swimming together and suggest that the squid is monogamous, with male-female pairs remaining together from the juvenile stage to death. However, Takeda and Tanda (1998) suggest that fishermen in the Sea of Japan used an unreliable method for sexing squid and while the squid may normally occur in pairs these pairs are not always bisexual.

Horizontal Migration

The only evidence of a horizontal migration for *T. rhombus* is the influx of squids into the Sea of Japan. Nishimura (1966) noted the common occurrence of *T. rhombus* along the western coasts of mostly middle and southern Honshu but occasionally as far north as Hokkaido. Records were based on beach strandings and captures in set nets near shore and other fishing methods offshore. Catches were mostly from mid-October to mid-January and disappeared after late January despite the continued presence of set nets. The squid appear in offshore waters just north of the Korean Straits (southwestern end of the Sea of Japan) from late August to mid-

November and appear in November to January in the inshore waters of the same region as well as the inshore waters of middle Honsu. In addition, occasionally in the northern waters near the Tsugaru Straits (between Honsu and Hokkaido) *T. rhombus* is sometimes caught earlier in the season than in the more southern locations. These data suggest to Nishimura (1966) that the following migration occurs: (1) *T. rhombus*, like some warm-water species of fish and turtles, moves into the Sea of Japan on the Tsushima current through the Korean Straits during periods of peak transport from August to October and is distributed over most of its range in the open sea. (2) In mid-November when the northwest monsoon season begins, winds form onshore currents which carry the squid toward shore where much of the population is caught in set nets or stranded on beaches. (3) Surviving squid return to tropical waters following a southward current along the coast to the Korean Straits or some pass through the northern Tsugaru Straits with an unknown fate. The migration as envisioned by Nishimura could be largely passive with currents responsible for most transport. Nazumi (1975 - cited by Bower, 2004) suggested that this is a one-way migration and that *T. rhombus* dies in the cold water of the Sea of Japan during the winter. This latter conclusion has been accepted, until recently, by scientists reporting in the popular literature (Okutani, 1982; Okiyama, 1995 - cited in Takeda and Tanda, 1998). Takeda and Tanda (1998), however, found small squid (e.g., 156 mm ML) in December in the Sea of Japan, and they report that small sizes are caught off Kyoto in December. They suggest that the migration is not a simple one (a conclusion also reached by Nishimura in 1966) and the possibility exists that *T. rhombus* spawns and grows during the summer and autumn in the Sea of Japan.

Swimming Speed

Like most muscular squids, *T. rhombus* is negatively buoyant and must swim to stay afloat (Nigmatullin and Arkhipkin, 1998). Nigmatullin, et al. (1995) report that the length of the statoliths in large *T. rhombus* is about half that of large oceanic ommastrephid squids. The significance of this is uncertain but could relate to fast acceleration. According to Nigmatullin and Arkhipkin (1998), however, *T. rhombus* is relatively inactive and is usually observed at night-light stations moving slowly with sinusoidal undulations of the large fins and with little contribution from their jet. Nishimura (1966) observing swimming *T. rhombus* in set nets also found they were slow swimmers that swam mostly by movement of the fins. Nigmatullin and Arkhipkin (1998), however, note that *T. rhombus* is easily disturbed and reacts quickly with powerful escape jets that, in small squid (at least to 250 mm ML according to Nishimura, 1966), can propel it from the water. Ultrasonic telemetry (of three squid 750-770 mm ML followed for 14 -72 hrs. off Okinawa) averaged about 2.0 km/hr (= 0.56 m sec^{-1} or about 0.7 MLs sec^{-1}), during both day and night (Yano, et al., 2000). The range among the averages of the three squid was 1.76 km hr^{-1} (0.49 m sec^{-1}) to 2.32 km hr^{-1} (0.64m sec^{-1}). The maximum one hour average was 3.9 km/hr and the minimum about 0.2 km/hr. At 0.7 ML sec^{-1} (mantle lengths per second); their average speed is comparable to that of *O. bartramii* which exhibits a far more active behavior around night-lights. Yano, et al. (2000) mentions measurements made by Iizuka on swimming speeds of *T. rhombus* in the Sea of Japan by ultrasonic telemetry. The squids were smaller (480 and 490 mm ML), with swimming speeds of 0.9-1.3 km/hr or 0.5-0.7 MLs sec^{-1} which is comparable to the Okinawa measurements.

Spawning

T. rhombus, based on circumstantial evidence, appears to be a "continuous spawner" with the following characteristics: continuous asynchronous ovulation and maturation of oocytes, spawning (i.e., monocyclic) over an extended period with intermittent spawning events (i.e., as the oviducts fill, they are emptied) and somatic growth during the period of spawning (Nigmatullin, et al., 1995). These authors suggest that the number of oocytes that potentially will develop into mature eggs is fixed before maturation of oocytes begins. They estimate total potential fecundity from the number of oocytes at up to 4.8 million eggs.. Nigmatullin and Arkhipkin (1998) suggest that individual spawning lasts 3-4 months and that a female will produce at least 8-12 egg masses during this period.

Vertical Distribution

Takeda and Tanda (1998) reported on experimental fishing near Okinawa using standard commercial fishing methods involving a buoy and vertical drop-line but with jigs placed at specific depths during the day. Squid were caught between depths of 300 and 750 m with greater catches and CPUE between 400 and 650 m and slight peaks at 500 and 550 m. Temperatures at 750m were 5.8°C and at 500-550m temperatures ranged from 8.1 - 12.0°C. Depth records determined from biotelemetry by Yano, et al. (2000), although somewhat inconsistent, showed the squid mostly at 300-550 m depth (considerable time was spent between 500-550m) during the daytime and from the surface to 150 m at night. Bower (2004) reports six other biotelemetry studies off Okinawa that confirm a day depth between 300-600m and a night depth at 0-150m. Yano et al. (2000) mention similar measurements made by Iizuks in the Sea of Japan where the squid occupied depths of 50-100 m during the day and 0-40 m at night (The Sea of Japan has a "false bottom" formed by extremely cold that temperatures that can be less than 2°C at depths of 250 m (anonymous, 2004)).

Prey and Predators

Prey

In the Sea of Japan *T. rhombus* has a very specialized diet. The review by Bower (2004) cites a study by Nazumi in 1975 on 52 adults which fed predominately on the adult ommastrephid squid *T. pacificus* (frequency of occurrence was 89 percent) but also had sardine scales in 11 percent of the squid. Stomach contents of *T. rhombus* > 200 mm ML from Okinawan waters referred to by Bower (2004) stated that fishes were in 84 percent of the stomachs and squids in 38 percent. Squid from open ocean waters of the eastern tropical Pacific and Atlantic Oceans fed mostly on mesopelagic fish and squid (Nigmatullin and Arkhipkin, 1998). In this latter study most prey were small: most of the fish were 30-100 mm in total length and squid were 30-120 mm in length (tip of mantle to tip of arms). Fish prey were mainly 6-8 percent of the squid length (not ML) except for long slender fish which were mainly 12-20 percent and squid prey were mainly 5-8 percent. Fish included *Cyclothone* (gonostomatidae), *Argyropelecus affinis* (Sternoptychidae), *Chauliodus sloani* (Chauliodontidae), *Paralepis* (Paralepedidae), Myctophum, Diaphus, Hygophum (Myctophidae), Nemichthes (Nemichthyidae), Beloniformes juveniles, *Cubiceps* (Nomeidae), *Diplospinus* (Gempylidae), *Stomias* (Stomiatidae). Squid included *Abraliopsis* (Enoploteuthidae), *Octopoteuthis* (Octopoteuthidae), *Onychoteuthis banksii* (Onychoteuthidae), *Chtenopteryx* (Ctenopterygidae), *Histioteuthis* (Histioteuthidae), *Dosidicus gigas*, *S. oualaniensis* (both young Ommastrephidae), *Liocranchia* (Cranchiidae), *Japetella diaphana* (Bolitaenidae) and *Ocythoe tuberculata* (Ocythoidae). Underwater observations by Nigmatullin in 1987 (Nigmatullin and Arkhipkin, 1998) show that *T. rhombus* feeds at night but not actively. Nigmatullin and Arkhipkin (1998) concluded that this squid feeds mainly in the daytime in deep water.

Predators

Nigmatullin and Arkhipkin (1998) found paralarvae and small juveniles of *T. rhombus* in the stomachs of several ommastrephid squids and a needlefish but in low frequency (<1-1.5 percent). They note that large juveniles of *T. rhombus* have been found in dolphin fish, lancet fish and various tunas generally in low frequency although in one study they occurred in 7.5 percent of bigeye tuna in the Gulf of Guinea. Young are rarely found in stomachs of sea birds. They report that large (>200 mm ML) *T. rhombus* are found in sharks, blue marlin, rough-toothed dolphins, spotted dolphins, false killer whales, sperm whales and swordfish. Hernandez-Garcia (1995) found frequencies of occurrence in swordfish of 0-11.8 percent in the eastern tropical Atlantic. Guerra et al. (1993) examined swordfish from the northeast Atlantic between 33° and 50°N but found no *T. rhombus* although *Sthenoteuthis pteropus* (similar Atlantic habitat to *T. rhombus*) was common. Seki (1993) found *T.rhombus* remains in 7 of 22 swordfish examined in the subtropical central North Pacific. Markaida and Sosa-Nishizaki (1998) found *T. rhombus* in 15 percent of swordfish stomachs captured off Baja California but that they contributed only 1.5 percent of the prey by weight. Tsuchiya et al. (1998, in Bower, 2004) found *T. rhombus* comprised 10 percent of the prey items of the swordfish in the tropical Eastern Pacific and 3 percent in both yellowfin and bigeye tunas.

Habitat

The general geographical distribution of *T. rhombus* was reviewed by Nigmatullin and Arkhipkin (1998). The species range includes the tropical and subtropical regions of the world's oceans and extends into warm temperate regions of the Mediterranean Sea, the Sea of Japan in summer, and off South Africa: (1) In the Atlantic the range extends to 30-40° north and south near the continents where western boundary currents carry warm waters into high latitudes. (2) In the central regions of the Atlantic *T. rhombus* occurs up to 20°N and 25°S. (3) In the Southeast Atlantic it reaches only 18°S due to the cold waters of the Benguela Current. (4) In marginal seas of the Atlantic, it is present in the Gulf of Mexico, Caribbean and Mediterranean Seas. (5) In the Indian Ocean it is known from the Arabian Sea and gulf of Bengal and up to 35°S off the tip of South Africa along with the warm Agulhas Current. (6) In the Western Pacific it is found from the Sea of Japan at 43°N to 25°S. (7) In the Western Pacific it reaches about 20° north and south. *T. rhombus* occupies waters primarily where surface temperatures are more than 20°C although it is known from SSTs of 15°C. A more detailed indication of the latitudinal boundaries in the central North Pacific is found in the reports of the by-catch of the drift-net fisheries: Seki (NMFS unpublished) reports pooled catches by large-mesh driftnets that show scattered catches of *T. rhombus* with northern-most catches at approximately 38.5°N at 170°E and further west at 35°-36°N at 149° - 163°E and eastward at 32°N at 158°W.

The vertical extent of the habitat extends from the surface to at least 600 m depth in oceanic waters.

Status of the Stock

Genetic data have, so far, failed to distinguish populations of *T. rhombus* across the North Pacific (see above) and morphological data have failed to distinguish populations world-wide (Nigmatullin and Arkhipkin, 1998). Some data (see above) from the Okinawa fishery suggest that catches are from a resident population. In most areas, however, little data exist on how mobile populations are.

The fishery off Okinawa, which started in 1989 and uses drop-line and long-line fishing methods, catches about 1600-2000 mt yr^{-1} (Kato, et al., 2001). The total Japanese fishery yield of *T. rhombus* was nearly 6000 mt in 2001 (Bower, 2004). Experimental fishing in the South China Sea produced almost no results (Dickson, et al., 2000).

Nigmatullin and Arkhipkin (1998), based on night-light observations and trawl catches, report an estimate of 1.5-2.5 million tons world-wide. This "educated guess" is, apparently, the only estimate that exists.

3.4.3 Purpleback squid (*S. oualaniensis)*

General Description

S. oualaniensis, commonly known as tobiika, hoyenjoo, yellow-backed squid, purpleback squid, flying squid and purple squid, is a member of the family Ommastrephidae and thought to be the most abundant large squid in the tropical and subtropical waters of the Indo-Pacific region (Young and Hirota, 1998; Dunning, 1998). A related species, *S. Pteropus,* the only other member of the genus, replaces *S. oualaniensis* in the Atlantic Ocean.

S. oualaniensis consists of five possible forms (see Section 3.4.3.4.2 Population Structure). This report is restricted primarily to the dominant form in the Pacific Ocean: the late-maturing medium form. We use the name, *S. oualaniensis*, to refer to this form; references to other forms will be made by using their form name. Unless indicated otherwise, data are taken only from Pacific populations.

Although abundant, concentrations of the squid are usually insufficient to support major fisheries. Local fisheries, however, have existed off Taiwan, the Ryukyu chain (Okutani and Tung, 1978) and Hawaii (Yuen, 1979).

In Hawaiian waters, *S. oualaniensis* females mature between 158 and 205 mm ML with 90 percent mature at 200 mm ML (maximum size is 335 mm ML, 1.6kg); males are mostly mature by 140 mm ML (maximum size is 210 mm ML) (Young and Hirota, 1998; Suzuki, et al., 1986). The length/weight relationship for females in Hawaiian waters is given by $W=(1.8 \times 10^{-5})L^{3.15}$ with L (length) in mm and W (weight) in g and the curve for males is essentially the same (Suzuki et al., 1986). The life span of *S. oualaniensis* is estimated to be about one year.

Sthenoteuthis is an obligate shoaling animal (numbering 2 to 1000 individuals) and, at low squid densities, it forms shoals of different sizes and will occasionally attempt to join fish shoals (Zuev, et al., 2002).

Eggs and Paralarvae

An egg mass from a Pacific Ocean member of *S. oualaniensis* has never been seen. An egg mass, spawned in captivity, by the giant form of *S. oualaniensis* from the Arabian Sea, however, has been reported to have the "typical ommastrephid" appearance (Chesalin and Giragosov, 1993). This means a large spherical, gelatinous egg mass with thousands of eggs distributed thoughout the mass. Mature oocytes (eggs) are small; those in the oviduct measure 0.79 x 0.87 mm (Okutani and Tung, 1978) or 0.70 x 0.84 mm, (Sakurai, et al., 1995).

The vertical distribution of paralarvae appears to be mostly the upper 50 m or so of the ocean during both the day and night. In Hawaiian waters Young and Hirota (1998) found 60-70 percent of the paralarvae in the upper 20 m during both the day and night with small numbers found to depths of 81-100 m. Harman and Young (1985), off Oahu, Hawaii, found most paralarvae in the upper 70 m in April and the upper 50 m in October, with some captures as deep as at least 150 m. Saito and Kubodera (1993), south of Japan, found paralarvae mostly in the upper 40 m, although over the continental shelf in the East China Sea they caught paralarvae between 30 m and about 60 m.

Harman and Young (1985) found that paralarvae were present throughout the year in Hawaiian waters but were most abundant in August, less abundant in April and least abundant in October and December. Some seasonal overlap occurs between the occurrence of paralarvae of *S. oualaniensis* and the related *O. bartramii* in Hawaiian waters. Off leeward Oahu, *O. bartramii* was not collected by Harman and Young (1985). Young and Hirota (1990), however, found both species at this same site and in the same month (April) in a subsequent year. Apparently during the 1985 study either *O. bartramii* had a more abbreviated spawning period or they did not spawn as far south as in the later study (Young and Hirota, 1990). Bower, et al. (1999) found that *O. bartramii* paralarvae were more abundant than *S. oualaniensis* paralarvae in northern Hawaiian waters in the winter by over a 12:1 ratio and that *S. oualaniensis* paralarvae were more "island associated." These data suggest that much of the spawning of these two species is out of phase with one another in time and space over much of the year in these waters. Saito and Kubodera (1993) found a similar inverse spatial relationship of *S. oualaniensis* and *O. bartramii* paralarvae in the western Pacific. The former was over ten times more abundant in

Saito and Kubodera's southern transect to the south of Japan and the latter was about three times more abundant in the northern transect off Tokyo.

S. oualaniensis paralarvae have only been positively identified since 1985 (Harman and Young, 1985) so some earlier records may be unreliable. Paralarvae in the Pacific Ocean are known from Hawaiian waters (Harman and Young, 1985; Young and Hirota, 1998; Bower, et al., 1999), Japan and Taiwan (Okutani and Tung, 1978); off Japan at about 34°N (water temperature 25-26°C) and a transect across the Amami-Ryukyu Islands into the East China Sea (water temperatures 21-31°C) (Saito and Kubodera, 1993), Eastern tropical Pacific (Yatsu, 1999). Dunning (1998) reports paralarvae between 14° and 34°S off the eastern Australian coast where temperatures range from 20.4°-28°C in the summer. He found paralarvae rare from January to May 1983 in the region from 28°-34°S and absent from this same area in the summer of 1985. An assumption that spawning occurs throughout the habitat of *S. oualaniensis* (except, perhaps, at the high latitude extremes of their distribution) is unwarranted considering the sparsity of data and the evidence that marked patterns in the distribution of mature females can occur on rather small scales. Indeed, in the Atlantic Ocean *S. Pteropus* spawns primarily in specific regions on either side of the tropical Atlantic (Zuev and Nikolsky, 1993).

Bigelow (1991) examined growth of paralarvae based on statolith increments of 6 paralarvae and derived a growth curve of $ML=1.46e^{0.034x}$, where ML is in mm and x is in days. This curve indicates that a paralarva of 4 mm ML is 30 days old which is in strong contrast to the growth of *O. bartramii* which reaches 7 mm ML at 30 days. Arkhipkin and Mikheev (1992) in a detailed study of *S. oualaniensis*'s larger congener, *S. pteropus* from the tropical Atlantic, found paralarval growth comparable to that of *O. bartramii*. Proboscis separation in *S. pteropus* occurred at a ML of 8.5 mm and an age of 33-35 days. Presumably the Bigelow study examined too few specimens to obtain a reliable curve, but emphasizes the probable large variation that exists in growth rates of paralarvae.

Harman and Young (1985) found that the morphological event separation of the tentacles, usually thought to mark the end of the paralarval period in ommastrephids, occurred at about 9 mm ML in *S. oualaniensis*. The validity of this event as the marker, however, has been questioned by Yatsu and Mori (2000).

Juvenile

Little direct evidence exists on the geographical distribution of juveniles although Dunning (1998) was successful in capturing juveniles with scoop nets between 22°50'S and 38°25'S where SSTs were 26.7°-20.8°C. According to Okutani juveniles are frequently aggregated in inshore waters around oceanic islands such as Hachijo Island and Ogasawara Islands (Bonin Islands), Seychelles in the Indian Ocean and Guadalupe Island, Mexico (Okutani and Tung, 1978).

The vertical distribution of juveniles is also poorly known. Presumably they occupy near-surface waters during the day and night. Small *S. oualaniensis* have been found to glide onboard ship during the day (Young and Hirota, 1998). Small *Sthenoteuthis* have been observed gliding over the surface of the ocean during the day (Arata, 1954; Young, 1975; Okutani and Tung, 1978) and are commonly found in the stomachs of day feeding birds (Ashmole and Ashmole, 1967). They are also encountered at the surface at night (Young and Hirota, 1998).

The features that mark the end of the juvenile period in *S. oualaniensis* have never been clearly defined. *S. oualaniensis*, however, has a diagnostic photophore patch on the anterodorsal surface of the mantle. The dorsal photophore patch becomes apparent at approximately 100 mm ML (Kishimoto and Kohno, 1992; Nesis, 1993). The presence of the photophore patch can be taken as a working marker for the end of the juvenile phase and the beginning of the subadult phase. The hectocotylus develops at about 110 mm ML (Okutani and Tung, 1978). In the study by Arkhipkin and Mikheev (1992) on the age of *S. pteropus,* based on statolith examination, they recognized a "dark zone" in the statolith characterized by the lower transparency of the statolith and the width of the increments. They found that this period ended at about 100-110 days at a ML of about 100 mm which they considered to be the end of the juvenile period for *S. pteropus*.

Subadult and Adult

Age and Growth

Russian research, reviewed by Nesis (1993), indicates males of *S. oualaniensis* reach 15-17 mm in 6-7 months and are thought to live less than a year. The growth rates, determined by growth marks on statoliths and gladii, of the middle and dwarf forms are nearly the same, but the life span is short in the small forms, probably not more than 6 months. Gross growth efficiency (weight of growth divided by the weight of food eaten) is estimated at 10 percent throughout the postparalarval life.

Yatsu (2000) determined growth curves for both male and female *S. oualaniensis* based on statolith increments from about 120 mm ML to about 290 mm ML for females and about 185 mm ML for males. His curves are: $ML=9.9511X^{0.634}$ (females) and $ML=29.9X^{0.3494}$ (males) with ML in mm and x in days (presumably). According to this curve a female of 120 mm ML is 51 days old. This contrasts strongly with data of Zaidi bin Zakaria (2000), which places a 115 mm ML female at an age of 95 days. Because ommastrephid growth is affected by food availability and ambient temperature, growth rates can vary with season, geographic area and year (Yatsu, 2000). The data of Zaidi bin Zakaria came from the South China Sea west of the Philippines but, unfortunately, Yatsu (2000) didn't state the locality from which his data were obtained.

In Hawaiian waters *S. oualaniensis* females mature between 158 and 205 mm ML with 50 percent mature at 166-175 mm ML and 90 percent mature at 200 mm ML (maximum size is 335 mm ML); males are mostly mature by 140 mm ML (maximum size is 210 mm ML) (Young and Hirota, 1998; Suzuki et al., 1986). In northern Australian waters males reached maturity from 160 mm ML and females from 250 mm ML. In the eastern tropical Pacific, Nesis (1977 in Dunning, 1998) found males mature over 110 mm ML and females at 180-190 mm ML.

Population Structure

Nesis (1993) has described a complex population structure for *S. oualaniensis* that incorporates three major and two minor forms. A giant form that occurs only in the northern Indian Ocean in the region of the Red Sea, Gulf of Aden and Arabian Sea (modal sizes of 400-500 mm ML in the Arabian Sea, maximum size of 650 mm ML), a medium form (modal sizes of 120-150 mm for mature males and 190-250 mm for mature females) that occurs throughout the range of the species and a dwarf form (modal size of 90-100 mm ML for mature males and 90-120 mm ML for mature females, 140-150 mm ML maximum) that occurs in equatorial waters and lacks the dorsal mantle photophore patch characteristic of the species. The medium form may be subdivided into two forms based on features of the gladius (double or single lateral axes of the rhachis). One of the two medium forms (single lateral axes of the rhachis) occurs only in the Red Sea, the Gulf of Aden and the Arabian Sea north of 15°-17°N. Complicating this picture is a small form, similar to the medium form but maturing at a smaller size (mode for females is 120-140 mm with a range of 90-160 mm ML) that is nearly the same size as the dwarf form and is found in the Western Indian Ocean and the eastern tropical Pacific. Of the five possible forms, giant, medium with single axis, medium with double axis (the typical *S. oualaniensis*), small and dwarf, the latter three occur in the Pacific Ocean. The dwarf equatorial form is found roughly within 10° latitude of the equator where it co-occurs with the typical *S. oualaniensis*.

The dwarf form has several morphological characters that separate it from the typical *S. oualaniensis* (absence of the dorsal photophore patch, slightly different hectocotylus and slight differences in the spermatophore structure and in the gladius structure [Nesis, 1993]). Nesis (1993) could find no differences in the appearance of paralarvae between the dwarf and middle forms. Researchers have disagreed on whether or not the dwarf form is a distinct species (Clarke, 1965; Wormuth, 1976; Nesis, 1993). The most recent research on the status of the dwarf form has been done by M. Roeleveld-Companyo and she considers it to be a separate species that can only be identified as an adult. In Hawaiian waters only the typical *S. oualaniensis* is present. Snyder (1998) suggests that the giant form results from a plastic phenotype in the species.

On a more local scale, Okutani and Tung (1978) found *S. oualaniensis* in Taiwanese waters to consist of three different seasonal cohorts: a June-spawning group, a September-October spawning group and a February-March spawning group.

Horizontal Migration

S. oualaniensis does not undergo horizontal migrations like *O. bartramii* although the high-latitude limits of the population may change seasonally. *S. oualaniensis*, however, does exhibit small-scale areal patterns in the vicinity of islands. Around the Hawaiian Islands large mature females are located on the windward (northeastern) sides of the islands, small immature females are located primarily within 25 km of the leeward (southwestern) sides of the islands and somewhat larger mostly immature females are found mainly further offshore on the leeward sides of the islands (Young and Hirota, 1998). The reason for these patterns is unknown but

Young and Hirota (1998) found some differences in feeding patterns between windward and leeward areas. These local patterns and those observed in juveniles (Okutani and Tung, 1978) and in paralarvae (Bower, et al., 1999) support a general occurrence for island-related distribution patterns.

Nesis (1993) found that the sex ratio is nearly equal among young squids but strongly shifted to females among subadults/adults, which he attributed, apparently incorrectly, to the shorter lifetime of males. In Hawaiian waters among all squid captured larger than 100 mm ML females exceed males in abundance by a 3:1 ratio (Young and Hirota, 1998). At 140-150 mm ML (the size of peak abundance of males) the ratio of females to males was about 1.6:1. The shape of the size-frequency curves of all squids caught suggests that the sexes are about equally abundant until about 130 mm ML when males start to mature. This sex ratio is in strong contrast to that found for adult *O. bartramii* captured in Hawaiian waters, where the female to male ratio was 1:8 (Young et al., 1997). Young and Hirota (1998) after examining several alternatives concluded that the reason for the predominance of females in the catches was unresolved. Okutani and Tung (1978) report a similar situation off Taiwan and Okinawa. The sex ratio is 1:1 at 100-130 mm ML while the relative abundance of males decreases beyond 140 mm ML. The average commercial catch favors females by a 3:1 ratio. In the Philippines the ratio of females to males caught by jigging machines was 4:1 (Siriraksophon and Nakamura, 2001).

Swimming Speed

There is no information available on swimming speed for this species.

Spawning

S. oualaniensis, based on strong circumstantial evidence, is a “continuous spawner” (Harman, et al., 1989; Young and Hirota, 1998; Rocha, et al., 2001) with continuous asynchronous ovulation, ovulation during the spawning period, monocyclic maturation of oocytes, spawning over an extended period where spawning is intermittent but spawning events are continuous (i.e., as the oviducts fill, they are emptied) and somatic growth during the period of spawning. The batch fecundity of a female about 300 mm ML is 250,000 eggs in the combined oviducts (Harman, et al., 1989). The number of oocytes in various stages of development in a female of 251 mm ML was estimated to be 1,643,000 (Harman, et al., 1989). The length of the spawning period and the frequency of spawning episodes during this period are unknown.

Vertical Distribution

At night squids are commonly observed from ships in surface waters. Young and Hirota (1998) suggest, based on the near absence of *S. oualaniensis* subadults/adults at night over bottom depths of less than 650 m, that this squid descends to at least 650 m during the day in Hawaiian waters where water temperatures would be around 4°-5°C. Dunning (1998) caught adult *S. oualaniensis* in eastern Australian waters only where bottom depths exceeded 600 m. In deep water, however, oxygen concentrations can be very low, which should prohibit a highly active squid from entering there.

S. oualaniensis has a very high metabolic rate (standard metabolism of 348 ml O_2/kg/hr) that exceeds that of most fast-swimming oceanic fishes (Zuev, et al., 2002). Its energy metabolism, as in other squids, is based mostly on protein; however, during metabolism a considerable proportion of the protein is catabolized anaerobically (Shulman et al., 2002). In this sense, these squid may be "preadapted" for low oxygen environments. In the Indian Ocean *S. oualaniensis* occupies depths of 300-400 m during the day where the oxygen concentration is 0.1-0.2 mg/L (2-4 percent of saturation) (Shulman et al., 2002).

Prey and Predators

Prey

The high metabolic rate and fast growth rates of *S. oualaniensis* indicate a high rate of food intake is required. Shulman et al. (2002), estimate that adult *S. oualaniensis* require a very high 8-10 percent body weight as a daily ration.

Schetinnikov (1992), in one of the most detailed feeding studies of *S. oualaniensis*, examined squids attracted by night-lights in the eastern tropical Pacific. He found that *S. oualaniensis* fed heavily on crustaceans (up to 50 percent of the volume of the diet) and fish larvae between 40 and 100 mm ML. Between 100 and 150 mm ML the proportion of crustaceans decreased greatly and crustaceans were largely absent at larger sizes. Beyond 150 mm ML myctophids dominated the diet but, as size increased, squids became progressively more important in the diet and by 300 mm ML squids comprised about 40 percent of the diet.

Local variation in the stomach contents of *S. oualaniensis* has been reported near oceanic islands. Squid captured southwest of Taiwan contained mostly fish, those taken east of Taiwan contained a mixture of fish and squid and around Okinawa they frequently contained crustaceans (Okutani and Tung, 1978). In contrast to a nearly exclusively fish and squid diet in other areas around the Islands (Parry, 2003), mature females captured off the northeastern coast of the island of Hawaii ate mainly crustaceans (Taguchi et al., 1985).

Okutani and Tung (1978) found that the stomach weight (relative to body weight) was higher in the first half of the night. Apparently the primary feeding period of subadults and adults follows their arrival in near-surface waters at night.

Among the 302 specimens of *S. oualaniensis* examined by Parry (2003) in Hawaiian waters, fish and squid comprised virtually the entire diet with fish being more abundant than squid. Stomach contents were analyzed by identifying fish otoliths and squid beaks contained in the stomachs. Among squids, enoploteuthids comprised 17 percent of the diet. Parry (2003) found that while *S. oualaniensis* fed on a subset of the broad diet of adult *O. bartramii* captured in the same waters and that myctophids were the most abundant items in both diets, *S. oualaniensis* is a more specialized predator than *O. bartramii*. For example, *Symbolophorus evermanni* comprised 7.5 percent of the stomach otoliths in *O. bartramii* but 37 percent in *S. oualaniensis*. Even when feeding on the same species of fish, differences in the size of the prey were apparent. Parry concluded that competition between the two squids in Hawaiian waters was low. Parry (2003) examined ∂^{15}N values of *S. oualaniensis* mantle muscle and found that values slowly increased in an exponential fashion with mantle length of the squid from paralarvae at 6.2°/oo to about 8.2°/oo in the larger squid. The curve is $\partial^{15}N=4.208+1.873*1.0037^{ML}$ where ML is in mm, however considerable variability was present. The ∂^{15}N values suggest that *S. oualaniensis* occupies a lower trophic level than *O. bartramii* and supports the conclusion that competition between them is low.

Predators

The distribution of *S. oualaniensis* overlaps with some of its larger close relatives in the same subfamily (Ommastrephinae), *O. bartramii* at the high latitudinal end of *S. oualaniensis*'s distribution and *D. gigas* in the tropical Eastern Pacific. Schetinnikov (1992) in examining the feeding habits of *S. oualaniensis* in the southeastern Pacific found that large *S. oualaniensis* would consume other species of squid up to 40 percent of its own mantle length and, in one region studied, fed heavily on young *D. gigas*. This predator/prey size-relationship suggests that, where their distributions overlap, adult *O. bartramii* and *D. gigas* could be important predators on *S. oualaniensis*. In Parry's (2003) examination of the stomach contents of *S. oualaniensis* and *O. bartramii* he found no evidence for prey/predator interaction between the two species even though he commonly caught both species at the same station. His study dealt almost exclusively with mature *O. bartramii* and possible interaction among paralarvae and juveniles of both species is unknown, although their primary periods of spawning in Hawaiian waters appear to be somewhat out of phase seasonally and spatially.

A variety of studies indicate the presence of *S. oualaniensis* in the stomach of various predators. For example: *S. oualaniensis* made up 0.5 percent of the food items in the stomach and 8.6 percent of the weight (fifth most important) of prey of *Stenella attenuata* near Taiwan (Wang, et al., 2003) with the average size of *S. oualaniensi*s being 210 mm ML; *S. oualaniensis* comprised 11.5 percent by weight of the diet of the dolphinfish, *Coryphaena hippurus* in the eastern tropical Pacific (Olson and Galvan-Magana, 2002); off Baja California, *S. oualaniensis* dominated the food of the swordfish in four of eight studies (Markaida and Sosa-Nishizaki, 1998); *S. oualaniensis* made up 26 percent by weight of the diet of the pigmy sperm whale (*Kogia breviceps*) and 2.2 percent (by weight) of the diet of the dwarf sperm whale (*Kogia sima*) off Taiwan (Wang, et al., 2002); Ashmole and Ashmole (1967) found *S. oualaniensis* in 34-97 percent of the birds examined at Christmas Island (Central Equatorial Pacific); Harrison, et al. (1983) also found juvenile ommastrephid squid (frequently identifiable as *S. oualaniensis*) a common item in the diet of seabirds in the Northwest Hawaiian Islands but somewhat less so than at Christmas Island; Young (1975) reported skipjack tuna, yellowfin tuna, wahoo, probably bigeye tuna, the sooty tern and brown noddy as predators; Wormuth (1976) mentions the snake mackerel, *Gemplus serpens*, among other predators.

Although the evidence is still sketchy, *S. oualaniensis* is probably important in the diet of many, if not most, large fishes, marine mammals and many sea birds that forage within its habitat.

Habitat

S. oualaniensis is a tropical Indopacific species that occurs in the Pacific from southern Japan to southern Queensland and from just south of Baja California to northern Chile (Nesis, 1987). Dunning (1998), records *S. oualaniensis* as far south as 38°40'S (SST 20.7°C), at the northern edge of the Bass Straits, near the coast of Australia. In the Coral Sea Basin (east of 155°E), however, adults were caught only north of 32°S (SSTs>23.5°C). Eastward from the Coral Sea to near the coast of South America Wormuth (1976) records its presence roughly along 20°S to about 110°W then his southern records reach about 15°S but stop about 4° of longitude west of Peru apparently at the edge of the Peru current. In the region of the Hawaiian Archipelago, *S. oualaniensis* did not occur in winter north of 28°N. Between 23°N and 28°N large females were few and of those few most were not mature; the ratio of mature to immature females of squid 200 mm ML or larger was 1:27 during one cruise (Young and Hirota, 1998). This suggests that at the northern end of their range, the females are not maturing normally. Tung et al. (1973) states that Taiwan (which lies roughly between 22 and 25°N) is at “the edge area of the migration sphere of the common squid [*S. oualaniensis*] in the southwest water of Taiwan….” *S. oualaniensis* is recorded off Southern Japan at nearly 35°N (SST 25-26°C) (Saito and Kubodera (1993). Wormuth (1976) recorded the northern limit of distribution at 33.6°N and 165.5°E (September) and about 31°N at 156°W, 139°W and 129°W off Southern California west of the California Current. During the change of seasons the SSTs across most of the Pacific undergo a dramatic north-south movement. For example, north of Hawaii the 18°C isotherm can move from near 30°N in February to over 40°N in August (Laurs and Lynn, 1991). The extent to which the latitudinal limits of the distribution of *S. oualaniensis* change with season are not known but do not appear to be very dramatic.

Status of the Stock

S. oualaniensis has been commercially fished off Okinawa (in the Ryukyu chain), Taiwan and Hawaii. Fishing grounds existed on the southwestern coasts of Taiwan and beyond the 200 m bottom isobath of the Ryukyu chain (Okutani and Tung, 1978). The fishing season in Taiwan is from March to November with a peak in May-August. Fishing was most productive at SSTs of 26°-28°C. The annual landings of squid and cuttlefish in Taiwan and Okinawa from 1947-1969 averaged 325 tons with 70 percent being *S. oualaniensis* (Okutani and Tung, 1978). The *S. oualaniensis* catch is used for tuna bait and for human consumption (Okutani and Tung, 1978). According to Lu (personal communication, 2003) the fishery never was very successful as the squid had low value for human consumption relative to other squid, due to its toughness. He states that at present there is no longer a targeted fishery for *S. oualaniensis* but fishers still take incidental catches of the squid. In Hawaii the fishery began with immigrants from Okinawa that fished off Hilo at night in small boats with handlines; however, it soon became apparent that they could also catch tuna and quickly tuna became the target of the fishery with squid being used as bait for the tuna or as incidental catch (Yuen, 1979). This nighttime handline fishery has become known as the *ika-shibi* (squid-tuna) fishery. Between 1973 and 1975 the annual squid catch varied between 0.5 and 5.0 tons (Yuen, 1979). Between 1976 and 1992 the annual squid landings in Hawaii varied from about 1-12 tons with large year-to-year fluctuations and no clear trends (unpublished data from the Hawaii Division of Aquatic Resources).

The biomass of *S. oualaniensis* standing stock in the South China Sea Area III (west of the Philippines) was estimated from jigging surveys at 283,000 metric tons (Labe, 2000).

Zuev et al. (2002) estimated, based mostly on visual survey methods, the total instantaneous stock size of *S. oualaniensis* at 3-4 million tons (1.9-2.4 million tons for the middle-sized form) and an annual production to biomass ratio for adult squids of 8.0-8.5.

Other Pelagic Cephalopods of the Western Pacific Region

With the exception of Hawaiian waters the pelagic cephalopod species found in the Western Pacific Region are poorly known. In Hawaiian waters there are about 70 species of pelagic cephalopods, most of which are mesopelagic species. There are three additional species of squids in the family Ommastrephidae (*Eucleoteuthis luminosa*, occurring at the northern limits of the Hawaiian EEZ, and *Nototodarus hawaiiensis*, a demersal species found near the islands and *Hyaloteuthis pelagicus*, a small species, less than 100 mm ML. None of the three is common and none are fished commercially. There are three species of *Onychoteuthis* that are rather muscular and presumably edible but they are rather small (less than 200 mm ML) and infrequently encountered. Other squids are mostly very small or weakly muscled and none occur in commercial quantities.

A large pelagic octopod, *Tremoctopus gracilis*, has a muscular mantle but the animal is rare in Hawaiian waters. Another large, muscular octopod, *O. turberculata*, is found north of Hawaiian waters but is occasionally encountered by Hawaiian fishermen targeting *O. bartramii*. Neither of these octopods appears to occur in commercial quantities and neither is fished anywhere in the world.

It can be assumed that a similar cephalopod fauna, although with mostly different but related species, is found in the other areas of the Western Pacific Region. In these latter areas there are also neritic and often demersal cephalopods (loliginid squids and sepiid cuttlefishes) that may be fished for personal consumption.

Because none of these species are domestically targeted or caught commercially, the Council has not considered them for inclusion as PMUS.

3.5 Protected Species

3.5.1 Seabirds

Squid is a primary prey item for albatrosses. The U.S. high-seas jig fishery for red flying squid and foraging habitat for Laysan and black-footed albatrosses are in the same oceanic fronts and transition zone of high biological productivity at latitudes north of Hawaii. Elevated squid concentrations attract these seabirds. Albatrosses feed close to the ocean surface, so are unlikely to be hooked on pointed jigs that are deployed 30-100m below the surface. However, seabirds may perch on the vessel waiting to plunge at squid near the surface, thereby becoming entangled. Depending on their size, seabirds that are accidentally entangled may a) break off the line, b) be pulled over the rollers onto the deck, or c) stop or break loose from the line at the rollers.

Squid jigging has been conducted at night when black-footed albatross are not feeding. Because of the bright lights used on high-seas jig vessels, large vessels may have two above-deck rows with 25-50 (2,000-4,000 watt) lamps per row. Some concerns have been expressed about Laysan albatross (which have better vision and may feed at night) becoming disoriented and colliding with squid vessels. The U.S. vessels recently have been fitted with submerged lights to allow for squid jigging at greater depth during daylight. Submerged lights during daytime squid jigging should not impact albatrosses. Offal discard during onboard processing of squid might also attract seabirds.

Logbooks and anecdotal reports (B. Endreson, pers. comm. 10/03) from limited squid jigging in the North Pacific by four U.S. vessels provide no evidence of any interactions with seabirds.

In the cooperative squid jigging survey conducted by U.S. and Japanese participants in the EEZ off Oregon and Washington in 1990 (June and Wilkins 1991) no birds were observed to be directly affected by the fishing gear or operations.

The AFMA observer program reported that none of the seabirds (1 shy albatross and 2 shorttailed shearwaters) sighted near vessels jigging for squid in southern Australia were observed to interact with either the boats or fishing gear.

Small-boat fishermen use low-wattage surface and underwater lights to attract purpleback squid to lures deployed in coastal fisheries. (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA analyst, WPRFMC, Jan. 7, 2004). There are no reports of hookings or entanglements of seabirds in Hawaii's small-scale jig fisheries (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Jan. 7, 2004).

Albatrosses (Order Procellariiformes, Family Diomedeidae)

Three species of albatross breed and forage in the North Pacific: the short-tailed albatross, the black-footed albatross and the Laysan albatross (Table 9). NMFS observer data show that fishery-seabird interactions occur between the Hawaii-based longline fishery and two species of albatross: the black-footed albatross and the Laysan albatross. Neither the black-footed albatross nor the Laysan albatross are listed as endangered under ESA. Under the World Conservation Union (IUCN), the black-footed albatross is listed as "endangered" and the Laysan albatross as "vulnerable." The short-tailed albatross is listed as endangered under ESA and is considered "vulnerable" under IUCN. There have been no reports of interactions between the short-tailed albatross and the Hawaii-based longline fishery.

Short-tailed Albatross (*Phoebastria albatrus*)
The short-tailed albatross is the largest seabird in the North Pacific with a wingspan of more than 3 meters (9 ft) in length. The short-tailed albatross is known to breed only in the western North Pacific Ocean, south of the main islands of Japan. Although at one time there may have been more than ten breeding locations (Hasegawa 1979), today there are only two known active breeding colonies, Minami Tori Shima Island ("Torishima") (30º29′N, 140º19′E) and Minami-Kojima Island (25°56′N, 123°42′E).

A few short-tailed albatrosses have also been observed attempting to breed, although unsuccessfully, at Midway Atoll National Wildlife in the NWHI. Midway lies roughly 1,750 miles east and slightly to the north of Torishima. It is unknown if short-tailed albatrosses historically bred in the NWHI. Visits to the NWHI by short-tailed albatrosses were first recorded on Midway in 1938, when a female was seen incubating an infertile egg (Haden, 1941; Munro, 1944). Sighting and banding records show that between 1938 and 2003, at the most, 22 short-tailed albatrosses visited the NWHI, with only one or two sighted on the same island at any one time. The first time two short-tailed albatrosses were known to be present on Midway at the same time, although located at different locations, occurred in February 1981. One female, has returned to Midway in most years since 1988, and has laid a total of four infertile eggs.

Today, the breeding population of the short-tailed albatross is estimated at approximately 326 breeding pairs: 276 pairs on Torishima and 50 pairs on Minami-Kojima The short-tailed albatross have an annual survival rate of 96 percent and a population growth rate of 7.8 percent (65 FR 46643, July 31, 2000; Hasegawa, 1997). Because of the robust growth of the population at Torishima, and the fact that short-tailed albatrosses do not return to the colony until three or four years of age, a large number of these birds are dispersed at sea. At least 25 percent of the reproducing adults also remain at sea during each breeding season (Cochrane and Starfield, 1999). As a consequence, the exact number of individuals in the population is difficult to assess and at this time is unknown. The population size has been estimated at about 1,900 (P. Sievert, pers. comm.).

Black-footed Albatross (Phoebastria nigripes)
The NWHI contain the primary breeding colonies of the black-footed albatross population. A comparatively smaller population estimated at about 11,000 black-footed albatrosses breed on Torishima (P. Sievert, pers.comm.). Although the at-sea distributions of Hawaiian and Japanese black-footed albatrosses overlap both in the western Pacific and around the NWHI, these two populations have been reproductively separated (genetically distinct units) for no more than three quarters of a million years (Walsh and Edwards, in review).

Discriptively, the black-footed albatross has a dark bill, legs and feet at all stages of their development. The black-footed albatross is slightly larger and heavier than the Laysan albatross, (Harrison et al., 1983; Whittow, pers. comm.). Black-footed and Laysan albatrosses range throughout the North Pacific between 20°N and 58°N. Knowledge of their distribution comes primarily from reports of encounters with banded birds, from scientific transects, and from observations. A few birds have been tracked over long distances by satellites (Anderson and Fernandez, 1998). Researchers used satellite telemetry to study the movements of a male black-footed albatross during its pelagic travels off the coast of California (Hyrenbach and Dotson, 2001). This albatross covered a distance of 5,067 km during 35 days, and moved over a broad range of ocean water temperatures (22–15°C). The rate of movement of the tracked albatross varied significantly during different periods of the day, and was influenced by ambient light levels during the night (Hyrenback and Dotson, 2001). The black-footed albatross occurs regularly in large numbers off the west coast of Canada and the United States and off the East Coast of Japan.

The most recent estimate of the world population of breeding black-footed albatrosses is 327,753 individuals, with 58,898 breeding pairs in 12 colonies. Nine of the colonies are located in the NWHI comprising the majority of the breeding population.

Seventy-five percent of the NWHI breeding pairs nest in three colonies that are routinely surveyed by the USFWS: Laysan Island, Midway Atoll and French Frigate Shoals (Figure 6). The two largest black-footed albatross colonies accounting for approximately 70 percent of world population are on Midway Atoll and Laysan Island. French Frigate Shoals accounts for about 6 percent of the world population.

Three black-footed albatross colonies are also located in the Western Pacific (estimated 3,123 breeding pairs) accounting for 5 percent of the world population. On, Torishima, six black-footed albatross chicks were successfully reared in 1957, and since then the number of chicks reared has increased from 914 in 1998, to 1,170 in 2003 (H. Hasegawa, unpubl. data). The black-footed albatross populations on Bonin and Senkaku Islands have also modestly increased.

Harrison (1990) reports that in the early 1980s, black-footed albatross populations in the NWHI ranged from 36,240 to 49,410 nesting pairs, or taking the average, about 43,000 pairs. The most recent nesting population estimate for the NWHI is about 55,775 nesting pairs (NMFS 2004). The difference represents an increase of 12,775 nesting pairs or an increase of 30 percent over this time period. Midway's black-footed albatross population has increased to over 20,000 nesting pairs, from a population in the early 1980s of 6,500-7,500 nesters - an increase of 300 percent in less than two decades. Using an even more conservative estimate from the early 1960s of 7,000 pairs (Robbins 1961) indicates a tripling of the black-footed albatross population size over the past 40 years. The Midway nesting population of black-footed albatrosses in 2005 amounted to 21,829 nesting pairs, or a 7 percent increase on the 2004 total (USFWS 2005) Similarly, both the black-footed albatross nesting populations at French Frigate Shoals and Laysan Island in 2003 appeared to be at the high end of the population sizes observed in the early 1980s (Harrison 1990). In addition, the overall increase of black-footed albatross nesting pairs in the NWHI increased by 7.2 percent between 2001 and 2003 (USFWS 2004b). The most recent information indicates that NWHI nesting numbers have remained stable since 1991(USFWS 2005). Taken together, these observations strongly suggest either an increasing population, or at worst, a stable population.

Similarly, at sea counts of black-footed albatrosses off the California coast show an upward trend from 1994 to 2002, with some of the highest numbers observed in 2000 and 2001. The increasing trend in apparent albatross abundance off the California coast appears to be related to oceanographic phenomena such as El Niños, and the Pacific Decadal Oscillation (PDO) to a cold PDO (Larry Spear personal communication).

Laysan Albatross (Phoebastria immutabilis)
Laysan albatrosses are characterized by white plumage on their head, neck and chest, and sooty brown plumage on their upper wings, back and tail. The most recent estimate of the Laysan albatross population is 3.4 million individuals, with 623,622 breeding pairs in 15 colonies (Table 9). Twelve of the colonies are located in the NWHI comprising of the majority of the breeding population (623,495 breeding pairs). The largest Laysan albatross colony (71 percent of the world population) is on Midway Atoll (Figure 7). A complete direct nest count on Midway Atoll in 2003 found that the number of nesting pairs of Laysan Albatrosses had increased by 53.9 percent since 2001 (USFWS 2004b). The most recent census in 2004 showed that the number of nesting pairs was still elevated but had declined by 7.5 percent as compared to the previous year (USFWS 2005). Laysan Island has the second largest colony (22 percent of the world population). The most recent information indicates that NWHI nesting numbers for these populations remain stable (USFWS 2005). Taken together, therefore, these observations suggest either an increasing population or at worst a stable population. A Laysan albatross colony located on Bonin Island is comprised of 14 breeding pairs while three other colonies (with a total of 113 breeding pairs) are located in the Eastern Pacific on Guadelupe (Dunlap, 1988), the San Benedicto Islands, and Isla Clarion, Mexico (Howell and Webb, 1992). Since 1998, there have been no reports of visitations by Laysan albatrosses to Johnston Atoll or to Marcus Island (E. Flint, pers. comm.). More Laysan sightings are being reported on the California coast, perhaps due to the colony in Mexico. It is unknown at this time if the colony is growing due to juvenile recruitment or to immigration from other colonies. The great majority of pelagic encounters of Laysan albatross have come from west of the 180° meridian (Robbins and Rice, 1974).

Shearwaters (Order Procellariiformes, Family Procellariidae)
Three species of shearwaters breed in the Hawaiian Islands. These are the wedge-tailed shearwater (*P. pacificus*), Christmas shearwater (*P. nativitatis*) and the Newell's shearwater (*P. auricularis newelli*). A fourth shearwater, the short-tailed shearwater (*P. tenuirostris*), breeds in Australia but migrates to foraging areas at Kotzebue Sound which is north of the Arctic Circle in Alaska. Short-tailed shearwaters may be present in Hawaiian waters between September and May during their annual migration.

The Newell's shearwater is listed as threatened under the U.S. Endangered Species Act and is considered vulnerable by the IUCN. The Newell's shearwater has been given this conservation status because of its small population size, approximately 14,600 breeding pairs, their isolated breeding colonies, and the numerous hazards affecting them at their breeding colonies including urban development and introduced predators like rats, cats, dogs and mongoose (Ainley et al., 1997). The conservation status of the Christmas shearwater to date is unknown. Harrison (1990) estimated that there were approximately 3,100 Christmas shearwaters nesting in the Hawaiian Islands in the late 1980s. Given that the Hawaiian Islands are at the species most northern boundary, it is possible that the Christmas shearwater population is more abundant near breeding colonies located in the mid- and South Pacific. The wedge-tailed shearwater is one of the most abundant seabirds in the Hawaiian Islands with an estimated 1,330,000 birds (Harrison, 1990). Worldwide there is an estimated 5.2 million wedge-tailed shearwaters (Whittow, 1997).

Newell's Shearwater (P. auricularis newelli)
The Newell's shearwater was listed as a threatened species under the ESA on September 25, 1975 (40 FR 44149). The Newell's shearwater breeds only in colonies on the main Hawaiian Islands, such as on Molokai, Hawaii, and mainly on Kauai (Pratt et al., 1987; Harrison, 1990; Reynolds et al., 1997a,b). The Newell's shearwater (*P. auricularis newelli*) was once widespread in the main Hawaiian Islands, but is reduced to a few remnant breeding colonies because of urbanization and predation by introduced mammals.

The Newell's shearwater is highly pelagic, occurring year-round in the tropical and subtropical waters mostly to the east and south of the Hawaiian Islands (Ainley et al., 1997). The bird especially frequents the Equatorial Countercurrent, from near the portion of the equator lying south of the Hawaiian Islands east to about 120°W and north to and around the main Hawaiian Islands (22°N). Isolated sightings of Newell's shearwater are recorded from central and south Pacific, west to the Commonwealth of the Northern Mariana Islands and Guam, Wake Island, and Johnston Atoll (King and Gould, 1967; Pratt et al., 1987), and south to the Marquesas Islands and Samoa (Pratt et al., 1987; Grant et al., 1994; Spear et al., 1995).

For unknown reasons, fledglings are attracted to lights which can lead to mortality in urban settings (Reed et al., 1985). The annual adult survivorship of a Newell's shearwater is estimated to be about 90 percent (Ainley et al., 1997).

Wedge-tailed Shearwater (P. pacificus)
The wedge-tailed shearwater is one of the largest of the tropical shearwters with an overall length of 43 cm, and body mass of 390 g (Whittow, 1997). The bird has grayish brown plumage on its back and white on its belly and underparts except for dark edge to the wings and dark undertail coverts.

The wedge-tailed shearwater has migratory behaviors. From September to November, large flocks of the species gather offshore before migrating near the Hawaiian Islands (King, 1974). Often during this period there may be rafts of birds with up to 700 individuals. The wedge-tailed shearwater breeds between February and November in the Northern Hemisphere and August and October to May and June in the Southern Hemisphere.

The wedge-tailed shearwater breeds from Kure Island in the NWHI to Maui Island in the main Hawaiian Islands (Ainley et al., 1997). The wedge-tailed shearwater also breeds on other islands spread throughout the Northeast and South Pacific, including Johnston Atoll and Christmas, Bonin, Volcano, Marshall, and Caroline Islands, and the Indian Ocean where it is known to breed as far west as Madagascar (Whittow, 1997).

Christmas Shearwater (Puffinus nativitatis)
Christmas shearwaters are slender-bodied with a length of 35-38 cm and body mass of 354 g. (Harrison,1983). Their plumage is dark brown with their underparts being lighter than their upperparts. The Christmas shearwater breeds primarily in the tropical Pacific ranging as far north as the Hawaiian Islands to as far south as Easter Island (Harrison, 1996). Breeding adults return to the NWHI from early to late February (Naughton, 1982). A breeding pair will occupy a nest site in early to late March (Seto, 2001). Chicks fledge between September and October on Midway Atoll The oldest record of a banded Christmas shearwater was 17 years on Laysan Island (K. Swift in Seto, 2001).

Boobies (Order Pelecaniformes, Family Sulidae)
Three species of boobies also breed in the NWHI and forage in the North Pacific: the masked booby (*Sula dactylatra*), the brown booby (*Sula leucogaster*) and the red-footed booby *(Sula sula*). Currently, the World Conservation Union classifies boobies as "not globally threatened."

Boobies breed throughout the Hawaiian Archipelago, and three localities have been routinely monitored by the USFWS in Honolulu). Harrison (1990) reported breeding pair numbers from surveys of booby colonies completed between 1981 and 1988. From the surveys completed in the 1980s, it was estimated that there were about 14,000 masked boobies, 1,500 brown boobies and 11,000 red-footed boobies (Harrison, 1990).

3.5.2 Sea Turtles

All sea turtles are designated under the ESA as either threatened or endangered. The breeding populations of the Mexico olive ridley turtles (*Lepidochelys olivacea*) are currently listed as endangered. Also listed as endangered are the leatherback turtles (*Dermochelys coriacea*) and hawksbill turtles (*Eretmochelys imbricata*). Green sea turtles (*Chelonia mydas*) and loggerhead turtles (*Caretta caretta*) are listed as threatened, but are afforded the same protection as endangered sea turtles. These five species of sea turtle are highly migratory, or have a highly migratory phase in their life history, and therefore, are susceptible to being incidentally caught by longline fisheries operating in the Pacific Ocean.

The populations of several species of sea turtles have declined in the Pacific as the result of nesting habitat loss and excessive and widespread harvesting for commercial and subsistence purposes (Eckert 1993). Leatherback and loggerhead turtles are the species of principal concern with regard to incidental take in Pacific pelagic longline fisheries. These fisheries are conducted mainly by Japan, Taiwan, Korea and the U.S. There are only two populations of loggerhead turtles in the Pacific, one originating in Australia where serious declines are occurring, and the other in southern Japan (Eckert 1993). Leatherback turtles inhabiting the Pacific mainly originate from nesting beaches in Mexico and Costa Rica where significant declines have been documented; from Indonesia where their status is uncertain but possibly stable; and from Malaysia where the nesting colony is nearly extinct despite 30 years of conservation measures (Eckert 1993).

The diet of the leatherback turtle generally consists of cnidarians (i.e., medusae and siphonophores) in the pelagic environment. Leatherback turtles have the most extensive range of any living reptile and have been reported circumglobally from latitudes 71° N. to 42° S. in the Pacific and in all other major oceans. In a single year a leatherback may swim more than 10,000 km. They lead a completely pelagic existence, foraging widely in temperate waters except during the nesting season, when gravid females return to beaches to lay eggs. Typically leatherback turtles are found in convergence zones and upwelling areas in the open ocean, along continental margins, and in archipelagic waters. Hawaii fishers in offshore waters commonly see leatherback turtles, generally beyond the 100 fm curve but within sight of land. Two areas where sightings often take place are off the north coast of Oahu and the west coast of the Island of Hawaii. The pelagic zone surrounding the Hawaiian Islands is apparently regularly used as foraging habitat and migratory pathways for this species. Further to the north of the Hawaiian islands, a high seas aggregation of leatherback turtles is known to occur at 35° N. latitude, between 175° W. and 180° longitudes (NMFS, 1991).

The loggerhead turtle is listed as a threatened species throughout its range, primarily due to incidental mortality associated with commercial fishing operations and the alteration and destruction of its habitat. It is a cosmopolitan species found in temperate and subtropical waters and inhabiting continental shelves, bays, estuaries and lagoons. Major nesting grounds are generally located in warm temperate and subtropical regions, generally north of 25° N. or south of 25° S. latitude in the Pacific Ocean. For their first several years of life, loggerheads forage in open ocean pelagic habitats. Both juvenile and subadult loggerheads feed on pelagic crustaceans, mollusks, fish, and algae. As they age, loggerheads begin to move into shallower waters, where, as adults, they forage over a variety of benthic hard- and soft-bottom habitats (reviewed in Dodd, 1988). Satellite telemetry studies show that loggerhead turtles tend to follow 17° and 20° C sea surface isotherms north of the Hawaiian islands.

The olive ridley turtle is listed as threatened in the Pacific, except for the Mexican nesting population, which is listed as endangered, primarily because of over-harvesting of females and eggs. The olive ridley is one of the smallest living sea turtles (carapace length usually between 60 and 70 cm) and is regarded as the most abundant sea turtle in the world. Since the directed take of sea turtles was stopped in the early 1990s, the nesting populations in Mexico appear to be recovering, with females nesting in record numbers in recent years. In 1996, the primary nesting beach at La Escobilla in Oaxaca sustained over 800,000 nests. There is some discussion in Mexico that the species should be considered recovered. The olive ridley turtle is omnivorous and identified prey include a variety of benthic and pelagic items such as shrimp, jellyfish, crabs, snails, and fish, as well as algae and sea grass (Marquez, 1990).

Green turtles in Hawaii are genetically distinct and geographically isolated which is uncharacteristic of other regional sea turtle populations. Both the nesting population and foraging populations of green turtles in Hawaii appear to have increased over the last 30 years. Balazs and Chaloupka (2004) document a substantial long-term increase in abundance of the once seriously depleted green sea turtle stock in Hawaii. This population increase has occurred in a far shorter period of time than previously thought possible. Most green turtles appear to have a nearly exclusive herbivorous diet, consisting primarily of sea grass and algae (Wetherall et al, 1993; Hirth, 1997), those by the eastern pacific coast appear to have a more carnivorous diet.

The hawksbill turtle is listed as endangered throughout its range. In the Pacific, this species is apparently declining due to the harvesting of the species for its meat, eggs and shell, as well as the destruction of nesting habitat by human occupation and disruption. There are no reports of interactions between this species and the Hawaii-based longline fishery, although the potential for interaction exists. Hawksbill turtles have a relatively unique diet of sponges.

3.5.3 Marine Mammals

Based on research, observer, and logbook data, the following marine mammals occur in the region and may be affected by the fisheries managed under the Pelagics FMP:

Marine mammals listed as threatened or endangered:

Humpback whale (Megaptera novaeangliae)
Sperm whale (Physeter macrocephalus)
Hawaiian monk seal (*Monachus schauinslandi*)
Blue whale (Balaenoptera musculus)
Fin whale (Balaenoptera physalus)
Northern right whale (*Eubalaena glacialis*)
Sei whale (Balaenoptera borealis)

Other marine mammals:

Rough-toothed dolphin (*Steno bredanensis*)
Risso’s dolphin (*Grampus griseus*)
Bottlenose dolphin (*Tursiops truncatus*)
Pantropical spotted dolphin (*Stenella attenuata*)
Spinner dolphin (Stenella longirostris)
Striped dolphin (Stenella coeruleoalba)
Melon-headed whale (*Peponocephala electra*)
Pygmy killer whale (*Feresa attenuata*)
False killer whale (*Pseudorca crassidens*)
Killer whale (*Orcinus orca*)
Pilot whale, short-finned (*Globicephala melas*)
Blainville’s beaked whale (*Mesoplodon densirostris*)
Cuvier’s beached whale (*Ziphius cavirostris*)

Pygmy sperm whale (*Kogia breviceps*)
Dwarf sperm whale (*Kogia simus*)
Bryde's whale (Balaenoptera edeni)

Although blue whales, fin whales, northern right whales, and sei whales are found within the area and could potentially interact with the Pelagics FMP fisheries, there have been no reported or observed incidental takes of these species in these fisheries. Therefore, these species are not discussed in this document.

Humpback whales

The International Whaling Commission first protected humpback whales in the North Pacific in 1965. Humpback whales were listed as endangered under the ESA in 1973. They are also protected by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) and the MMPA. Critical habitat has not been designated for this species.

Humpback whales typically migrate between tropical/sub-tropical and temperate/polar latitudes. Humpback whales feed on krill and small schooling fish on their summer grounds. The whales occupy tropical areas during winter months when they are breeding and calving, and polar areas during the spring, summer, and fall, when they are feeding, primarily on small schooling fish and krill (Caldwell and Caldwell, 1983).

Humpback whales occur off all eight Hawaiian Islands during the winter breeding season, but particularly within the shallow waters of the "four-island" region (Kaho'olawe, Molokai, Lanai, and Maui), the northwestern coast of the island of Hawaii (Big Island), and the waters around Niihau, Kauai and Oahu (Wolman and Jurasz, 1977; Herman et al., 1980; Baker and Herman, 1981).

Estimates of the number of individuals in the Northern Pacific stock have recently risen. Estimates in the 1980s ranged from 1,407 to 2,100 (Baker, 1985; Darling and Morowitz, 1986; Baker and Herman, 1981), while recent estimates of abundances were approximately 6,000 (Calambokidis et al., 1997; Mobley et al., 1999).

Studies based on resighting individuals through photographs resulted in an estimate of 6,010 animals (S.E. = 474) for the entire North Pacific (Calambokidis et al., 1997). The central North Pacific stock of humpback whales winters in the waters of the main Hawaiian Islands and feeds on the summer grounds of Southeast Alaska and Prince William Sound. A population estimate of 1,407 whales was derived using capture-recapture methodology (95 percent CI 1,113 - 1,701) for data collected in 1980-83 (Baker and Herman, 1987).

Cerchio (1998) estimated that about 4,000 animals visit Hawaii annually. Aerial surveys conducted between 1976 and 1990 found a significant increase in sighting rates of humpbacks over that time (Mobley et al., 1999), consistent with the increase in photographic estimates. Finally, aerial surveys using line-transect methodologies were conducted in 1993, 1995 and 1998. Hawaii population estimates for nearshore waters derived from the sighting data show an increase from 2,717 (+/- 608) in 1993, to 3,284 (+/- 646) in 1995 and 3,852 (+/- 777) in 1998 (Mobley et al., 1999).

Sperm whales

Sperm whales have been protected from commercial harvest by the IWC since 1981, although the Japanese continued to harvest sperm whales in the North Pacific until 1988 (Reeves and Whitehead 1997). Sperm whales were listed as endangered under the ESA in 1973. They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the Marine Mammal Protection Act of 1972. Critical habitat has not been designated for sperm whales.

Sperm whales are distributed in all of the world's oceans. Several authors have recommended three or more stocks of sperm whales in the North Pacific for management purposes (Kasuya 1991, Bannister and Mitchell 1980). However, the IWC's Scientific Committee designated two sperm whale stocks in the North Pacific: a western and eastern stock (Donovan 1991). The line separating these stocks has been debated since their acceptance by the IWC's Scientific Committee. For stock assessment purposes, NMFS recognizes three discrete population "centers" of sperm whales: (1) Alaska, (2) California/Oregon/Washington, and (3) Hawaii.

A 1997 survey to investigate sperm whale stock structure and abundance in the eastern temperate North Pacific area did not detect a seasonal distribution pattern between the U S EEZ waters off California and areas farther west, out to Hawaii (Forney et al., 2000). A 1997 survey, which combined visual and acoustic line-transect methods, resulted in estimates of 24,000 (CV=0.46) sperm whales based on visual sightings, and 39,200 sperm whales (CV=0.60) based on acoustic detections and visual group size estimates (Forney et al., 2000). An analysis for the eastern tropical Pacific estimates abundance at 22,700 sperm whales (95 percent C. I. = 14,800-34,000; Forney et al., 2000).

Sperm whales have been sighted in the Kauai Channel, the Alenuihaha Channel between Maui and the island of Hawaii, and off the island of Hawaii (Mobley, et al.1999, Forney et al., 2000). Additionally, the sounds of sperm whales have been recorded throughout the year off Oahu (Thompson and Friedl 1982). Twenty-one sperm whales were sighted during aerial surveys conducted in nearshore Hawaiian waters conducted from 1993 through 1998. Sperm whales sighted during the survey tended to be on the outer edge of a 50 - 70 km distance from the Hawaiian Islands, indicating that presence may increase with distance from shore (Mobley, pers.comm. 2000). However, from the results of these surveys, NMFS has calculated a minimum abundance of sperm whales within 46 km of Hawaii to be 43 individuals (Forney et al., 2000).

Hawaiian monk seals

The Hawaiian monk seal was listed as endangered under the ESA in 1976. The species is endemic to the Hawaiian Archipelago and Johnston Atoll, and is one of the most endangered marine mammals in the United States. It is also the only endangered marine mammal that exists wholly within the jurisdiction of the United States.

Monks seals are one of the most primitive genera of seals. They are non-migratory, but recent studies show that their home ranges may be extensive (Abernathy and Sniff, 1998). Counts of individuals or shore compared with enumerated subpopulations at some of the NWHI indicate that monk seals spend about one-third of their time on land and about two thirds in the water. (Forney et al. 2000)

Before human habitation of the Hawaiian Archipelago, the monk seal population may have measured in the tens of thousands as opposed to the hundreds of thousands or millions typical of some pinniped species. When population measurements were first taken in the 1950s, the population was already considered to be in a state of decline. In 1998, minimum population estimate for monk seals was 1,436 individuals (based on enumeration of individuals of all age classes at each of the subpopulations in the NWHI, derived estimates based on beach counts for Nihoa and Necker, and estimates for the MHI) (Forney et al., 2001). Taking into account the first year survival rates, NMFS Southwest Fisheries Science Center - Honolulu Laboratory estimated the species population size to be between 1,300 and 1,400 individuals (Laurs, 2000). Monk seals are found at six main reproductive sites in the NWHI: Kure Atoll, Midway Island, Pearl and Hermes Reef, Lisianski Island, Laysan Island and French Frigate Shoals. Smaller populations also occur on Necker Island, and Nihoa Island. NMFS researchers have also observed monk seals at Gardner Pinnacles and Maro Reef. Monk seals are also increasingly found in the MHI (including Niihau), where preliminary surveys have counted more than 50 individuals. Additional sightings and at least one birth have occurred at Johnston Atoll, excluding eleven adult males that were translocated to Johnston Atoll (nine from Laysan Island and two from French Frigate Shoals) over the past 30 years.

Population trends for monk seals are determined by the highly variable dynamics of the six main reproductive subpopulations. At the species level, demographic trends over the past decade have been driven primarily by the dynamics of the French Frigate Shoals subpopulation, where the largest monk seal population is experiencing an unstable age distribution resulting in an inverted age structure. This age structure indicates that recruitment of females and pup production may soon decrease. In the near future, total population trends for the species will likely depend on the balance between continued losses at French Frigate Shoals and gains at other breeding locations including the Main Hawaiian Islands.

There was some evidence in the early 1990s that longline operations were adversely affecting the Hawaiian monk seals, as indicated by the sighting of a few animals with hooks and other non-natural injuries. In 1991, Amendment 3 established a permanent 50-mile Protected Species Zone around the NWHI that is closed to longline fishing. Since 1993, no interactions with Hawaiian monk seals in the pelagic longline fishery have been reported.

Delphinids

The Pacific white-sided dolphin is found throughout the temperate North Pacific (Hill and DeMaster, 1999). Two stocks of this species are recognized, but the stock structure throughout the North Pacific is poorly defined. Population trends and status of the Central North

Pacificstock of Pacific white-sided dolphins relative to the optimum sustainable population are currently unknown (Hill and DeMaster, 1999).

The rough-toothed dolphin's distribution is worldwide in oceanic tropical and warm temperate waters (Miyazaki and Perrin, 1994). They have been sighted northeast of the Northern Mariana Islands during winter (Reeves *et al.*, 1999). Rough-toothed dolphins are also found in the waters off the Main Hawaiian islands (Shallenberger, 1981) and have been observed at least as far north as French Frigate Shoals in the Northwestern Hawaiian Islands (Nitta and Henderson, 1993). The stock structure for this species in the North Pacific is unknown (Forney *et al.*, 2000). The status of rough-toothed dolphins in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Risso's dolphins are found in tropical to warm-temperate waters worldwide (Kruse *et al.*, 1999) but appear to be rare in the waters around Hawaii. There have been four reported strandings of Risso's dolphins on the Main Hawaiian Islands (Nitta, 1991). Risso's dolphins have also been sighted near Guam and the Northern Mariana Islands (Reeves *et al.*, 1999). Nothing is known about stock structure for this species in the North Pacific (Forney *et al.*, 2000). The status of Risso's dolphins in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Bottlenose dolphins are widely distributed throughout the world in tropical and warm-temperate waters (Reeves *et al.*, 1999). The species is primarily coastal, but there are also populations in offshore waters. Bottlenose dolphins are common throughout the Hawaiian Islands (Shallenberger, 1981). Data suggest that the bottlenose dolphins in Hawaii belong to a separate stock from those in the eastern tropical Pacific (Scott and Chivers, 1990). The status of bottlenose dolphins in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

As its name implies, the pantropical spotted dolphin has a pantropical distribution in both coastal and oceanic waters (Perris and Hohn, 1994). Pantropical spotted dolphins are common in Hawaii, primarily on the lee sides of the islands and in the inter-island channels (Shallenberger, 1981). They are also considered common in American Samoa (Reeves *et al.*, 1999). Morphological differences and distribution patterns have been used to establish that the spotted dolphins around Hawaii belong to a stock that is distinct from those in the eastern tropical Pacific (Dizon *et al.*, 1994). The status of pantropical dolphins in Hawaii waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Spinner dolphins are the cetaceans most likely to be seen around oceanic islands throughout the Pacific and are also seen in pelagic areas far from land (Perrin and Gilpatrick, 1994). This species is common around American Samoa (Reeves *et al.* 1999). There is some suggestion of a large, relatively stable resident population surrounding the island of Hawaii (Norris *et al.*, 1994). Spinner dolphins are among the most abundant cetaceans in Hawaii's waters. However, the status of spinner dolphins in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The striped dolphin occurs in tropical and warm temperate waters worldwide (Perrin *et al.*, 1994). Several sightings were made in winter to the north and west of the Northern Mariana Islands (Reeves *et al.*, 1999). In Hawaii, striped dolphins have been reported stranded 13 times between the years of 1936-1996 (Nitta, 1991), yet there have been only two at-sea sightings of this species (Shallenberger, 1981). Striped dolphin population estimates are available for the waters around Japan and in the eastern tropical Pacific, but it is not known whether any of these animals are part of the same population that occurs in Hawaii (Forney *et al.*, 2000). The status of striped dolphins in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Whales

The pygmy killer whale has a circumglobal distribution in tropical and subtropical waters (Ross and Leatherwood, 1994). They have been observed several times off the lee shore of Oahu (Pryor *et al.*, 1965), and Nitta (1991) documented five strandings on Maui and the island of Hawaii. According to the MMPA stock assessment reports, there is a single Pacific management stock (Forney *et al.*, 2000). The status of pygmy killer whales in Hawaii waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

False killer whales occur in tropical, subtropical and warm temperate seas worldwide (Stacey *et al.*, 1994). This species occurs around the Main Hawaiian Islands, but its presence around the Northwestern Hawaiian Islands has not yet been established (Nitta and Henderson, 1993). For the MMPA stock assessment reports, there is a single Pacific management stock (Forney *et al.*, 2000). The status of false killer whales in Hawaii waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The killer whale has a cosmopolitan distribution (Reeves *et al.* 1999). Observations from Japanese whaling or whale sighting vessels indicate large concentrations of these whales north of the Northern Mariana Islands and near Samoa (Reeves *et al.* 1999). Killer whales are rare in Hawaii's waters. There have been two reported sightings of killer whales, one off the Waianae coast of Oahu, and the other near Kauai (Shallenberger, 1981). Except in the northeastern Pacific, little is known about stock structure of killer whales in the North Pacific (Forney *et al.*, 2000). The status of killer whales in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The melon-headed whale has a circumglobal, tropical to subtropical distribution (Perryman *et al.*, 1994). Large herds of this species are seen regularly in Hawaii's waters (Shallenberger, 1981). Strandings of melon-headed whales have been reported in Guam (Reeves *et al.* 1999). For the MMPA stock assessment reports, there is a single Pacific management stock (Forney *et al.*, 2000). The status of melon-headed whales in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The short-finned pilot whale ranges throughout tropical and warm temperate waters in all the oceans, often in sizable herds (Reeves *et al.*, 1999). It is one of the most frequently observed cetaceans around Guam (Reeves *et al.*, 1999). Short-finned pilot whales are commonly observed around the Main Hawaiian Islands, and are probably present around the Northwestern Hawaiian Islands (Shallenberger, 1981). Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in the waters around Japan (Forney *et al.*, 2000). The status of short-finned whales in Hawaii's waters relative to their optimum sustainable population is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Bryde's whales have a pantropical distribution and are common in much of the tropical Pacific (Reeves *et al.*, 1999). Shallenberger (1981) reported a sighting of a Bryde's whale southeast of Nihoa in 1977. Available evidence provides no biological basis for defining separate stocks of Bryde's whales in the central North Pacific (Forney *et al.*, 2000). The status of Bryde's whales in Hawaii waters relative to their optimum sustainable populations is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The Blainsville's beaked whale has a cosmopolitan distribution in tropical and temperate waters (Mead, 1989). Sixteen sightings of this species were reported from the Main Hawaiian Islands by Shallenberger (1981). Cuvier's beaked whale probably occurs in deep waters throughout much of the tropical and subtropical Pacific (Heyning, 1989). Strandings of this species have been reported in the Main and Northwestern Hawaiian Islands (Nitta, 1991; Shallenberger, 1981). There is no information on stock structure of the Blainsville's beaked whale or Cuvier's beaked whale. The status of Blainsville's beaked whales and Cuvier's beaked whales in Hawaii's waters relative to their optimum sustainable populations is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

The pygmy sperm whale is likely to occur all year in many parts of the tropical and subtropical Pacific (Caldwell and Caldwell, 1989). There have been at least nine reported strandings of this species in the Hawaiian Islands (Nitta, 1991). The dwarf sperm whale is rarely observed at sea in most areas, but is apparently abundant in some (Nagorsen, 1985). Its distribution, as inferred mainly from strandings, is worldwide in tropical and temperate waters. There have been two strandings of this species in the Hawaiian Islands (Nitta, 1991). The status of pygmy sperm whales and dwarf sperm whales in Hawaii's waters relative to their optimum sustainable populations is unknown, and there are insufficient data to evaluate trends in abundance (Forney *et al.*, 2000).

Pinnipeds

Northern fur seals and northern elephant seals commonly migrate into the northeastern portion of the historic Hawaii-based fishing zone (Bigg, 1990; Stewart and DeLong, 1995). Both species may occur in this region anytime of the year, but there are periods when the probability of their presence is greatest, especially for certain age and sex groups. Juvenile northern fur seals of both sexes are believed primarily to occur in the region during the fall, early winter and early summer (Bigg, 1990). Northern elephant seal adult females also migrate into the area twice a year, returning briefly to land to breed in the winter and molt in the spring (Stewart and Delong, 1995). The eastern Pacific stock of the northern fur seal is classified as a strategic stock because it is designated as depleted under the MMPA (Hill and DeMaster, 1999). A review of elephant seal population dynamics through 1991 concluded that the status of this species could not be determined with certainty, but that these animals might be within their optimal sustainable population range (Barlow *et al.*, 1993).

3.6 Fisheries

The description of the environment provided here focuses on pelagic fisheries that could be potentially affected by the proposed actions. These fisheries include the ika shibi component of the Hawaii pelagic handline fishery, and the domestic squid jigging and Hawaii near-shore squid fisheries

3.6.1 Squid Fisheries

The domestic fisheries potentially affected by the proposed action can be separated into two distinct categories based on the location of the fisheries and target species. One category consists of the incipient domestic distant-water squid jigging fishery occurring in various areas of the Pacific Ocean. This fishery typically occurs outside the U.S. EEZ, and the major target species include *O. bartramii*. A description of the distant-water fishery is presented in section 3.7.3.2. The second category of fisheries potentially affected by the proposed action includes the long-established ika shibi component of the Hawaii pelagic handline fishery, in which squid are caught and used as tuna bait, and a small artisanal fishery in Hawaii that mainly captures squid for human consumption. These fisheries occur in the U.S. EEZ or state waters around the Main Hawaiian Islands and mainly target *S. oualaniensis*. A description of the ika shibi portion of the Hawaii pelagic handline fishery is provided in section 3.7.3.3, while the artisanal directed squid fishery is described in section 3.7.3.4.

There are no directed commercial squid fisheries in any sub-region of the Western Pacific Region other than Hawaii (although small amounts of squid may occasionally be sold in local markets in Guam, American Samoa and the Northern Mariana Islands). It is possible that squid are sometimes caught for personal consumption in Guam, American Samoa and the Northern Mariana Islands, but no data on the subsistence catch in these islands are available. The only sub-region in the Western Pacific Region in which the ika shibi style of fishing is widely practiced is Hawaii. While early experiments with ika shibi fishing in Guam showed promise (Amesbury and Meyers, 2001), it is a rarely used method of catching pelagic species in the Territory (Meyers, 1993). Similarly, exploratory ika shibi fishing was conducted in the Northern

Mariana Islands (Palacios, 1989), but no commercial fishery developed, A survey of the literature revealed no reports of ika shibi fishing in American Samoa or the U.S. Pacific remote island areas.

Squid is an international commodity produced and sold in many areas around the world. Consequently, the economic aspects of squid fisheries, particularly those involving distant-water fleets producing squid products for export, can only be fully understood by examining trends in squid fisheries worldwide. To provide this global perspective, the descriptions of the near-shore and distant-water squid fisheries of interest are prefaced by an overview of 1) landings trends in the major squid fisheries in the U.S. EEZ and elsewhere in the world; 2) squid capture methods; 3) squid handling and processing techniques; and 4) market trends for squid products.

3.6.1.1 Overview of Global Squid Fishery2

Squid fisheries are among the fastest growing fisheries in the world (Sonu, 1993). World squid production nearly doubled during the past two decades in order to keep pace with the rise in

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[2] This section depends heavily on reported landings provided by FISHSTAT Plus (FAO, 2000). Caddy (1989) notes that the quality of the information available to the FAO depends greatly on national reporting by governments. He suggests that the quality of government reporting may be decreasing as evidenced by a growing proportion of squid catch remaining unidentified to species group in official statistics.

demand and appears to be still growing. Currently, more than 2 million mt of squid are landed throughout the world (FAO, 2000). From landing trends it seems that squid and other cephalopods are one of the few remaining marine groups of resources where some species in some areas are still experiencing increases in landings, in a world fishery marked by overfishing and decline of many finfish (FAO, 1992, 1994 cited in Caddy and Rodhouse, 1998). The fast pace of growth in squid fisheries is generally attributed to the development of squid fisheries in several regions around the world. In addition, it has been hypothesized that fishing-related reductions in predatory fish biomass and declines of other cephalopod predators such as marine mammals (e.g., toothed whales (Odontocetidae) have, in fact, positively affected oceanic squid and other cephalopod populations (Caddy and Rodhouse, 1998). Just as fast growing weeds can quickly colonize an area of ground that has been denuded of vegetation, it has been suggested that the rapid growth of squid and their short life cycles may have enabled them to move into regions that have been heavily overfished (Jackson, 2001). An increase in water temperature due to global warming could also favor population expansion of squids over fish (Christie, 2002; Jackson, 2001).What is remarkable is that as recently as three decades ago squid fisheries were concentrated in the Northwest Pacific and virtually dominated by one nation, Japan, and one species, Japanese flying squid (*T. pacificus*) (Sonu, 1993) (Figure 1). For instance, the 1968 catch of *T. pacificus* which totaled 668,000 mt, an historical high for this species, comprised 73 percent of the total world landings of squid for that year. Japan's share of the world catch for 1968 was nearly 83 percent (Sonu, 1993).

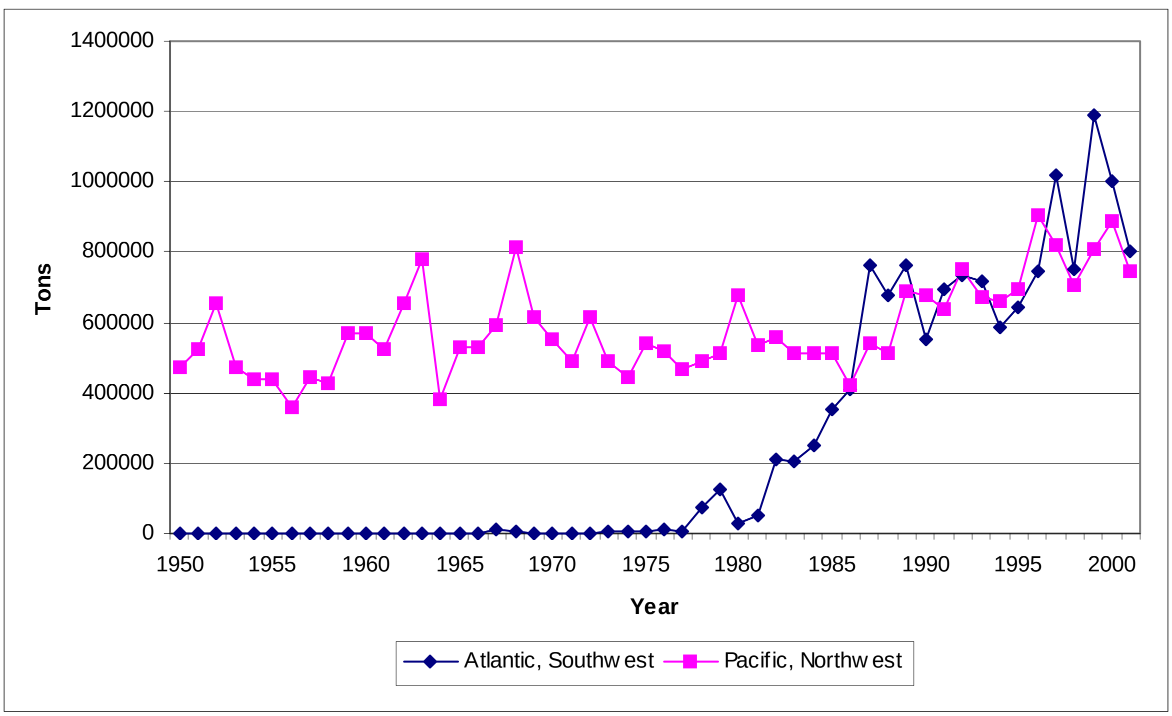

Figure 1: Annual Squid Catch in the Southwest Atlantic and Northwest Pacific, 1950-2000.
Source: FAO, 2000

The catch of *T. pacificus* in the waters near Japan dropped precipitously between 1969 and 1974 as a result of environmental factors and increasingly intense fishing pressure. However, by that time Japanese squid jigging vessels had increased in size and were using more sophisticated navigational and fishing equipment. These changes improved the ability of vessels to locate seasonally migrating schools of oceanic squid species over considerable distances and to select those areas of densest squid concentration to carry out their fishing operations (Murata, 1989). Beginning in the 1970s, there was an expansion of the Western Central Pacific fisheries by Japan using jigging and driftnet techniques and a development of fisheries outside the North Pacific targeting several different species (Sonu, 1993) (Figure 2). The diversification of squid fisheries in terms of regions and species was accompanied by an increase in the number of nations actively engaged in squid fisheries, as countries sought to increase export earnings as well as domestic food supplies (Japan External Trade Organization, 1993 cited in Sonu, 1993). The number of nations with more than 20,000 mt in annual squid catch rose from two in 1966 to 12 in 1990 (Sonu, 1993). Between 1975 and 1989, the world squid catch more than doubled, from 929 thousand mt to about 2.2 million mt.

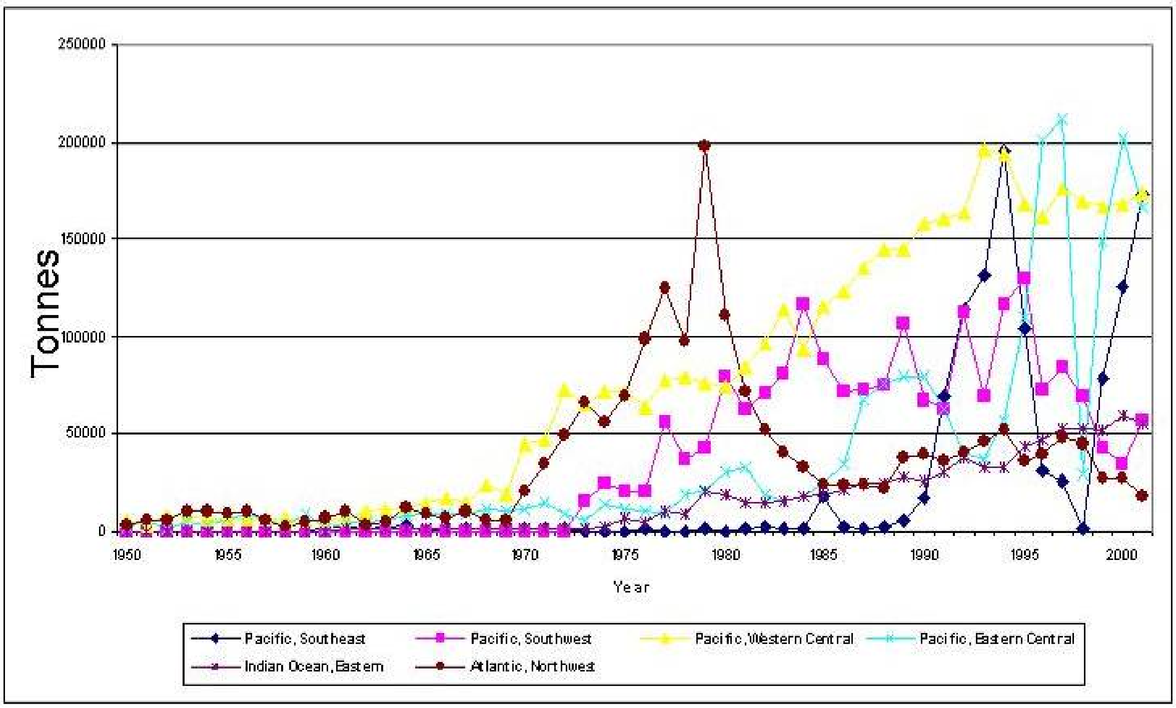

Figure 2 Annual Squid Catch in the Southeast Pacific, Southwest Pacific, Western Central Pacific, Eastern Central Pacific, Eastern Indian Ocean and Northwest Atlantic, 1950-2000. Source: FAO, 2000

One region in which an especially major expansion occurred was the Southwest Atlantic around the Falkland Islands and off Argentina. Japanese fishermen began to increase the harvest of Argentine shortfin squid (*Illex argentinus)* off Argentina in 1978 (Kohrin Sha, 1989 cited in Sonu, 1993). Typically, Japanese squid jiggers would fish for Wellington flying squid (*Nototodarus sloanii*) off of New Zealand for a short time before continuing on to the Southwest

Atlantic. Eventually, Eastern European countries also began participating in this fishery and through this participation became important suppliers of squid to the world market. By the late 1980s, vessels from Japan, the Republic of Korea, Russia, Spain, Argentina, Poland, Germany, the United Kingdom and the Ukraine were fishing for squid in the region. During the late 1990's, the Southwest Atlantic fishery accounted for about one-third of world squid landings and was worth up to $1 billion (Bostano, 2002; FAO, 2000). The proceeds from the sale of squid fishing licenses in the EEZ around the Falkland Islands dramatically improved the economy of that country (Thomas, 2002). However, *Illex* catches in the Southwest Atlantic declined sharply in 2002. Some researchers are of the opinion that overfishing did not cause the fishery to collapse; rather, they believe that temperature-driven ocean currents swept squid larvae into the open ocean (Bostano, 2002). Catches in the Southwest Atlantic rebounded in 2003, but another drastic decrease in 2004 resulted in an early closure of the fishery by the Falkland Islands and Argentina.

Large fluctuations in abundance and availability are a feature of squid fisheries worldwide. They are short-lived animals, and catches of most species fluctuate widely from year to year, depending on water temperature and many other factors (SeaFood Business, 2000). It is difficult to count, with any degree of confidence, on a guaranteed supply from any one source. For example, Canada was the major supplier of frozen squid to Japan until 1982, when squid catches by Canadian vessels decreased sharply and exports to Japan from that country dwindled to zero (Sonu, 1993). From 1982 to 1990, Poland was the main squid supplier to Japan, but its exports declined in half in 1991 due to poor catches off the Falkland Islands.

Although individual squid fisheries tend to be very irregular, there is rarely a shortage because squid are now fished around the world. Generally, squid are always readily available from somewhere. Moreover, because squid reproduce rapidly, they tend to recover quickly from environmental factors or fishing effort. For example, stock abundance of *O. bartramii* in the Western Central Pacific was extremely low in 1993, probably due to high fishing rates derived from the driftnet fishery (Yatsu et al., 1999). After the driftnet fishery ended in 1992 as a result of a United Nations global moratorium on all large-scale driftnet fisheries, the *O. bartramii* stock seemed to quickly recover and abundance was high during 1994-96. Stock abundance was again depressed in 1997, the most prominent El Niño year in this century, but was high in 1998.

There is also the possibility that some squid species are considerably underutilized. Although almost a hundred species of squid are fished commercially, two species, the *T. pacificus* and *I. argentinus*, account for over half the world harvest (Pacific Seafood Group, 2001-2002). Fewer than a dozen species of squid account for almost 90 percent of the world production (SeaFood Business, 2000). Results from experimental fisheries suggest that there are squid species existing in substantial quantities that have yet to be significantly exploited. For example, one likely candidate for expanded harvests is the seven star flying squid (*Martialia hyadesi*), a Subantarctic, oceanic species (Rodhouse, 1994).

3.6.1.2 Major U.S. Squid Fisheries

Squid are harvested by U.S. vessels along both the East and West Coasts. Three species of squid are commercially important in U.S. waters, market squid (*Loligo opalescens*) on the Pacific coast, and long-finned squid *(L. pealei*) and short-finned squid (*I. illecebrosus*) on the Atlantic coast. Vessels based in California and Rhode Island produced 92 percent of the total national harvest in 2001 (USDA, 2003). Annual landings of the U.S. squid fishery averaged approximately 69 thousand mt from 1980 through 2001 (FAO, 2000). However, the U.S. squid supply is characterized by cyclical periods of relative scarcity and abundance. The El Niño periods of 1983-1985 and 1997-1998 on the West Coast had an especially dramatic negative effect on domestic production.

A large portion of the U.S. catch is exported to markets in Europe and Asia/Southeast Asia (Pacific Seafood Group, 2001-2002). Despite the wide fluctuations in harvest, squid exports are an important component of U.S. seafood trade, increasing steadily from $25.5 million in 1990 to $91.5 million in 1997, a 258 percent increase (USDA, 2003). U.S. squid exports fell sharply in 1998 but averaged around $72.2 million from 1999 through 2002. China has generally been the largest single destination for U.S. squid exports since the mid-1990s, receiving $24.5 million, or about 40 percent of the total U.S. exports in 2002 (USDA, 2003).

California

As noted above, much of the variability in U.S. squid landings during the past decade is accounted for by periodic increase and decline in the catch of *L. opalescens* in the California fishery. In general, this harvest involves luring the animals to the surface with high wattage lamps, encircling them with purse seine nets and pumping and/or using brail nets to remove the squid from the water. The California fishery has a long history, dating back to the mid-nineteenth century, although catches were usually less than 10,000 tons until the 1960s (CDFG, 2003). During the early 1990s, the waters of California saw a rapid squid fishery expansion due to the exploitation of a previously “underutilized” population of squid off of southern California and an increased market demand fueled by the emergence of international markets (notably China). In the 1996-1997 season, California fishermen caught a record 124,309 tons of market squid, with an estimated dockside value of $33.3 million. *L. opalescens* was the most valuable commercial fishery product to the state in terms of volume and revenue and became one of the most highly sought after fisheries in California (Lutz and Pendleton, 2000). However, landings plummeted to less than 12,000 tons during the El Niño of 1997-1998. The fishery bounced back during the 1999-2000 season, surpassing the previous record with a catch of 126,772 tons, worth nearly $35 million. This catch was followed by another good year in which 119,000 tons were caught with a value of $22.8 million. However, the 173 licensed purse seiners and 39 light boats brought in only 39,000 tons during 2003.

The market squid resource is managed by the California Department of Fish and Game and California Fish and Game Commission. Prior to 1997, the market squid fishery was largely an unregulated, open access fishery. In that year, California legislators placed a moratorium on the number of vessels in the fishery as a result of the increasing market interest and rising squid landings. There is currently no quota on squid; however, the Department of Fish and Game is preparing a fishery management plan for this species.

New England

L. pealei is an important U.S. commercial squid species because of its comparatively high value (Rathjen, 1983 cited in Sonu, 1993). This species is preferred in the European markets for its excellent taste and texture qualities compared to *I. illecebrosus* and larger size compared to *L. opalescens*, and brings a considerably higher price on foreign markets than the other two species.[3] Both *L. pealei* and *I. illecebrosus* inhabit deep waters of the continental shelf through most of the year, moving into shallow waters in spring and summer at which time they become available to fishermen employing bottom trawl gear (Rathjen, 1973). While foreign vessels had been catching these species since the mid-1960s, heavy fishing by U.S. fishermen only began after 1983. During the early 1980s, NOAA Fisheries and the Mid-Atlantic Fishery Management Council initiated a policy of tying foreign fishing allocations to agreements by foreign interests to purchase squid from U.S. fishermen. As a result, foreign allocations and catches declined, while the U.S. domestic catches increased. Between 1981 and 1990, the domestic catches of *L. pealei* and *I. illecebrosus* rose from 2,947 mt to 26,509 mt, while foreign catches dropped from about 35,000 mt to zero. In 2001, about 14,211 mt of *L. pealei* and 4,009 mt of *I. illecebrosus*

[3] In general, the loligo species, which account for about 20 percent of the world catch, are generally preferred because they are considered more tender (SeaFood Business, 2000). As a rule, squid belonging to the Ommastrephidae family are larger and have a tougher membrane, which gives them a more coarse texture.

were landed in the East Coast fishery, accounting for around 14 percent and 4 percent of the domestic squid catch, respectively.

Both the *L. pealei* and *I. illecebrosus* fisheries are managed by the Mid-Atlantic Fishery Management Council under provisions of the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan. The fisheries are managed under separate limited entry programs. Every year the Council establishes the maximum allowable biological catch for each species. The commercial quota for *L. pealei* is allocated into quarterly periods. With some exemptions, otter trawl vessels possessing *L. pealei* are subject to a mesh size restriction.

Difficult economic conditions for New England's commercial fishing fleet have led to a search for new fishery resources, and alternative species of squid are among the potential resources of interest (Vecchione and Galbraith, 2001). Moreover, there is interest in adopting alternatives to bottom trawl gear in order to reduce bycatch, interactions with marine mammals, gear conflicts with other types of fishing operations, and disturbance of bottom habitat. To further these combined goals, an experimental jig fishery was conducted by a private firm in 1996 under a Saltonstall-Kennedy grant. The fishery tested the feasibility of a commercial fishery for squid using jigging gear and assessing the availability and distribution of oceanic squid resources along the edge and off the margins of the continental shelf in the New England and the Mid-Atlantic regions. While there were hopes to find an abundance of orangeback squid (*S. Pteropus*) and other squid species, *O. bartramii* was the only species that showed any potential for future expanded exploitation.

Hawaii

Ika Shibi Component of the Hawaii Pelagic Handline Fishery

Handline fishing is an ancient technique used to catch yellowfin and bigeye tunas with simple gear and small boats. Handline gear is set below the surface to catch relatively small quantities of large, deep-swimming tuna that are suitable for sashimi markets. This fishery continues in isolated areas of the Pacific and is the basis of an important commercial fishery in Hawaii. Three methods of pelagic handline fishing are practiced in Hawaii, the ika shibi (nighttime) method, the palu-ahi (daytime) method and seamount fishing (which combines both handline and troll methods).

The ika shibi method of catching tuna developed from a squid fishery that was started in the early 1900s by early immigrants to Hawaii from Okinawa (Yuen, 1979). The incidental tuna caught in the squid fishery were known as “ika-shibi” (squid-tuna in Japanese). After World War II, participants in the fishery who owned boats equipped with iceboxes began to target tuna using the squid as bait (Yuen, 1979). Assisted by increased demand for sashimi grade tuna, the ika shibi fishery became a well established component of the Hawaii pelagic fishery (Itano, 2004).

In the late 1970s and early 1980s, participation in the ika shibi component of the Hawaii pelagic handline fishery increased as a result of the introduction of fuel-efficient small-scale vessels and the expansion of the restaurant market in Honolulu (Pooley, 1993). The rising price for fresh tuna and reduced shipping costs made air shipment to Honolulu economically feasible (Boggs and Ito, 1993; Yuen, 1979). In 1977, about 40 boats (many of them part-timers) were involved in the fishery from Hilo and about 10 or so boats were fishing from Kona on the west side of the island (Yuen, 1979). By 1980, at least 230 boats were participating in the fishery (Ikehara, 1982). However, during the early 1990s, some of the larger handline boats began to shift their fishing effort to the seamount and weather buoy fishery 100-200 nm from the coast (Boggs and Ito, 1993). More recently, some handline fishermen have focused their effort on home-made "private" fish aggregation devices (PFADs) anchored offshore.[4] The first of these private buoys appears to have been set in 1999. With the shift of many pelagic handline vessels to fishing around FADs there has been a significant decrease in the size of the ika shibi fleet. Currently, the ika shibi fleet based in Hilo consists of only one to three boats that fish regularly (pers. comm., Craig Severance, University of Hawaii-Hilo, 7/2/04).

A wide assortment of boats has adopted the ika shibi method of harvesting tuna. The fishery generally employs small boats, between 18 and 30 feet in length. In a 1995-1996 survey the average length of an ika shibi boat was eight meters (26.65 ft) (Hamilton and Huffman, 1997).

[4] The State of Hawaii also constructs and deploys FADs. To date, there are 55 state-funded FADs: 18 are in the waters surrounding the Big Island, 14 are in Oahu, 14 are in Maui County (which includes Lanai, Molokai, and Kahoolawe) and 9 are in Kauai.

Many of the smaller boats are tailored to launching ramps such as those located on the Wailua River in Hilo and at Pohoiki, southeast of Hilo and south of Cape Kumukahi (Itano, 2004). Some larger boats tie up at wharves and slips on either side of the lower Wailua River.

The average trip length in the ika shibi fishery during 1995-1996 was one day. The boats are usually manned by two people, but fishermen will often go out alone (Yuen, 1979). Typically, participants in the fishery leave port to get to the grounds at sundown (Yuen, 1979). Upon arrival, the engine is turned off and a parachute sea anchor is attached to the bow and lowered into the water. The sea anchor reduces the drift of the vessel allowing it to stay fishing over a congregation of squid and/or tuna longer. It also reduces the pitch and roll of the vessel to produce a more stable working platform. Surface and underwater lights powered by storage batteries are turned on to attract the squid. Above surface lights are usually 25-watt incandescent bulbs with polished metal reflectors. Often two of these are used. The single underwater light is a 50-watt incandescent bulb that has been waterproofed and weighted. Brighter bulbs are sometimes used for moonlit nights.

Yuen (1979) reports that some squid are caught by angling and gaffing. In angling for the squid, hooks are baited with mackerel scad by cutting off the tail so that the body of the scad is the proper length to fit on the shank of the hook and inserting the shank of the hook through the length of the fish starting with the cut end and ending at the mouth. A light line or wire attached to the proximal tip of the shank is wound around the fish to keep it from falling apart. This makes it possible to use the same piece of bait repeatedly despite the squid bites that are inflicted upon it. The baited hook is tossed out about 5 m and slowly pulled back to the boat. In this manner the hook is used not only to hook squid but also to lure the school of squid to within gaffing range of the boat. A few fishermen prefer to gaff the squid exclusively. In this case the squid are lured to the boat by tossing out a whole scad hooked through the head with a fish hook and retrieving it in the same manner applied to the squid hook.

Itano (2004), reports that some ika shibi fishermen also employ a variety of jigs to capture squid. All of the jigs are locally made and most are relatively small, thin and dense in comparison to many commercially available squid jigs. Typically, the jigs are constructed of or painted with a green luminescent material. Squid jigs are usually fished with a light fishing rod with a spinning reel equipped with 8 - 15 lb test monofilament. The jig is allowed to sink and retrieved with a steady or jerky motion. Fiberglass rods with a short, fixed length of monofilament line are also used with the smaller jigs. These rods are swung in a rapid “figure-8” motion to entice squid to strike near the surface.

In the past, fishing for tuna began after five to 10 squid had been caught. Today most fishermen bait their tuna lines with mackerel scad and proceed with fishing while catching squid for bait. The tuna bait is typically fished at a 30 m depth (Nitta and Henderson, 1993).

In the ika shibi component of the Hawaii pelagic handline fishery squid are caught and used as bait to capture yellowfin tuna and to a lesser extent bigeye tuna and albacore tuna. The squid species primarily caught is *S. oualaniensis* (purpleback squid).

The ika shibi fleet is based largely on the island of Hawaii (Big Island), but this style of fishing is also occasionally employed by fishermen on the other MHI (Ikehara, 1989; Nitta and Henderson, 1993). The Big Island ika shibi fishery occurs predominantly south of the island from Hilo to around the town of Captain Cook. Fishing effort is generally focused at the edge of the island shelf near the 600 to 1,000 fathom contour from 2 to 20 km from shore (Ikehara, 1989; Nitta and Henderson, 1993). The ika shibi season may start as early as April and continue through December (Rizzuto, 1987). Peak fishing activity usually occurs in the summer months. The west side of the Big Island may also have a winter "run" of large tuna near the South Point area. Specific ika shibi fishing locations and seasons on the Big Island are provided in Table 2.

The effectiveness of the fishing lights to attract squid is influenced by the phase of the moon, with the new moon producing higher catches of squid. During the full moon phase fewer squid are attracted to the lights. Brighter bulbs are sometimes used for moonlit nights (Yuen, 1979). Some ika shibi fishermen believe the highest tuna catches occur when the moon is in the first or third quarter (Ikehara, 1989). However, other fishermen indicate that the tuna catch is unaffected by the moon phase.

Table 2: Ika Shibi Fishing Locations and Seasons in the Waters Around the Island of Hawaii.
Source: Ikehara (1989)

Region	Area/Season
East Hawaii	Pohoiki - March-June. 92.50
	Hilo/Pepeekeo - July-September
	North Pepeekeo - October-November
	South Point - December-January
West Hawaii	Keauhou - June-August
	Milolii - September-December

Some of the ika-shibi catch of yellowfin tuna is marketed through the Honolulu fish auction. However, the majority of the catch is sold through the fish auction in Hilo and through intermediary buyers on the island of Hawaii. Most of the catch is sold fresh, but surpluses caught during the peak summer season are sometimes dried and smoked.

Output of the pelagic commercial handline fishery was estimated at $9.35 million in 1995-1996. This total was composed of $0.36 million in sales for palu ahi vessels, $2.82 million for ika shibi vessels, and $6.17 million for seamount vessels (Hamilton and Huffman, 1997). In more recent years, however, tuna landings by the ika shibi fleet have reportedly sharply declined. While the reasons for the collapse of the fishery are uncertain, questions have been raised concerning whether or not the privately owned fish aggregation devices (PFADs) deployed off the Big Island in recent years are intercepting fish that would otherwise be available to the ika shibi boats and other small handline vessels (Environment Hawaii, 2001; WPFMC, 2003). There is also concern that the increasing effort on FADs may be resulting in unsustainable harvests of small, pre-reproductive yellowfin and bigeye tuna.

A 1995-1996 survey of Big Island full-time ika shibi vessels indicated that ika shibi fishermen earned 92 percent of their personal income from fishing (Table 3).

Table 3: The 1995-1996 Average Characteristics of Island of Hawaii Full-Time Ika Shibi Vessels.
Source: Hamilton and Huffman (1997)

Respondent Characteristic	Value
Percent of Personal Income from Fishing	92.50
Total Household Income	$46,111
Age	42.10 yrs.

Average pro forma cost and earnings estimates for Big Island full-time ika shibi vessels for 1995-1996 are shown in Table 30. The average full-time ika-shibi handline vessel generated $70,813 in gross revenues from the sale of pelagic species in 1995-1996. After fixed costs and variable costs for the average of 99 pelagic trips during the year are subtracted, the vessel has a net operating income of about $38,948 (Table 4). After one-third of net operating income for crew share is subtracted, income to the owner and/or the captain of the vessel is $25,706. Sales of tuna account for nearly all of this income; although ika shibi fishermen may occasionally sell surplus catches of squid, the revenue earned from these sales is probably negligible. Although no recent economic data are available, the aforementioned recent decline in the catch of the ika shibi fleet has likely had an adverse effect on the economic performance of this fleet, although some of these vessels have presumably switched to more lucrative pelagic handline fisheries.

Table 4: The 1995-1996 Average annual Revenue and Costs for Full-time Ika Shibi Vessels.
Source: Adapted from Hamilton and Huffman (1997)

Statement	Value ($)
Gross revenue	70,813
Fixed costs total	11,233
Variable costs total	20,632
Total costs	31,865
Net revenue	38,948

Charter boats occasionally engage in ika shibi fishing, as described in the following excerpt from the Web page of a Kauai-based charter boat operation:

There is a fishery called IKA/SHIBI, or Squid/Tuna. It is a very productive method to fish for Tuna.

Basically, we head out before sunset to deeper waters, and find our spot where we deploy a parachute (sea anchor) off our bow. This will slow our drift. We then submerge a light off the side and start chumming. Soon you will be catching Squid on light spinning tackle using Squid lures (good fun). Those same Squid will then be used to bait the big Yellow Fin Tuna or AHI. If you're lucky and the AHI find the boat, watch out because you are in for the battle of your angler's life. This type of fishing is seasonal and the conditions have to be favorable (True Blue Fishing Tours).

No information is available on the current level of harvests of squid in the charter ika shibi fishery.

Some ika shibi fishermen occasionally hook squid for home consumption, to provide gifts for friends and family or supply a specific banquet or large social gathering with fresh squid (Itano, 2004). The amount of this recreational or subsistence catch is unknown.

Kauai-based Directed Squid Fishery

A small directed squid fishery exists in Hawaii, primarily on Kauai. In addition, a few Hilo-based fishermen may occasionally make directed fishing trips for squid, mainly for personal consumption.

It is estimated that there are currently 20 to 30 participants in the Kauai-based fishery (Itano, 2004).

The Kauai-based squid fishery is primarily conducted from tailored boats ranging in size from around 16 to 22 ft and powered by single or twin gasoline powered outboard engines of 30 to 70 hp (Itano, 2004). Due to the small size of the vessels, two or more boats may fish in the same general area for safety, but fishermen indicate that catches may suffer if vessels fish too close to one another. Vessels are usually manned with two or three fishermen equipped with a single baited handline rig.

Fishery participants use a standardized style of fishing with little apparent variation (Itano, 2004). The common luminous squid jigs are generally not used in favor of bait covered steel rods armed with two "baskets" of barbless hooks set at one end. Fishermen typically make their own rigs by soldering hooks to a short section of 3/16-in diameter stainless steel rod. A three-foot section of fine stainless steel wire is attached close to the hooks for wrapping the bait. Each lure is wrapped with a thin section of squid mantle and secured in place with the attached wire.

Most fishermen prefer to fish the baited rigs with a small monofilament handline spooled on a wooden handreel (Itano, 2004). The handreels are fished from drifting vessels, while fishing rods and reels are sometimes preferred when fishing for bait squid from slower moving vessels that are drifting on a parachute anchor. A 12-volt, 25-watt above water light is used to attract the squid or to attract the small fish and crustaceans that attract squid. The above water lights are believed to be more efficient than submersible lights. In addition, they create a shadow under the hull where the squid often wait to ambush prey. Sometimes only a very small light or no light at all may be used.

An essential piece of gear is a round scoop net to land the squid caught on the baited rigs (Itano, 2004). Wood handled nets with 14- to 18-in diameter circular hoops are typical. Hooked squid are hauled quickly to the surface and netted or lifted from the water and stored in 5-gal buckets or small ice chests.

The small-scale jig fishery targets *S. oualaniensis* (purpleback squid) (Itano, 2004). A small amount of *T. rhombus* (diamondback squid) is also caught. The primary fishing grounds lie along the south and southwest coasts of Kauai between Makahuena Point (Koloa) and Kekaha. Fishermen indicate that the squid on the windward coast are larger but much less abundant. Boats typically launch from Port Allen or the Kikiaola small boat harbor in Kekaha. These launch sites are preferred due to their location in relation to prevailing winds and currents that transport boats along the shore or slightly offshore. A small amount of squid fishing effort may also be based in Nawiliwili and Hanalei Bay. However, Nawiliwili Harbor is not commonly used by the squid fleet, as the drift is strongly onshore, requiring vessels to run several miles south of the harbor to set up for a safe longshore or offshore drift.

The fishing grounds are close to shore, often only 2 to 4 miles from the southern harbors (Itano, 2004). Vessels normally do not attempt to slow their drift with a sea anchor or parachute drogue as is typical in the ika shibi fishery. Once a drift is set up, an above-water light is activated to attract squid or squid prey and the vessel allowed to drift freely with the wind. On the southeast coast of Kauai, the prevailing wind will transport a vessel in an east-northeast to west-southwest direction parallel to the shoreline and depth contours. This provides the fisherman a considerable advantage as he can maintain a near constant depth over productive grounds and be confident that he will not be taken toward the reef or too far out to sea.

Squid fishing is a seasonal activity (Itano, 2004). Participants may also engage in the ika shibi fishery, pelagic troll fishery or handline fishery for akule, squirrelfish or bonefish. Fishermen noted that as a rule of thumb the season for squid jigging roughly coincides with the months when humpback whales are not found in local waters, i.e., April to November, although there is no apparent link between the species. The main squid jigging time occurs from the beginning of May to October. Larger, egg bearing females were reported as being more common early in the season, with small squid being more common during July and August.

In order to take advantage of the maximum period of dark in the early evening hours (most of the fishing occurs from sunset to about 10 pm), squid jigging generally begins two days after the full moon, continues through the dark new moon period, and ends between the quarter to half moon period (Itano, 2004). This strategy equates to a maximum of 18 to 20 fishing nights per lunar month.

Catches of purpleback squid generally remain within the community for home consumption; however, some of the squid caught are sold. No cost-earnings studies have been conducted for the Kauai-based fishery; however, a rough estimate of gross revenues can be derived from the data available. Fishery participants measure catch in terms of how many 5-gal buckets are filled in an evening of fishing (Itano, 2004). It is estimated that one bucket contains approximately 130 to 200 squid. Roughly speaking, two buckets of squid is considered a good catch, while a half bucket represents a poor catch. Itano (2004) reports that seafood buyers on the Big Island purchase fresh squid from handline fishermen at $1.00 - $1.25/lb. [5] Assuming that a typical daily catch is one 5-gal bucket of squid weighing 45lb, a fisherman could gross about $50 per fishing trip. If a fisherman made 114 trips per year, his total income from squid fishing would be about $5,700. This estimate is consistent with Itano's (2004) finding that revenues in the directed squid fishery are modest.

As noted above, catches of purpleback squid in the Kauai-based fishery generally remain within the community for home consumption. Another important function of the fishery is to provide a special food item for banquets, outdoor barbecues and large social gatherings (Itano, 2004). The squid is favored as a local delicacy, and fishermen sometimes fish to fulfill social obligations. Occasionally, surplus catch may be sold to local grocery stores or markets. The small catches of diamondback squid made are never sold, as this particular delicacy is used for personal consumption or shared among friends.

Distant-water

The domestic distant-water squid jigging fishery in the Pacific is currently being conducted by a single operation and is a very small contributor to the Pacific squid harvest. The vessels of this

[5] Some fishermen may earn more by selling their squid directly to grocery outlets, thus eliminating the wholesalers and gaining a slightly higher price (Itano, 2004).

one operation occasionally call into Honolulu and Dutch Harbor, but the operation may be relying mostly on at-sea transshipment to deliver product to buyers. The level of on-board processing depends on the size of the squid caught and the preferences of buyers (pers. comm., Bob Endreson, 10/8/03). All of the product of the operation is currently destined for the Japanese market (pers. comm., Bob Endreson, 10/8/03).

According to a representative of the U.S. distant-water squid harvesting operation, the operation consists of four catcher vessels (pers. comm., Bob Endreson, 10/8/03) (Table 5). The mothership is 47 m long and holds 1 million lb of squid. It is a Japanese-built vessel that was seized by the USCG for illegal driftnet fishing, bought at auction, and given a U.S. fisheries endorsement. It has 38 jigging machines on board and cost $1.5 million to convert. The other three catcher boats are converted crab boats from Alaska. They range from 32 m to 34 m in length, and each holds between 450,000 lb and 850,000 lb of squid. Fitting out the vessels for squid fishing was costly (the least expensive boat was $1.2 million) because of the need to install blast freezers aboard each boat (pers. comm., Bob Endreson, 10/8/03). The total investment of the operation is about $20 million.

Honolulu is listed on the High Seas Fishing Compliance Act (HSFCA) fishing permit and application as the hailing port of all the vessels. Each vessel is incorporated under a different name, but the owner's address listed in the USCG vessel data base is the same for all vessels.

Table 5: Characteristics of the the Mothership (Pacific Wind) and the Three Jig Vessels Participating in the Domestic Distant-Water Squid Fishery in the Pacific.
Source: NOAA Fisheries PIRO.

Vessel Name	HSFCA permit issue date	Length (m)	Gross tonnage	Hold capacity (m^3)	Crew Number
Pacific Wind	22-Apr-02	47.1	642	443.77	18
Pacific Ballad	04-Sep-01	32.5	327	438.27	12
Pacific Star	04-Sep-01	33.3	277	208.19	12
Pacific Venture	04-Sep-01	34.2	335	527.05	12

The U.S. distant-water operation relies solely on the jigging method of harvesting squid. The four catcher boats each carry 21-38 jigging machines (pers. comm., Bob Endreson, 10/8/03).

According to the HSFCA fishing permit and application, the vessels participating in the U.S. distant-water operation are licensed to fish in the following six FAO fishing areas:

61. Northwest Pacific;
67. Northeast Pacific;
71. Western Central Pacific;
77. Eastern Central Pacific;
81. Southwest Pacific; and

87. Southeast Pacific.

The U.S. distant-water operation competes directly with international fleets in oceanic squid fisheries outside the U.S. EEZ. The operation fishes to the north of the Hawaiian Archipelago (at around 45°N) in zones of enhanced biological productivity. The primary species targeted in the North Pacific fishery is *O. bartramii*. This fishery is seasonal, usually occurring during the summer months of the Northern Hemisphere.

In addition, the U.S. distant-water operation fishes in the New Zealand EEZ where it operates under charter to a New Zealand-owned company. The New Zealand fishery is managed by an individual transferable quota (ITQ) system (Easton, 1989). The target species in the fishery is *N. sloanii* (Wellington flying squid). Participation by the U.S. distant-water operation in this fishery generally occurs between October and February. The HSFCA would not apply to U.S. vessels fishing in the New Zealand EEZ, and that the target species for this fishery (*N. sloanii*) is not among those to be added to the PMUS.

A representative of the U.S. distant-water operation reports that the squid catch can be as high as 35,000 to 40,000 lb per night when fishing in the waters off New Zealand; while the catch on the North Pacific fishing grounds can reach 18,000 lb per night (pers. comm., Bob Endreson, 10/8/03). At an assumed ex-vessel price of $1,000 per ton, these catches would generate gross revenues ranging from $9,000 to $20,000 per night of fishing. However, average catches and revenues may be much lower. During fishing trips made in the 2003 fishing season, the combined squid catch of three of the vessels participating in the U.S. distant-water operation was only 44,596 lb after about 22 days of fishing on the North Pacific grounds (these fishery statistics are based on 2003 North Pacific high seas squid jig logbook data provided by the NOAA Fisheries Pacific Islands Regional Office).

3.6.1.3 Types of Fishing Gear Used

Squid are caught in a variety of ways, but on a worldwide basis jigging has historically been the most important single fishing method employed (Rathjen, 1991). This technique is especially favored for harvest of pelagic species of squid, including *O. bartramii*. Jigging also accounts for the bulk of production of *I. argentinus* taken from the southwest Atlantic (Rathjen, 1991). The fishing gear description presented here centers upon that method of fishing, but a number of squid netting techniques are briefly described and contrasted in various ways with jig gear.

Jigging

Squid jigging is carried out on very specialized boats. Almost all aspects of the jigging fishery have undergone rapid changes within the past few decades (Saharuddin et al., 1990). Automatic squid jigging machines have been widely used since around 1965. Computer operated automatic jigging machines were developed in the late 1980s (Lee et al., 1997). These changes were related to boat size and reflected the increase in fishing intensity as squid fisheries changed from coastal to distant-water fisheries (Saharuddin et al., 1990).

Japanese researchers are responsible for many, if not most, of the advancements in squid jigging techniques. While these researchers have published numerous articles on squid fishing technology in trade journals and scientific publications, a major portion of this literature is written in Japanese and thus is difficult for non-Japanese to utilize (Rathjen, 1991). The description of squid jigging gear provided here represents a précis of the more accessible literature.

Many automatic jigging machines are available on the world markets today for both hydraulic and electric power (Bjarnason, 1992). A modern 50-70 m vessel will be equipped with 50-70 jigging machines (Rathjen, 1993).[6] These machines work on the same principle as jigging by hand but are made less labor intensive by the use of electric or hydraulic motors which automatically move the line up and down in a jigging motion and retrieve the line when squid are hooked. The adoption of this technology led to a significant reduction in the number of crew employed on each vessel (Murata, 1990).

The jigging machines wind a line over an elliptical or oval shaped reel. Normally a single squid jigging machine drives two reels. Two reels are mounted on each side of a shaft and one sinker-weighted line is attached to each drum (Court, 1978). Most machines are equipped with a line-

[6] The number of jigging machines that can be placed on a vessel depends on the vessel's deck configuration as well as its size.

laying device. Earlier machines had an externally mounted sliding-train device, while on later machines the whole shaft moves slowly back and forth, causing the line to wind onto the reel at intervals along its axis. A mesh-covered frame extending the full width of the machine, is hinged outboard, and when lowered during fishing, projects about one meter over the water. Lures or jigs equipped with sharp, barb-less hooks are attached to each line at short (e.g.,70 to 90 cm) intervals, and the lines are passed over rollers mounted on the outboard edge of the mesh-covered frame.

The lines are lowered to a 30 to 100 m depth depending on the strength of the lights used (Bjarnason, 1992). The turning of the reels causes the lure to move upwards through the water in a rhythmic jerking movement which attracts the squid and helps ensure that they remain on the hooks (Black et al, 1987). [7]As the lures are recovered over the front rollers this pressure is released, and the squid drop onto the mesh-covered frame between the two rollers. The screen is sloped so that the squid will drop onto the deck or into a flume which carries them below deck for processing. The jigging machines are designed to fish continuously, and when everything is operating properly, a minimal amount of labor is needed (Lemon and Rycroft, 1982). Most machines will stop automatically when they malfunction. Because a machine continuously reels many jigs, it functions best in dense concentrations of squid (Court, 1978). The machines are

[7] The hooks may penetrate the skin of the tentacles as a squid grasps the lure, but they generally leave only barely perceptible marks on the animal (pers. comm., Mike Seki, NOAA Fisheries Pacific Islands Fisheries Science Center, 10/21/03).

operated so that adjacent lines move in opposite directions; thus, no matter when a school of squid passes under the boat, half the lines are apt to be productive. A vessel fishing a large school of squid will often deploy a sea anchor in order to maintain position (Lemon and Rycroft, 1982).

Most automatic jigging machines have an easily operated control board which can be adjusted to suit most fishing conditions. Variables that can be controlled include: hauling power and speed; jigging speed and span or length; jigging timing in relation to span or length; depth or distance from bottom; and sensitivity when hauling to prevent slackening or overloading of the line even when the boat rolls. These variables can be adjusted using a computer console to increase fishing efficiency and catch rates (Lee et al., 1997).

A typical lure is about 70-mm long and consists of one or more rings of hooks with an ellipsoid lure above. However, the lures are manufactured in various sizes, shapes and colors, and new ones types are continually being developed. For example, Guo et al. (1997) describe two new kinds of jigs that have been devised, the impeller-jig and the roller-jig, which attract the squid and hold them firmly with the visual stimulation of the rotating parts. In addition, some fishermen attach lights to the lines to increase catch rates (Flores, 1982).

Jigging uses the squid's natural behavioral characteristics to make catching easier. The boats have powerful lights strung above the deck that illuminate the water and attract small fish. The squid group in the boat's shadow and then dart into the light to feed on the fish. The knowledge that squid can be attracted to light has been utilized as an aid in harvesting squid for centuries (Flores, 1982). Torches were replaced by the electrified fishing lamp around 1950, and since then, the invention of the high intensity discharge (HID) lamp and other types of lamps have improved the performance of jigging operations. The optimal light intensity is the most important item in jigging activity and has been the subject of intense study in Japan (Flores, 1982).

The light arrangement on a squid jigging vessel basically consists of a row of lamps along the fore-and-aft line of the vessel which are hung to a pole or a line stretched horizontally between the fore mast and the mizzen mast (Flores, 1982). Large vessels may have two of such rows with 25 - 50 (2,000-4,000 watt) lamps per row. This specific arrangement of the lamps over the vessel rather than over the water is due to the peculiar reaction of the squid, which prefer to aggregate in the boundary area between the shadow of the vessel and the lighted area. The position of the lines in relation to the location of the boundary area is therefore of great importance. The location of the boundary area can be adjusted by the height of the lamp and by its distance from the centerline of the vessel. The position of the lines can be adjusted by the length of the roller arm. Ogura (1981 cited in Flores, 1982) reports that if the lines are set in the boundary area the catch is best. Further investigations showed that the relationship between the lamp light beam, water line, and fishing lines influences the catch considerably. Results showed that the catch is better when the so called triangle falls below the waterline. This is achieved by adjusting the length of the roller arm and position of the fishing lamp. Catches of some species of squid may be affected by the phases of the moon, with lower catches during the full moon period (Flores, 1982).

Sometimes underwater lights are used on large boats. They are sunk as deep as possible and then slowly hauled back to the boat (Bjarnason, 1992). This is done to try to lure the squid from deep water into the light or shade from the above deck lights. In addition to experimenting with different lighting arrangements, researchers have investigated other ways to increase catch rates, such as using artificial sound (Choo and An, 1998).

Jigging can be a very productive form of fishing. For example, near New Zealand one jigging machine reportedly caught 1,491 kg of squid in six hours (Wolfe, 1973 cited in Court, 1978), and Voss (1973 cited in Court, 1978) notes similar catch rates for boats which had 20 to 24 machines. A representative of the Hawaii-based distant-water squid jigging operation reports that the catch of that operation reaches 16,000-18,000 kg per night when fishing in the waters off New Zealand; while the catch on North Pacific fishing grounds can reach 8,000 kg per night (pers. comm., Bob Endreson, 10/8/03). The representative notes that the squid caught in New Zealand are substantially smaller than those caught in the North Pacific.

Moreover, the quality of the squid caught with jigging tends to be comparatively high — the squid arrive on deck still alive and with little or no mechanical damage. The time lag between being caught and frozen is low with jigging, as this fishing method tends to assure steady and controlled catches (Court, 1982; Leta, 1982). Furthermore, jigging has the benefit of being a “clean” fishing method with little incidental catch of non-targeted species and no destructive interference with benthic fauna or habitat (Rathjen, 1993). A representative of the Hawaii-based distant-water squid jigging operation reports that operation brings no bycatch species on-board, but it loses a large quantity of fishing gear due to interactions with blue sharks (pers. comm., Bob Endreson, 10/8/03). The operation uses fishing lines that are 30-60 lb test, and the lines quickly break when sharks attack the hooked squid.

Bower (2004) cites Japanese studies indicating that large squid often drop from jigs as they break the surface due to their weak tentacles. Surveys of *O. bartramii* fisheries in the North Pacific central and eastern sea areas reported drop-off rates of 36 to 52 percent (JAMARC, 2003a, 2003b cited in Bower, 2004). Guo et al. (1997) note that the long, thin arms of *O. bartramii* make this species susceptible to drop-off when pulled up by jigs. Japanese researchers have developed new jig designs in an effort to reduce the number of drop-offs (Guo et al., 1997; Yada et al., 1997).

Netting

The use of various types of nets is the method often used for harvesting loliginids, which generally occur in shallow, nearshore waters. The most productive netting technique is trawl fishing. At present, trawling tends to be the most important squid harvesting technique in the North Atlantic, probably due to the intensive use of trawling gear in the fisheries of this region (Rathjen, 1991). The principal fishing gear used in the U.S. *L. pealei* and *I. illecebrosus* fisheries is the squid otter trawl. This gear type is also commonly used to catch squid and cuttlefish in the Gulf of Thailand. In all types of otter trawls, the diverting ("paravaning") effect of otter boards or doors keeps the otter trawl spread open horizontally. A weighted ground-rope and floats on the head-rope keep the net open vertically as the nets are towed over the seabed.

While trawling can be an economically efficient method of catching squid, catch quality may be more difficult to control in comparison to jigging. A major deteriorative reaction bringing about a loss in quality in squid has been identified as enzymatic proteolysis that results in the formation of free protein degradation products such as peptides and amino acids (Rathjen and Stanley, 1982). The enzymes responsible for this reaction are present in squid in levels much higher than other marine species. This reaction leads to a softer texture and probably enhanced bacterial action with concomitant off odors and flavors. Trawling exposes the susceptible squid tissue to high levels of physical forces including squeezing and compression that could initiate liberation of proteolytic enzymes and the ensuing loss of quality.

Moreover, unlike jigging, trawls may produce large amounts of species that are not targeted. For example, the directed fisheries for *L. pealeii* in the Northwest Atlantic frequently catch large amounts of butterfish (*Peprilus triacanthus*) (Kolator and Long, 1979; Rathjen, 1991). This finfish is itself commercially valuable, but the small individuals caught in the squid fishery are unmarketable and therefore discarded. In October 2001, a Northeast Fisheries Center observer documented the take of a leatherback sea turtle in a bottom otter trawl fishing for *L. pealeii* off of Delaware. The mainland squid trawl fishery in New Zealand has generated opposition from environmental advocacy groups because of incidental catches of sea lions, fur seals, basking sharks, and seabirds (Weeber, 2004).

Seine and lift nets of various forms are also employed to harvest squid (Rathjen, 1991). Although seining is for the most part a comparatively little used technique, the purse seine is important in the California market squid fishery (Lutz and Pendleton, 2000; Rathjen, 1991). Purse seine gear functions by encircling squid in a netted bag. When deploying the net (making a set), a motor skiff is used to position the net around a school of squid. A typical seine net used in the California fishery is 185 fathoms long and 22 fathoms deep. A crew of four or five is commonly needed to handle typical seine gear although fewer are needed if a drum seine is used, which rewinds the net onto a large reel. After the net has been set and closed, the squid are typically sucked into the hold by centrifugal wet pump machinery lowered into the drawn net. In a seining operation, spotter planes and satellite and sonar technology assist fishermen in locating and tracking schools of squid. Additionally, at night, "light boats" equipped with generators and a large array of high-powered electrical lights are employed to attract and maintain schools of squid.

The incidental catch of non-target species is minimal in the commercial market squid fishery, although it cannot be avoided entirely (CDFG, 2003). Most of the incidental catch is other coastal pelagic species, including Pacific sardine (*Sardinops sagax*), Pacific mackerel (*Scomber japonicus*), northern anchovy (*Engraulis mordax*) and jack mackerel (*Trachurus symmetricus*). Smaller vessels in the California fishery use power-assisted lift nets (brail nets) in conjunction with attracting lights (CDFG, 2003). A similar fishing method is used in Southeast Asia, especially in the Gulf of Thailand and Philippines squid fisheries (Rathjen, 1989; SEAFDEC, 2002-2003).

The now largely defunct high-seas driftnet squid fishery targeting *O. bartramii* was prosecuted in the waters of the central North Pacific by fleets from Japan, Korea and Taiwan. Squid driftnets were made of transparent, monofilament nylon and manufactured in panels (tans or poks) approximately 9 meters wide and 50 meters long (Gong et al., 1993; Yatsu et al., 1993). The mesh size that was employed varied with the fleet and with the time of year. Mesh sizes increased as the squid grew during the fishing season. Individual net panels were attached together to form sections a few kilometers long. A lead line was attached to the bottom of the driftnet to stretch it out. Larger buoys, flashing lights and radio beacons were usually attached to help locate the driftnet for retrieval. Most of the larger vessels deployed 810 sections per night or between 40 and 60 kilometers of netting (Wetherall, 1989). The sections were strung along a float line with 100 to 1000 meters between sections. Sometimes sections were set parallel to one another and/or a fleet of vessels would form an array of nets.

During the 1980s, between 200,000 and 300,000 mt of squid were caught annually by driftnets in the North Pacific, with a landed value exceeding $250 million (Gong et al., 1993; Wetherall, 1989). Lee et al. (1997) report that the fishing efficiency of driftnets was higher than that of jigging when targeting *O. bartramii*. This species has long, thin arms which may break off when pulled up by jigs (Guo et al., 1997). In addition, the shape of their fins, which form an angle at the point of attachment to the mantle, is conducive to entanglement at certain combinations of body size/mesh size (Rathjen, 1991). The catch per boat per fishing day using driftnets was 1.5-3.8 times greater than that of jigging in the same fishing grounds (Murata, 1990). In addition, operating costs were less with driftnet fishing, as no lights were used to attract the squid, resulting in lower fuel consumption (Yeh and Tung, 1991). Driftnet fishing was also attractive because capital costs were comparatively low. Many different types of vessels could easily shift to this fishing method with the purchase of relatively cheap, second-hand nets.

Although driftnets were deemed more effective in catching squid than jigs, the non-selective nature of this gear and the impacts of the fishery on marine mammals, seabirds and other marine life led to United Nations General Assembly Resolution 46-215 which mandated a global moratorium on all large-scale driftnet fisheries by December 31, 1992. However, despite the actions taken by the international community to implement the UN moratorium, sporadic large-scale high seas driftnet fishing activity persists in the North Pacific. For example, the USCG received two unconfirmed reports of illegal high seas driftnet activity in the North Pacific in July and August 2002 (NMFS, 2002a). On 25 July 2002, Japanese squid jigging vessels reported three driftnet vessels operating at 41°25'N, 169°06'E. One of the vessels was identified as a vessel from China. Approximately two weeks later, U.S. and Canadian commercial tuna fishermen observed two vessels tending driftnets near 42°06'N, 166°12'E. It is possible that the sightings may have involved the same vessel or vessels.

3.6.1.4 Processing of Pelagic Squid

On-board processing

In addition to being highly perishable, squid are more susceptible to damage than gutted finfish if not handled carefully; crushing, scuffing or tearing of the skin, and burst ink sacs are indicative of rough handling (Stroud, 2001). An important factor in maintaining good quality is speed and workmanship (Kreuzer, 1984). Furthermore, in today's highly competitive markets, generating top quality seafood often means freezing products at sea at very low temperatures (20 degrees below zero or colder). By freezing a fishery product at sea, the natural deterioration of fish products is halted. In addition, preservation of the skin color of fresh squid (an important quality criterion in the demanding Japanese market) entails freezing the squid as soon as they are brought on board in order to prevent drying (Sugiyama et al., 1989). On-board freezing of squid increased in importance with the development of distant-water fishing in the 1960s (Kreuzer, 1984). Today, freezing is the most important method of preservation in squid fisheries, and frozen at-sea squid is of considerable importance in international trade. In order to produce a high quality product, the squid are blast frozen within 20 minutes of being caught.

On a typical industrial-scale squid jigging vessel, squid which have been caught are transmitted directly to the below-deck working area by trough, slipway, conveyor, etc. (Lemon and Rycroft, 1982). Water washing and drainage occurs at the working area, although some vessels are equipped to carry out water washing during transit. Squid in poor condition are culled out and thrown overboard. The squid are hand sorted into different size classes and carefully packed in two or three layers, laid out evenly tail by tail with tentacles folded under and along the outside of the block. The traditional block size is 8.5 kg.[8] Each block carries a tag indicating the number of squid per block. This is an important marketing consideration, for in the market, all things being equal, larger squid command a higher price (Lemon and Rycroft, 1982).

The blocks of squid are quickly frozen in a freezing chamber using the contact-freezer or semi-air blast method. At the completion of freezing, the squid are removed and a glaze is applied by immersing the frozen blocks in fresh water for 5 to 6 seconds. The glazed squid are then placed in a corrugated board box for sheathing and are stored in the fish hold at -25°C to -35°C. Glazing and packing the frozen blocks are essential in order to prevent desiccation during cold storage (Kreuzer, 1984). In addition, stowage in boxes is generally better than bulk stowage because there is less risk of crushing and bursting the ink sac. Whole squid keep in good condition in cold storage at -30°C for 9 months or more.

Squid are not normally gutted at sea because many markets prefer them whole; the ink and the tentacles are often used along with the flesh of the mantle when preparing squid for eating. The form in which squid is frozen at sea is changing. In the past they were all frozen whole, now some vessels freeze their catch as skin-on uncleaned tubes (Kreuzer, 1984). The fins and head

[8] Sorted squid may be packed in containers of different sizes. For example, large squid such as *O. bartramii* are packed in containers of 10 kg or larger (Sugiyama et al., 1980).

and tentacles are removed and packed onto separate freezing trays. Next, the mantles are butterflied, the viscera are removed and discarded, and the product is placed on a third set of trays. Alternatively, the squid are headed and eviscerated and only the tubes are frozen.

Vessels that supply markets for squid in which product color is not an important quality criterion may forego investments in on-board freezing capacity. No difference in taste is apparent between squid that are frozen immediately or after having been properly chilled or iced for 1-2 days or so, provided optimal handling procedures are followed on board the vessels from the time the squid are caught (Kreuzer, 1984). For example, in the California market squid fishery none of the vessels have on-board flash freezing capability. However, the fishery occurs in shallow waters (generally within a mile of shore), and usually the squid are landed within hours of capture (Lutz and Pendleton, 2000). After being offloaded, the squid are trucked to processing facilities where most of the squid is frozen whole in blocks or individually quick frozen.

Shoreside Processing

Land processing methods vary according to type of fishery, kind of raw material and specific products produced (Kreuzer, 1984). However, after being transported frozen to a processor, the edible parts of squid are generally prepared in the following manner. First, the whole squid are thawed by hot water and washed. The tentacles are cut off just in front of the eyes and retained, as they can be eaten once the suckers have been removed. The head is twisted and the mantle is squeezed while the head, pen and viscera are gently pulled out. The mantle can be left whole, with the gut cavity washed out, or it can be split and opened so that any remaining guts can be scraped or washed away. The skin on the mantle can be peeled or scraped off; blanching in hot water at 25-30°C for about 15 seconds makes the skin easier to remove. Machinery for the entire process of heading, gutting, skinning and cutting is available.

The yield of edible meat from squid depends on various factors such as species, size, season, processing methods, etc. (Kreuzer, 1984). Although squid have a much higher yield than finfish, at least 30 percent of the animal may be inedible when processing products for human consumption. However, most inedible parts can be transformed into potentially valuable products. The skin can be used to produce a high protein solution that is added to animal feed (Learson et al., 1982). The viscera can also be used as animal feed. The eyes can be used in the paint industry for their high luminosity, and certain parts of the gut wall may be used in the cosmetics industry. The lipid and fatty acid composition of the integument of *O. bartramii* is being assessed as a possible new source of phospholipids containing docosahexaenoic acid (DHA) (Deng et al., 1999). Omega-3 fatty acids, specifically DHA, are widely touted for their health benefits. Its high chitin content (90 percent) also makes the internal shell useful for many other medical and health-related applications (Learson et al., 1982). For example, it is currently used for bandages and burn dressings, as it reduces scars and infection and improves healing. At one time the integument was also investigated for its use in the manufacture of contact lenses (Learson et al., 1982). Finally, the squid beak is prized in Japan for its purported aphrodisiacal attributes (Learson et al., 1982).

As a result of the extensive international trade of frozen squid, costs largely dictate the level of processing that occurs in various countries. For example, due to lower labor costs overseas, many U.S. processors freeze whole squid into blocks and export the blocks to China and other countries for secondary processing into tubes, tentacles, rings, breaded or canned seafood products for re-export. Relatively small quantities of U.S.-caught squid receive additional domestic processing.

In addition to being processed for human consumption, squid are frozen for bait and supplied to domestic commercial and recreational anglers. Squid is an especially desirable bait in longline fisheries because it holds up well in the water and will not easily tear off the hook (Sonu, 1993). The market for *I. illecebrosus* has primarily been for bait. This species is preferred over *L. pealei* because it is larger, has a thicker and tougher mantle, and also because it is significantly less expensive. In addition to providing bait to domestic fishermen, East Coast producers provide *I. illecebrosus* to export bait markets in Canada, Iceland and other countries. The *L. opalescens* fishery is an important source of both frozen bait and live bait for the California recreational fishing industry (CDFG, 2003).

3.6.1.5 Market Trends for Squid

The volume and value of international trade in squid products have increased dramatically over the past two decades. World imports of squid in all forms (frozen, fresh or chilled, seasoned, dried, salted or pickled) rose from about 89,000 mt (valued at approximately $138 million) in 1980 to just over 506,000 mt ($849 million) in 2001 (FAO, 2000). Squid have a well-defined group of consumers concentrated in relatively few markets, the principal ones being Japan and countries of Southern Europe (primarily Spain). In these markets, squid products have a definite segment of the food market and compete with meat or other fish products to a limited extent only. There is, however, significant competition within the global squid market. For the most part squid products are commodities that face strong international competition for access to export markets. For example, California market squid competes with squid from the New Zealand and Falkland Islands fisheries for the Chinese market. Because of the international competition, prices tend to move in parallel over the medium to long term, with Japanese demand setting the trend (ITC, 1989).

In some markets, particularly Japan, there is also competition between domestic and imported products (Sonu, 1993). To supplement its domestic catch Japan imports around 50,000 mt of squid each year. These imports make up about 10 percent of the Japanese market. Before Japanese landings of *T. pacificus* dropped sharply in 1971 Japan prohibited imports of squid. In 1971, imports were allowed but import quotas are maintained on seven product forms of squid and cuttlefish: live, fresh, chilled, frozen, salted, brine-soaked and dried. Product forms which are exempt from import regulations include processed squid which has been flavored, such as smoked and prepared or preserved products (i.e., canned, boiled, seasoned or fermented products). Import quotas are set every six months. Because imports represent a small percentage of total domestic consumption of squid, they are too small to influence domestic prices.

Japan's quota system sets not only the amount of annual imports but also decrees recipients of import quotas (Sonu, 1993). Quota allocations can be purchased for a fee, which varies according to prevailing squid prices. The transferred import quota is, however, credited to the original holder. Since the import quota allocation is based mainly on previous import records, the system guarantees that the same holders will continue to be given allocations even if they have no intention of buying squid themselves. There is a great deal of variation in the amount of quota held by individual importers, who are reported to number more than 200. In Japan (and other countries such as China) a major share of squid imports has been handled by trading companies, which usually have one or more seafood import departments (ITC, 1989). In recent years, however, the numerous supermarkets under large national chains have also become a significant factor in Japan's seafood industry.
Because of the limited import quotas, importers seek items which bring high profitability, usually those that fill special niches in the Japanese market (Sonu, 1993). Even with import quotas it appears that the volume of imports is affected by prices of domestic squid. When prices are low, importers have little incentive to use their allotted quotas.

Imports of squid into Japan are also subject to tariffs (Sonu, 1993). As Japan and the United States are signatories to the General Agreement on Tariffs and Trade, lower tariffs apply to U.S. exports of squid products: five percent for fresh or frozen products, and 15 percent for salted, dried, prepared or preserved products (including products in airtight containers). Tariff rates are calculated as a percentage of CIF (cost, insurance, freight) value.

Squid prices have a seasonal cycle, being lower in July-September owing to Japanese landings during that period (Food Market Exchange.com). Another important element influencing squid prices are catches in the Southwest Atlantic. Eastern European countries have tended to sell at low prices when catches in the area are high, often depressing world market prices for other varieties of squid as well. In general, Japanese importers pay higher prices than Europeans, and most of the world supply goes to Japan for as long as the national import quota remains unfilled.

With respect to the prospect of market expansion, some of the traditional markets, including Japan and Spain, are expected to show little or no growth (Anon., 2001). Squid and cuttlefish combined remains the leading seafood consumed in Japan due to the wide range of utilization of these seafoods such as sashimi, family cooking use, institutional and restaurant use, and many kinds of processed food. The market for these cephalopods in Japan has returned to normal following the financial crisis in the late-1990s. However, the long-term demand is uncertain because of the switch of younger Japanese to a more western-style diet (Anon., 2001).

On the other hand, squid consumption is expanding in Northern Europe and the United States, which are areas traditionally having low consumption figures. Americans generally prefer to call squid "calamari," the Italian name for squid, and the average U.S. consumer has a strong aversion to buying whole, wet squid (although that may not be true of some ethnic groups in the United States, such as those with an Asian or Mediterranean background). Nevertheless, imports of squid into the United States are increasing and this trend is expected to continue. Since 1990, U.S. squid imports have grown from 13,000 to 47,600 mt in 2001 (SeaFood Business, 2000). Dozens of countries are now exporting squid to the United States. The biggest supplier is Asia, where squid from all over the world is reprocessed into a variety of products, including steaks, rings, cleaned tubes and tentacles. China, the single largest supplier of squid, accounts for about one-quarter of all U.S. squid imports, followed by Taiwan, India, South Korea, and Thailand. Almost all of the squid imported from China is reprocessed product, including large volumes of California market squid.

The domestic consumption of squid is spreading among the non-ethnic as well as the ethnic U.S. population (Sonu, 1989). New products catering to the non-ethnic groups, such as battered, breaded squid rings and steak strips are being successfully marketed. Other favorable factors include the so-called “grazing” trend — the tendency for restaurant patrons to forgo a full meal and be satisfied with an appetizer only — and the fact that squid products are easy to prepare at restaurants. Brown (2002) notes the mass-appeal of squid to restaurant patrons:

Fried calamari may be the most popular restaurant appetizer in all of Christendom. I’m amazed that McSquid hasn’t started popping out of drive-thrus worldwide.

SeaFood Business (2000) describes the attraction of squid as a menu item in the U.S. food service industry. They note that the world-wide abundance of squid maintains a downward pressure on prices. Recently, cleaned tubes and tentacles may be purchased from importers for \$1.10 to \$1.85 a pound. The cheapest squid are small (3- to 5-in) product from China, while large (8- to 12-in) tubes from Thailand are at the high end. Squid steaks may sell to distributors for \$2.45 to \$2.65 a pound. Restaurants can take 3 oz of squid, costing less than 50 cents, and charge \$6.95 or \$7.95 for it breaded or battered as an appetizer.

3.6.1.6 Bycatch in the Squid Jigging Fishery

Net fisheries for squid may experience significant interactions with marine mammals, seabirds and sea turtles (Weeber 2004). However, available information suggests that jig fisheries have very low rates of interaction with protected species. Jigs are used both in the nascent high-seas fishery targeting red flying squid north of Hawaii and in the small-scale fisheries operating in the coastal waters off west Kauai and east Hawaii.

Marine Mammals

Some species of marine mammals prey on squid and, therefore, might approach jigging vessels. Dolphins and small-toothed whales are adept at not being hooked while they steal hooked catches from slowly moving gear. Jigs pulled through the water column in a faster rhythmic jerking movement might pose a greater danger of accidental hooking. More likely than hooking, however, is that an active marine mammal searching for squid beneath high-seas vessels could become entangled in several jig lines because of their close spacing on large vessels (21-38 jig machines each driving two reels per vessel). Depending on their size, marine mammals that are accidentally entangled might a) break off the line, b) be pulled over the rollers onto the deck, or

c) stop or break loose from the line at the rollers. Logbooks and anecdotal reports (B. Endreson pers. Comm. 10/03) from limited squid jigging in the North Pacific by four U.S. vessels provide no evidence of any interactions with marine mammals.

Crespo, et al. (1997) reports on the results of monitoring interactions between marine mammals and the squid jigging fleet that fishes coastal waters (100-200 m depths) off the central Patagonian coast. The fleet numbers at least 110 vessels, and targets the shortfin squid (*I. argentinus*). The fishing area overlaps in part with sea lion foraging habitat. Records of interactions between the jigging fishery and marine mammals were recorded, but not quantified. Southern sea lions and Commerson's dolphins were reported to entangle lines of jigging machines, prey on squid, and scatter the schools.

A cooperative squid jigging survey was conducted by U.S. and Japanese participants in the EEZ off Oregon and Washington in 1990 (June and Wilkins 1991). Four Japanese squid jigging catcher/processor vessels occupied 142 fishing stations during August and September. No marine mammals were observed to be directly affected by the fishing gear or operations. Marine mammals were observed in the vicinity of the squid fishing operations during daylight. Dall's porpoise, Pacific white-sided dolphins, unidentified seals, and Sei whales were observed in the vicinity of the vessels during night fishing operations, but none were observed interacting directly with the fishing gear. The Japanese fishing masters indicated that marine mammals are rarely, if ever, encountered during active fishing operations.

A jig fishery operates in the waters around southern Australia, and a Bycatch Action Plan was recently prepared for this fishery by the Australian Fisheries Management Authority (AFMA 2004). The AFMA observer program reported an interaction with a little penguin (hooked in the flipper). Seals sometimes follow the vessels in this fishery and take squid from the hooks but there are no reports of seal hooking or entanglement (AFMA 2004). One of the small-scale jig fisheries in Hawaii, targets purpleback squid fish in coastal waters, off western Kauai, relatively close to Hawaiian monk seal colonies, on the islands of Niihau and Kauai. It is uncertain whether Hawaiian monk seals might behave similarly to seals in southern Australia but there are no reports of hookings or entanglements of monk seals or any other marine mammals in Hawaii's small-scale jig fisheries (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Jan. 7, 2004).

Boat collisions with whales occur in the North Pacific but none have been reported in U.S. squid jig fisheries.

Seabirds

Squid is a primary prey item for albatrosses. The U.S. high-seas jig fishery for red flying squid and foraging habitat for Laysan and black-footed albatrosses are in the same oceanic fronts and transition zone of high biological productivity at latitudes north of Hawaii. Elevated squid concentrations attract these seabirds. Albatrosses feed close to the ocean surface, so are unlikely to be hooked on pointed jigs that are deployed 30-100m below the surface. However, seabirds may perch on the vessel waiting to plunge at squid near the surface, thereby becoming entangled. Depending on their size, seabirds that are accidentally entangled might a) break off the line, b) be pulled over the rollers onto the deck, or c) stop or break loose from the line at the rollers.

Squid jigging has been done at night when black-footed albatross are not feeding. Because of the bright lights used on high-seas jig vessels, large vessels may have two above-deck rows with 25-50 (2,000-4,000 watt) lamps per row. Some concerns have been expressed about Laysan albatross (which have better vision and may feed at night) becoming disoriented and colliding with squid vessels. The U.S. vessels recently have been fitted with submerged lights to allow for squid jigging at greater depth during daylight. Submerged lights during daytime squid jigging should not impact albatrosses. Offal discard during onboard processing of squid might also attract seabirds. Logbooks and anecdotal reports (B. Endreson, pers. comm. 10/03) from limited squid jigging in the North Pacific by four U.S. vessels provide no evidence of any interactions with seabirds.

In the cooperative squid jigging survey conducted by U.S. and Japanese participants in the EEZ off Oregon and Washington in 1990 (June and Wilkins 1991) no birds were observed to be directly affected by the fishing gear or operations.

The AFMA observer program reported that none of the seabirds (1 shy albatross and 2 shorttailed shearwaters) sighted near vessels jigging for squid in southern Australia were observed to interact with either the boats or fishing gear.

Small-boat fishermen use low-wattage surface and underwater lights to attract purpleback squid to lures deployed in coastal fisheries. (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA analyst, WPRFMC, Jan. 7, 2004). There are no reports of hookings or entanglements of seabirds in Hawaii’s small-scale jig fisheries (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Jan. 7, 2004).

Sea Turtles

Sea turtles migrate through the North Pacific Transition Zone where red flying squid are concentrated. Loggerhead turtles are particularly known to be attracted to squid. The Hawaii longlines swordfish fishery was re-opened in 2004 with a prohibition on squid bait. Loggerhead turtles obviously bite squid when it is baited on longlines hooks that are slowly drifting but whether a loggerhead turtle would chase squid hooked on jigs being more rapidly moved upward is uncertain. If accidentally hooked or entangled in this manner, a sea turtle would be brought to the surface. Depending on its size, sea turtles that are accidentally entangled might a) break off the line, b) be pulled over the rollers onto the deck, or c) stop or break loose from the line at the rollers. Some of the lures used in squid jig fisheries are luminescent in various colors. Whether any of the colors might attract sea turtles close enough to become entangled in jig gear is uncertain. Submerged lights are employed by large-scale U.S. jig vessels to allow day jigging for squid at greater depths than night jigging. Whether sea turtles might be attracted to underwater lights is uncertain.

Logbooks and anecdotal reports (B. Endreson, pers. Comm. 10/03) from limited squid jigging in the North Pacific by four U.S. vessels provide no evidence of any interactions with sea turtles. There are no reports of any hookings or entanglements of sea turtles in Hawaii's small-scale squid jig fisheries (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Jan. 7, 2004).

Fish

Squid jig fisheries have very low fish bycatch and are reported to be a highly selective fishing method (Rathjen 1993, Alverson et al. 1992 cited in Harris and Ward 1999). The most common fish bycatch by the high seas U.S. squid jig fleet are small numbers of blue shark whose weight often breaks the 30-60 lb test lines before the shark is boated (B. Endreson, pers. comm., 10/03). Four U.S. vessels submitted logbooks for limited squid jigging in the North Pacific during 2001- 2003. Only the logbooks for 2001 provide any records of bycatch, which consisted of small numbers of squid that dropped off the jigs before being boated and small numbers of blue shark that broke off the line before being boated. In the somewhat similar Australian fishery, the most common bycatch species includes small quantities of blue shark (*Prionace glauca*), garfish (*Hyporhamphus* spp.) and baracouta (*Thyrsites atun*) (AFMA 2004).

3.6.2 Overview of Hawaii's Pelagic Fisheries

This section examines the relative importance of Hawaii's pelagic fisheries in terms of catch, ex-vessel value and participation and which are summarized in Tables 6-9. The state's pelagic fisheries are unique and diverse. Hawaii-based longline vessels are capable of traveling long distances to high-seas fishing grounds, while the smaller handline and troll fisheries—which may be commercial, charter, recreational or subsistence—generally occur within 25 miles of land, with trips lasting only one day. All of Hawaii's pelagic fisheries are small in comparison with other Pacific pelagic fisheries such as distant-water purse seine fisheries and other foreign pelagic longline fisheries, but they comprise the largest fishery sector in the State of Hawaii. Tuna, billfish and other tropical pelagic species supply most of the fresh pelagic fish consumed by Hawaii residents and support popular recreational fisheries.

In recent years, Hawaii's commercial pelagic fisheries have been greatly affected by a series of legal decisions that resulted in federal regulatory measures. In 2001, total catch and ex-vessel value decreased by about 7.8 million lb and $20.1 million, respectively, primarily as a result of the implementation of litigation-driven management measures that eliminated the swordfish portion of the Hawaii longline fishery (Table 6). Swordfish, the largest component of the catch by volume in 2000, has been a negligible component since that year (Table 7) In recent years, bigeye tuna has been the most important pelagic species by both volume and value, followed by yellowfin tuna and albacore. As a result of an increase in the catch of bigeye tuna the ex-vessel value of landings in Hawaii's pelagic fisheries increased to about $46.7 million in 2003.

Table 6: Volume and Ex-vessel Value of Landings in Hawaii's Commercial Pelagic Fisheries by Major Gear Type, 1999-2003.
Source: WPFMC (2004a)

Year	Volume (1000 lb)				Ex-Vessel Value ($1000)			
	Aku (Pole-and-Line)	Longline	Troll-Handline	Total	Aku (Pole-and-Line)	Longline	Troll-Handline	Total
1999	1,310	28,350	6,310	36,058	1,740	49,300	10,650	61,690
2000	710	23,810	4,970	29,600	1,120	51,300	10,170	62,590
2001	990	15,550	5,220	21,760	1,380	33,400	7,720	42,500
2002	530	17,160	3,710	21,400	750	37,500	5,650	43,900
2003[1]	1,020	17,640	3,700	22,360	1,000	37,500	8,210	46,710

The longline fishery is the largest commercial fishery in Hawaii. In 2002, longline catch was 17.2 million lb worth $37.5 million (Table 6). Catch in the commercial troll and handline fisheries has been relatively stable in recent years, while catch in the skipjack tuna or aku fishery continues to show a declining trend. An estimate of the level of participation in Hawaii's commercial pelagic fisheries can be derived from data collected by the HDAR Commercial Marine License, which asks fishermen to identify their primary fishing gear or method at the time of licensing (Table 8). This does not preclude fishermen from using other gears or methods, but does indicate the primary fishing method. A total of 3,195 fishermen were licensed in 2002, including 2,025 who indicated that their primary fishing method would use fishing gear intended to catch pelagic fish. Most licenses that indicated pelagic fishing as their primary method were issued to trollers (72 percent) and longline fishermen (18 percent). The remainder were issued to ika shibi and palu ahi (handline) (8 percent) and aku (pole-and-line) boat fishers (2 percent). The total number of licenses issued and licenses indicating pelagic fishing decreased six percent from the previous year.

The pelagic fish resources in the EEZ around Hawaii also support important charter and recreational fisheries (Table 9). Participants in Hawaii's charter boat fishery primarily troll for billfish. In 2002, blue marlin formed about half of the total annual charter vessel catch by weight. Big game sportfishing rods and reels are used, with four to six lines trolled at any time with outriggers. Both artificial and natural baits are used. In addition to lures, trollers occasionally use freshly caught skipjack tuna and small yellowfin tuna as live bait to attract marlin, the favored landings for charter vessels, as well as yellowfin tuna. Charter fishing in Hawaii and elsewhere in the Western Pacific Region has elements of both recreational and commercial fishing. The primary motivation for charter patrons is recreation, while the charter vessel skipper and crew receive compensation in the form of patron fees and fish sales in local markets.

Table 7: Volume and Ex-vessel Value of Landings in Hawaii's Commercial Pelagic

Fisheries by Species, 1999-2002.
Source: WPFMC (2004a)

Species	1999		2000		2001		2002	
	Volume (1000 lb)	Ex-Vessel Value ($1000	Volume (1000 lb)	Ex-Vessel Value ($1000)	Volume (1000 lb)	Ex-Vessel Value ($1000)	Volume (1000 lb)	Ex-Vessel Value ($1000)
Bigeye Tuna	6,200	20,400	6,240	21,611	5,873	19,675	10,266	27,513
Yellowfin Tuna	4,000	8,100	4,833	12,343	4,145	9,492	2,462	5,589
Albacore Tuna	4,000	4,400	2,282	3,336	3,229	3,584	1,522	1,781
Skipjack Tuna	1,900	2,300	1,111	1,471	1,696	1,900	986	1,252
Blue Marlin	1,400	1,400	1,125	1,252	1,494	1,061	1,001	1,171
Striped Marlin	900	1,200	473	832	73	925	558	893
Swordfish	6,900	13,000	6,520	12,789	500	1,155	461	904
Mahimahi	1,300	2,800	1,543	2,987	1,191	1,918	1,164	2,223
Ono	1,000	1,700	673	1,549	922	1,558	620	1,364
Moonfish	1,200	1,400	693	1,109	756	930	915	1,226
Sharks	6,300	1,600	3,400	863	327	131	388	163
Other	920	1,150	808	1,186	749	866	1,049	1,275
Total	36,020	59,450	29,528	61,283	21,755	43,194	21,392	45,354

Table 8: Primary Fishing Method Reported on HDAR Commercial Marine Licenses, 1999-2002.
Source: WPFMC (2004a)

Fishing Method	1999	2000	2001	2002
Longline	546	553	465	367
Trolling	1,572	1,464	1,449	1,451
Ika shibi and palu ahi (handline)	199	190	163	164
Aku boat (pole-and-line)	62	41	44	43
Total pelagic	2,379	2,248	2,121	2,025
Total all methods	3,876	3,609	3,401	3,195

Table 9: Species Composition of Landings Made by Hawaii Charter Vessels, 2002.

Source: WPFMC (2004a)

Species Caught	Landings (lb.)	Percent
Mahi mahi	71,741	17.3
Skipjack tuna	18,712	4.5
Wahoo	31,115	7.5
Blue marlin	196,084	47.4
Yellowfin tuna	57,633	13.9
Other	38,069	9.3
Total	413,893	100.0

Hawaii's recreational fleet also primarily employs troll gear to target pelagic species. Although their motivation for fishing is recreational, some of these vessel operators sell a portion of their landings to cover fishing expenses and have been termed “expense” fishermen (Hamilton, 1999). While some of the fishing methods and other characteristics of this fleet are similar to those described for the commercial troll fleet, a survey of recreational and expense fishermen showed substantial differences in equipment, avidity and catch rates compared to commercial operations. Vessel operators engaged in subsistence fishing are included in this recreational category. An estimate of catch in Hawaii’s recreational pelagic fishery is available from the NOAA Fisheries Marine Recreational Fisheries Statistical Survey (MRFSS), which was reinitiated in 2001 following a 20 year gap. The survey indicated that boat-based recreational fishing resulted in the harvest of 11.2 million lb of pelagic species in 2002 (WPFMC, 2004a). The contributions by the six major pelagic species caught by boat-based recreational fishing are shown in Figures 4 and 5. Skipjack is the most commonly caught pelagic species taken by recreational fishermen in terms of numbers, but it is only a minor fraction of the catch by weight. Yellowfin tuna and blue marlin are the most important species in terms of weight.

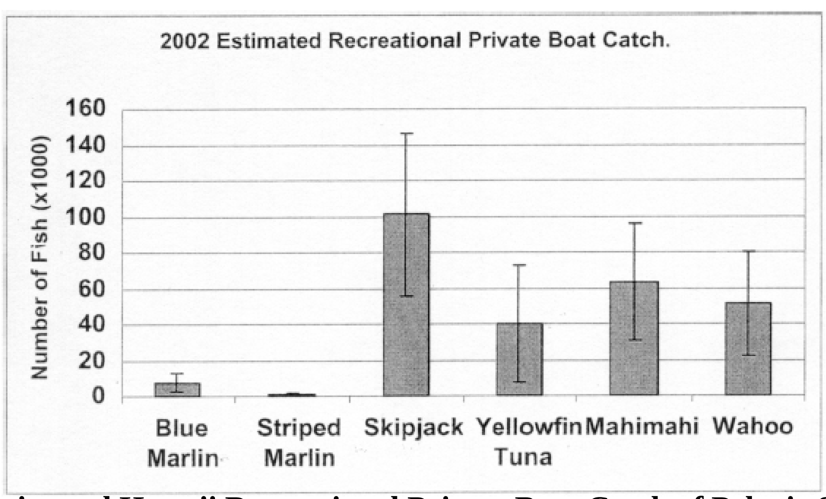

Figure 3: Estimated Hawaii Recreational Private Boat Catch of Pelagic Species by Number of Fish, 2002. Source: WPFMC (2004a)

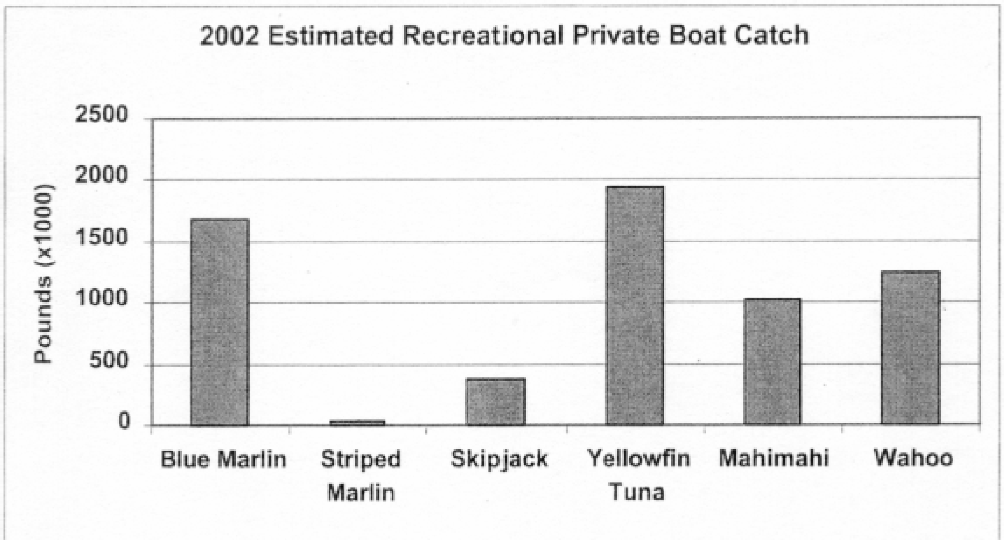

Figure 4: Estimated Hawaii Recreational Private Boat Catch of Pelagic Species by Weight of Fish, 2002. Source: WPFMC (2004a)

3.7 Sociocultural Setting and Fishing Communities

The following description of the sociocultural environment focuses on the pelagic fisheries that could be potentially affected by the proposed actions. These fisheries are the distant-water and Hawaii ika-shibi and near-shore squid fisheries.

3.7.1 Hawaii Sociocultural Setting

The squid species occurring around the Main Hawaiian Islands were known as *muheʻe* by the early Hawaiians (Titcomb, 1978). Although squid were eaten, they were not as popular as octopus (*heʻe*).[9] Squid also had mythological significance for early Hawaiians. The god Kanaloa was represented in the deep ocean depths by squid, octopus and certain kinds of seashells. A reference book on ancient Hawaiian myths by Beckwith (1970), which was published in 1940, stated that Hawaiian fishermen "still solicit [Kanaloa's] protection, but on the whole the squid is today looked upon with distrust as an aumakua." (p. 60).[10] Beckwith noted that, "This attitude is reflected in a tendency by Hawaiian antiquarians to equate Kanaloa with the Christian devil" (p. 60). The contemporary spiritual significance of Kanaloa is uncertain; however, the creation of a

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[9] In contemporary Hawaii the term "squid" is used indiscriminately to signify both squid and octopus (Titcomb, 1978).

[10] *ʻAumākua* are family or personal deities that can be called upon for protection, comfort, and spiritual support. An *ʻaumākua* can manifest itself in varying forms, including an animal, plant, or rock.

Web site (http://www.bluecoast.org/kanaloa.html) dedicated to the study of Kanaloa suggests a continuing interest in the deity.

As discussed in Section 3.7.3.3, commercial squid fishing in Hawaii was initiated in the 1920's by Japanese immigrants who brought squid fishing techniques from their native islands of Okinawa. The directed squid fishery has since largely disappeared, although a remnant continues as a small, artisanal fishery on Kauai. A description of this fishery is provided in Section 3.7.3.4. Although the Kauai-based directed squid fishery has been in existence since at least the immediate post-World War II era, only a few communities and social networks on Kauai are familiar with it (Itano, 2004). The squid caught in the fishery that are sold are typically marketed in local grocery stores.

Presently, there are 20 to 30 participants in the Kauai-based fishery (Itano, 2004). Many of the participants are elderly, with some individuals being 80 years of age or older. Itano (2004) estimated that about 50 percent of the participants have a Japanese ethnic background, 22 percent are of Filipino ancestry, 18 percent are of mixed Portuguese descent and 10 percent have a mixed Hawaiian ancestry. Catches of purpleback squid in the fishery generally remain within the community for home consumption (Itano, 2004). Another important function of the fishery is to provide a special food item for banquets, outdoor barbecues and large social gatherings. Squid is favored as a local delicacy, and fishermen sometimes fish to fulfill social obligations.

Squid also continues to be caught in the waters around the Big Island for bait in the ika shibi handline fishery. The ika shibi method of fishing for tuna evolved from the directed squid fishery and is currently employed by a few small-boat owner-operators targeting yellowfin tuna. A detailed description of the fishery is provided in Section 3.7.3.3.

The domestic distant-water squid jigging fishery in the Pacific is currently being conducted by a single operation reportedly operating in EEZ waters around New Zealand. Honolulu was listed on the HSFCA fishing permit as the hailing port of the four vessels involved in this operation, and the vessels occasionally called into Honolulu. However, the operation may be relying mostly on at-sea transshipment to deliver product to the Japanese market. The ethnic composition of the vessels' crews is unknown.

3.7.2 Fishing Communities

The Magnuson-Stevens Act defines a "fishing community" as "...a community that is substantially dependent upon or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew, and fish processors that are based in such communities" (Sec. 3 (16)). NMFS further specifies in the National Standard guidelines that a fishing community is "...a social or economic group whose members reside in a specific location and share a common dependency on commercial, recreational, or subsistence fishing or on directly related fisheries dependent services and industries (for example, boatyards, ice suppliers, tackle shops)".

In 1998, the Council identified the islands of American Samoa, the Northern Mariana Islands and Guam as fishing communities for the purposes of assessing the effects of fishery conservation and management measures on fishing communities, providing for the sustained participation of such communities, minimizing adverse economic impacts on such communities, and for other purposes under the MSA (64 FR 19067). In 2002, the Council identified each of the islands of Kauai, Ni'ihau, Oahu, Maui, Molokai, Lanai and Hawaii as a fishing community (68 FR 46112).

The city of Honolulu on the island of Oahu is the base of the longline and other industrial-scale fleets and the center of the state's fish marketing/distribution network (NMFS 2001a). However, the total number of pelagic fisheries-related jobs in the Honolulu metropolitan area compared to the overall number of jobs in the area is very small. Oahu contains approximately three-quarters of the state's total population, and over one-half of Oahu's residents live in the "primary urban center," which includes greater Honolulu. Thus, although Oahu has a high level of engagement in fishing and especially longline fishing relative to the other islands in Hawaii, the island's level of dependence on it is lower due to the size and scope of Oahu's population and economy.

The nature and magnitude of Hawaii communities' dependence on and engagement in pelagic fisheries have also been affected by the overall condition of the state's economy. As described in NMFS' 2001 and 2004 Final Environmental Impact Statements (NMFS 2001 and 2004a), tourism is by far the leading industry in Hawaii in terms of generating jobs and contributing to gross state product. In the first years of the new century Hawaii's tourism industry suffered major external shocks, including the September 11 terrorist attacks and SARS (severe acute respiratory syndrome) epidemic (Brewbaker 2003). The market for tuna weakened due to the decline in tourists arriving from Japan and elsewhere and due to a weak export demand. More recently, the decline in the value of the U.S. dollar compared with other currencies such as the Euro and the Japanese yen has made it more expensive for Americans to travel overseas and cheaper for foreign visitors to visit Hawaii. The weak U.S. dollar, combined with moderate growth in the national economy, is expected to help boost the state's tourism industry. Both domestic and international visitor counts have shown a general increasing trend (Brewbaker 2003). These improvements in Hawaii's tourist industry will likely have a positive economic effect on local businesses engaged in the harvesting, processing and marketing of pelagic fishery resources.

3.8 Administration and Enforcement

3.8.1 Permitting, Data Collection and Enforcement under the Pelagics FMP

Permitting

Permitting under the Pelagics FMP is accomplished by the Sustainable Fisheries Division of the Pacific Islands Regional Office. Permits are required for longline vessels, as well as troll and handline vessels fishing in EEZ waters around the PRIA. The only permit required to fish for squid in the high seas is an HSFCA permit; however these are currently unavailable as discussed in Section 1.5. There is currently no permit required to fish for squid in U.S. EEZ waters of the Western Pacific Region. However, any fishermen that commercially fishes for or sells squid in Hawaii must have a State of Hawaii Commercial Marine License. No permit or license is needed to fish for, land or sell squid in other U.S. areas in the Western Pacific Region.

A U.S. fishing vessel must be registered for use under general longline permit if that vessel is used: (1) to fish for PMUS using longline gear in the EEZ around American Samoa, Guam, the Northern Mariana Islands, or other U.S. island possessions in the Pacific Ocean; or (2) to land or transship, shoreward of the outer boundary of the EEZ around American Samoa, Guam, the Northern Mariana Islands or other U.S. island possessions in the Pacific Ocean, PMUS that were harvested with longline gear. In addition, a U.S. fishing vessel of the United States must be registered for use under a Hawaii longline limited access permit if that vessel is used: (1) to fish for PMUS using longline gear in the EEZ around Hawaii; or (2) to land or transship, shoreward of the outer boundary of the EEZ around Hawaii, PMUS that were harvested with longline gear. A receiving vessel must be registered for use with a receiving vessel permit if that vessel is used to land or transship, shoreward of the outer boundary of the EEZ, PMUS that were harvested with longline gear.

The Hawaii-based longline fishery is a limited-access fishery with a maximum of 164 permits. During 2002 (2002 Ann Rept), all 164 of the Hawaii-based permits were maintained, although 46 of these were held without vessels. In 2003, all 164 permits were maintained, 123 with vessels registered to them (PIRO, unpub. data).

In 2003, 66 General Longline Permits were issued, 64 for vessels in American Samoa, one in Guam and one in the CNMI (PIRO unpub. data). No PRIA troll and handline permits have been issued to date.

In 2002, the Council approved Amendment 11 to the Pelagics FMP, which is intended to create a limit access permit system for American Samoa's longline fishery. The intent of this action is to avoid gear conflicts in the American Samoa EEZ outside of the 50 nm area closed to large pelagic fishing vessels and to avoid overcapitalization in the fleet. The estimated maximum number of permits will be 138. To qualify for a permit an individual must have owned a vessel used to legally harvest PMUS in the EEZ around American Samoa prior to March 22, 2002. Permits would be established for four categories based on vessel length (less than 40 ft, 40-50 feet, 50-70 feet, and over 70 feet). "Upgrade permits" (26) will be available to permit holders in the smallest vessel size class. Vessels greater than 40 feet in length will be required to carry observers, if requested by NMFS. The final rule for this action was published on May 24, 2005 (70 FR 29646) with a final effective date of December 1, 2005.

Data Collection

Longline vessels based in Hawaii and American Samoa are required to submit federal logbooks recording their daily catch, effort, discards and protected species interactions. Operators of troll and handline vessels must maintain and submit similar federal logbooks. Participants in other pelagic fisheries in the region are required to comply with data collection programs maintained by the respective state or territories, as described below.

The requirement for completion of an HSFCA logbook when fishing on the high seas is satisfied by the federal Western Pacific Daily Longline Fishing Log. However, because there have been no specific HSFCA logbook for squid fishing, vessel operators have used a variety of logbooks and recorded a variety of information. For example, some report squid catches by species while others do not. The HSFCA logbooks were not collated and analyzed and their data was not routinely entered into a database system nor is it readily available to scientists or resource managers. According to a May 27, 2007 letter sent to the Council from NMFS's Pacific Islands Regional Administrator, NMFS is revising the HSFCA permit applications and logbooks to include squid jigging and to require the use of specific HSFCA squid fishing logbooks to record high seas catches.

Hawaii

State of Hawaii regulations require any person who takes marine life for commercial purposes, whether within or outside of the state, to first obtain a commercial marine license from the Hawaii Division of Aquatic Resources (HDAR). Every holder of a commercial marine license must furnish to HDAR a monthly catch report, including squid fishermen. Fish dealers are also required to report all sales, including squid, although there is no dealer permitting requirement and dealer reporting is incomplete. Any commercial albacore troll vessel that lands its catch in Hawaii is required to complete the HDAR Albacore Trolling Trip Report. Pole-and-line vessels in Hawaii are required to record their catches on the HDAR Aku Catch Report. Longline vessels are required to complete the NMFS Western Pacific Daily Longline Fishing Log, which requires recording of protected species interactions, and the HDAR Longline Trip Report.

All fishery participants who fish, or land at least one fish with an intent to sell, within 3 miles of the shoreline (i.e. within the state of Hawaii) are required to have an annually renewable Commercial Marine License (CML), and vessel operators are required to file state catch reports reporting the fishing effort, catch, discards, and landings and of all those onboard during each fishing trip. These data are reported below. There are no mandatory reporting requirements for recreational participants (those who do not sell one fish during the year). However in 2001 NMFS resumed its voluntary Marine Recreational Fishing Statistics Survey (MRFSS) in Hawaii. This is a random phone survey of all Hawaii households to determine statewide fishing participation rates. Also newly instituted are associated voluntary creel surveys (the Hawaii Marine Recreational Fishing Survey or HMRFS) conducted by State of Hawaii Division of Aquatic Resources' personnel to determine catch rates and species composition. The results from these two surveys are then combined to yield estimates of recreational catch and effort by both shore and land based fishermen. No final estimates for any year have yet been released.

Hawaii's seafood dealers are required to report to the Hawaii Division of Aquatic Resources the provenance (i.e. the CML number of the seller), weight and price of each fish which they buy. This provides a means to verify reported catches, to detect unreported catches, and to collect additional information regarding the weight and price of each fish. This relatively new requirement has yet to be fully implemented however it is believed that Hawaii's major fish dealers are now in compliance.

NMFS formerly administered a fish market sampling program in Honolulu. In cooperation with the state, staff from both NMFS and HDAR visited the fish auction managed by the United Fishing Agency and obtained size frequency and economic data on pelagic fish and bottomfish sold. These data are now submitted electronically to HDAR by the auction as part of the commercial marine dealer reporting system.

American Samoa

Longline vessels are required to complete the NMFS Western Pacific Daily Longline Fishing Log. Catch data for other fishing methods are collected through the Offshore Creel Survey administered by the Department of Marine and Wildlife Resources (DMWR) of the American Samoa Government. Under the pending longline limited entry program, operators of vessels over 40 feet in length will be required to carry federal observers if requested by NMFS. Since 1985, the Offshore Creel Survey conducted on the island of Tutuila has examined both commercial and recreational small boat trip catches at five designated sites. For two weekdays and one weekend day per week, DMWR data collectors sample offshore fishers between 0500 and 2100 hours. Two DMWR data collectors also collect fishing data on the islands of Tau and Ofu in the Manua Group.

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 Commercial Purchase System (receipt book) or in the Cannery Sampling Form. A Daily Effort Census is used to monitor the activity of the longline fleet. A vessel inventory conducted twice a year provides data on other vessel numbers and fishing effort.

Guam

An Offshore Creel Survey program administered by the Division of Aquatic and Wildlife Resources (DAWR) of the Government of Guam provides estimates of island-wide catch and effort for all the major fishing methods used in commercial and recreational fishing. In 1982, NMFS 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. Another major fish wholesaler and several retailers who make purchases directly from fishers also voluntarily provide data to WPacFIN using the Commercial Fish Receipt Book Program. That program, however, is not yet mandatory for local fish vendors. The Guam Department of Commerce also maintains a mandatory data submission program to monitor landings from foreign longliners transshipping their catch through Guam. In 200 the Guam Fishermen's Coop initiated the Guam

Volunteer Fishery Data Collection Project to provide additional information on the activities of its members.

Northern Mariana Islands

The Division of Fish and Wildlife (DFW) of the Commonwealth of the Northern Mariana Islands monitors the commercial fishery by summarizing sales ticket receipts from commercial establishments (commercial purchase database collection system). DFW staff, routinely distribute and collect invoice books from 80 participating local fish purchasers on the island of Saipan, including fish markets, stores, restaurants, government agencies and roadside vendors. Similar systems are being developed for Tinian and Rota.

The Western Pacific Fishery Information Network

The Western Pacific Fishery Information Network (WPacFIN) is a federal and state partnership for collecting, processing, analyzing, sharing and managing fisheries data from the Western Pacific Region. Through the cooperative efforts of the member agencies, WPacFIN provides fisheries data and information when, where, and in the quality needed by NOAA Fisheries and the and its various support groups to develop, implement, evaluate and amend FMPs for the region. WPacFIN assists island agencies in designing and implementing appropriate local fisheries data collecting, monitoring, analyzing and reporting programs, complete with associated microcomputer-based data processing systems, and helps promote data standards to facilitate information analyses and reports. WPacFIN manages the data used by the Pelagics Plan Team to produce the annual report for the Pelagics FMP.

Observer Program

The NMFS Hawaii Longline Observer Program implements field aspects of the Marine Mammal Protection Act, Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act. NMFS observers have been deployed in the Hawaii-based longline fishery since February 1994. Due to court decisions in recent years, observer coverage of the fleet has increased considerably.

The mission of the program is to observe and document all species caught, including sea turtles, seabirds, marine mammals, swordfish, tunas, sharks, and other non-target fishes and to collect selected biological specimens. In addition to protected species catch rates, the program has also gathered data on sea turtle life history. The program provides DNA samples, turtle morphometrics, and a means for gathering satellite telemetry data. Secondarily, data and tissue samples from target species (swordfish and tunas) are also collected.

More specifically, among other tasks, observers:

- identify protected species, target, and bycatch species by number and location;

- record incidental mortality and injury of sea turtles, and tally all sea turtle observations during fishing activity;
- dissect post-mortem marine species as instructed (gonads, stomachs, otoliths);
- record sea turtle life history data, and tag all live sea turtles without existing tags;
- record life history data on other selected marine species;
- collect data on vessel activity and fishing operations;
- review and enter all data into a computer data base when on-shore; and
- collection of bird/fishing vessel interaction data including observations of deployed deterrents.

Data are used to prepare annual reviews of BiOps, quarterly reports to the Western Pacific Fishery Management Council, and estimates of protected species interactions.

Enforcement

The USCG patrols the region with C-130 aircraft and surface vessels however, since 9/11 the Homeland Security mission has taken precedence over fisheries surveillance and enforcement activities. In FY02, the USCG flew approximately 800 hours of fisheries patrols, including 520 hours in the MHI, 8 hours in the NWHI, 105 hours in Guam and the CNMI, 56 hours in American Samoa, 15 hours in Palmyra Atoll/Kingman Reef, 49 hours in Jarvis Island, and 41 hours in Howland/Baker Islands. Over 1300 cutter hours of fisheries patrols were conducted in the region with almost 200 vessel boardings (133 U.S. and 63 foreign vessels).

Enforcement for the Hawaii-based longline fishery is facilitated by use of a Honolulu-based vessel monitoring system (VMS) operated by NMFS and USCG. A VMS is an automated real-time, satellite-based tracking system that obtains accurate and near-continuous position reports from vessels at sea. The VMS in Hawaii was established in 1994 to help enforce area closures around the Hawaiian Islands in which fishing with longline gear is prohibited. NMFS certifies the VMS system hardware and software aboard each vessel and assigns each VMS unit a unique identification number. VMS systems will also be required for longline vessels greater than 50’ in length under the American Samoa limited entry program.

Special Agents of NMFS’ Office of Law Enforcement (OLE) conduct investigations of alleged violations of NOAA statutes and regulations, including the Magnuson-Stevens Act, the Lacey Act, the Shark Finning Prohibition Act, the Marine Mammal Protection Act and the Endangered Species Act based on case packages forwarded from the Coast Guard.

3.8.2 Permitting, Data Collection and Enforcement under the High Seas Fishing Compliance Act

The High Seas Fishing Compliance Act of 1995 (HSFCA) (16 U.S.C. 5501 et seq.) establishes a system of permitting, reporting and regulation for all U.S. fishing vessels operating on the high seas. Applications for high seas permits are issued by NMFS Regional Offices. Permits are valid for five years. Permitted vessels must be marked, and operators must submit reports of fishing operations and catch. The only permit required to fish for squid in the high seas is an HSFCA permit; however these are currently unavailable as discussed in Section 1.5. There is currently no permit required to fish for squid in U.S. EEZ waters of the Western Pacific Region. Once HSFCA permits become available these will require the mandatory completion of logbooks for squid fishing.

The Act is enforced by the Secretary of Commerce and the Secretary of the department in which the Coast Guard is operating, using personnel and facilities of other federal or state agencies by agreement. Enforcement officers have enumerated powers, including searches, inspections, arrests and seizures of high seas fishing vessels used in violation of the Act and living marine resources taken unlawfully. Violators of the Act are liable for costs of storage, care and maintenance of living marine resources or other property seized in connection with the violation. Violations of the Act are subject to civil penalties of up to $100,000, with each day of a continuing violation a separate offense, and are also subject to criminal penalties. The Secretary may suspend, revoke, deny or impose additional conditions on a permit as a sanction for violation. High seas fishing vessels used, and living marine resources taken, in connection with a violation are subject to forfeiture to the U.S.

Chapter 4. Environmental Consequences of the Alternatives

Chapter 4 presents analyses of the impacts on the environment of the alternatives considered here (see Table 10). All alternatives apart from Alternative 3a were previously examined in the 2005 FEIS, which contains additional details on the impacts of these alternatives.

Table 10. Summary of Alternatives Considered in Detail

Alternative	Description
Alternative 1– No Action	Does not implement any new measures , do not actively manage domestic harvests of Pacific pelagic squid
Alternative 2– Improve Voluntary Monitoring	Provide voluntary observers and improved logbooks
3 – Establish Domestic Management Mechanisms, Improve Mandatory Monitoring via Extended Reporting Requirements,	Designate squid as PMUS. Replace HSFCA logbooks currently used with HSFCA logbooks specifically designed for squid harvesting and require operators of U.S squid vessels permitted under the HSFCA to also include any EEZ fishing in this logbook. Require vessels that harvest pelagic squid solely in EEZ waters to either use this logbook or to participate in local reporting systems.
3a – Establish Domestic Management Mechanisms, Improve Mandatory Monitoring via Extended Permitting and Reporting Requirements	Improve mandatory monitoring and establish mechanisms for management by including the following pelagic squid species, *O. bartramii, Thysanoteuthis rhombus* (Troschel 1875) and *S. oualaniensis,* as Pelagic Management Unit Species. Replace HSFCA logbooks currently used with logbooks specifically designed for squid fishing. [Note: although HSFCA logbooks are not managed under the MSA, in response to the Council's concerns NMFS began revising these logbooks in March 2007]. Require U.S. vessels greater than 50 ft in length overall that fish for pelagic squid in U.S. Pacific EEZ waters to obtain federal permits under the Pelagics FMP to carry observers if requested by NMFS and to report their high sea catch and effort using Pelagics FMP logbooks. Require these vessels to also report any U.S. Pacific EEZ pelagic squid catch and effort either in federal Pelagics Fishery Management Plan logbooks or to via

	existing local reporting systems. Centralize this data into a database easily available to resource scientists and managers.
4 - Improve Mandatory Monitoring, Establish Management Mechanisms	Develop new Squid FMP, require vessel operators that harvest squid solely in EEZ waters to participate in local reporting systems.
5 – Improve Mandatory Monitoring, Establish Mechanisms for both Domestic and International Management	Pursue action via participation in international agreements

4.1 Impacts on the Pelagic Environment

Squid vessels have the typical discharges associated with any ocean-going vessel, including bilge water, sanitary waste, garbage, etc. They also discharge offal from the on-board processing of the squid. For all the alternatives, the impacts to EFH and HAPC from the fishing gear and practices describe elsewhere in section 3.6.1.2, for the high seas jig fishery would have little to no impact on EFH or HAPC. Potential impacts would also be temporary and minimal. The coastal squid jig fishery may discharge a small amount of offal or spent bait, but these impacts would be temporary and minimal. Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, no additional adverse impacts to EFH or HAPC would be anticipated under the preferred alternative and no EFH consultation is required.

4.2 Impacts on Squid

The alternatives considered are not designed to limit fishing mortality of squid, but rather to increase our understanding of the fishery and the condition of the squid resources so that appropriate control measures may be instituted at some future time should the condition of the resources require it. Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, none of the action alternatives would be expected to change the impacts of U.S. vessels on squid resources in the short term. Impacts on the resource base could increase with increased future effort. This is why increasing our understanding of the status of the stocks and fishing mortality would be an important outcome of this action.

4.3 Impacts on PMUS and Non-PMUS

Squid jig fisheries have very low fish bycatch and are reported to be a highly selective fishing method (Rathjen 1993, Alverson et al. 1992 cited in Harris and Ward 1999). The most common fish bycatch by the high seas U.S. jig fleet are small numbers of blue shark whose weight often pulls them off the jigs before they are boated (B. Endreson, pers. Comm., 10/03). Logbooks from a limited 2001 jigging season in the North Pacific by four U.S. vessels indicate that squid, species unidentified but presumably non-marketable species, are also discarded in small numbers. In the somewhat similar Australian fishery, the most common bycatch species includes small quantities of blue shark (*P. glauca*), garfish (*Hyporhamphus* spp.) and baracouta (*T. atun*) (AFMA 2003).

It is unlikely that any of the alternatives would have a significant direct or indirect impact on PMUS or non-PMUS. The bycatch in the squid jigging fishery is reported to be extremely small (Alverson et al., 1992 cited in Harris and Ward, 1999).

Participants in the small boat squid fishery within the U.S. EEZ around Hawaii use a single monofilament handline spooled on a wooden handreel (Itano, 2004) and not the multiple rows of automatic jiggers employed by high seas fisheries. Although these small vessels fish for squid off the coast of western Kauai close to Hawaiian monk seal colonies on Kauai and Niihau, they present no more risk to monk seals than other fishermen deploying handlines for pelagics or bottomfish.

As discussed above and in Section 3.6.1.6 there do not appear to be substantive bycatch issues in the fishery. Alternative 3a would include *O. bartramii, T. rhombus* and *S. oualaniensis* as part of the Pelagic Management Unit, require federal permits for vessels greater than 50 ft in length targeting these squid and require all U.S. vessels fishing for these species in the Pacific to report their catches, either through HSFCA logbooks for high seas catches, or through federal logbooks or local reporting systems for catches made in U.S. EEZ waters. Vessels over 50 ft in length would also be required to carry observers if requested by NMFS. These measures would have no impacts on either targeted, incidental or bycatch species but would improve documentation of total catch (including bycatch) by these vessels and allow collection of additional biological data thereon. Alternative 4 would also enhance the collection of data on bycatch by implementing a separate FMP and requiring vessels targeting squid in U.S. EEZ waters to participate in local reporting systems, while high seas catches would be reported through HSFCA logbooks. By establishing pelagic squid as management unit species Alternatives 3, 3a, and 4 would all create mechanisms for the implementation of additional control measures should they become necessary, via adaptive management under the MSA process.

4.4 Impacts on Seabirds

Squid is a primary prey item for albatrosses, and their feeding area is likely to include the high seas jigging grounds north of Hawaii. However, commercial concentrations of red flying squid sought by the jig fishery currently occur far from the Northwestern Hawaiian Islands, where Laysan and Black-footed albatross nesting habitats attract the highest densities of these seabirds. It is noted that shifts in oceanographic conditions may displace the target species to the south –a displacement in the proximity to nesting sites and/or migration routes may increase the possibility of interactions between squid jigging vessels and birds.

Albatrosses feed close to the ocean surface, so are unlikely to be hooked on pointed jig hooks that are deployed below the surface. Squid jigging is occurs mostly at night when albatross are not feeding but because of the bright lights used on high-seas jig vessels, some concerns have been expressed about seabirds becoming disoriented. Offal discard during onboard processing of squid might also attract seabirds. Logbooks and anecdotal reports (B. Endreson, pers. Comm. 10/03) from a limited 2003 jigging season in the North Pacific by four U.S. vessels provide no evidence of any interactions with seabirds.

The AFMA observer program reported that none of the seabirds (1 shy albatross and 2 short-tailed shearwaters) seen by observers on vessels jigging for squid in southern Australia were observed to interact with either the boats or fishing gear.

Small-boat fishermen use low-wattage surface and underwater lights to lure purpleback squid to jigs deployed in coastal waters. (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA analyst, WPRFMC, Dec. 7, 2004). No hookings or entanglements of seabirds in small-scale jigging gear were reported by a researcher who made several trips on small-scale vessels squid jigging off Kauai and tuna fishing and squid jigging off the island of Hawaii (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Dec. 7, 2004).

Based on the above information presented here and in the 2005 FEIS, as compared to the No-Action alternative, none of the action alternatives considered would be anticipated to have any impacts on seabird populations.

4.5 Impacts on Sea Turtles

Loggerhead sea turtles migrate through the band of North Pacific ocean where red flying squid are concentrated. This species of sea turtle is known to be attracted to squid. The Hawaii longline swordfish fishery was re-opened in 2004 with a prohibition on squid bait as one of the conditions for re-entering the fishery. Loggerhead turtles obviously bite squid when it is baited on longline hooks that are slowly moving but whether a loggerhead turtle would have the mobility to chase a squid hooked jigs being moved more rapidly up and down is uncertain. Some of the lures used in squid jig fisheries are luminescent in various colors. Whether luminescent lures might attract sea turtles close enough to become entangled in jig gear is uncertain.

Logbooks and anecdotal reports (B. Endreson, pers. comm. 10/03) from a limited 2003 jigging season in the North Pacific by four U.S. vessels provide no evidence of any interactions with sea turtles; nor are any hookings or entanglements of sea turtles in small-scale jigging gear reported by a researcher who made several trips on small-scale vessels squid jigging off Kauai and tuna fishing and squid jigging off the island of Hawaii (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Dec. 7, 2004).

Alternative 3a's federal permitting, reporting and observer requirements would improve documentation of total catch by large vessels and allow collection of additional biological data thereon, including any potential or actual interactions with sea turtles. Alternative 4 would implement a separate FMP and require vessels targeting squid in the U.S. EEZ to participate in local reporting systems, while high seas catches would be reported through HSFCA logbooks. By establishing pelagic squid as management unit species Alternatives 3, 3a and 4 would all create mechanisms for the implementation of additional control measures should they become necessary, via adaptive management under the MSA process.

Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, none of the action alternatives considered would be anticipated to have any impacts on sea turtle populations.

4.6 Impacts on Marine Mammals

Some species of marine mammals prey on *O. bartramii* and therefore might approach jigging vessels. Some species of marine mammals might be accidentally hooked as they attempt to steal squid caught on jigs. Dolphins and small-toothed whales are adept at not being hooked on slowly drifting hook-and-line gear while obtaining such food subsidies but jigging gear is constantly moving up and down to attract squid. More likely than hooking is that an active marine mammal searching for squid beneath large-scale vessels could become entangled in several jig lines because of their close spacing on large vessels (21-38 jig machines per vessel). Logbooks and anecdotal reports (B. Endreson pers. comm. 10/03) from a limited 2003 jigging season in the North Pacific by four U.S. vessels provide no evidence of any interactions with marine mammals.

A jig fishery operates in the waters around southern Australia, and a draft Bycatch Action Plan was recently prepared for this fishery by the Australian Fisheries Management Authority (AFMA 2003). The AFMA observer program reported an interaction with a little penguin (hooked in the flipper). Seals sometimes follow the vessels in this fishery and take squid from the hooks but there are no reports of seal hooking or entanglement (AFMA 2003). Small-scale vessels targeting purpleback squid fish in coastal waters off western Kauai, relatively close to Hawaiian monk seal colonies on the islands of Niihau and Kauai. It is uncertain whether Hawaiian monk seals might behave similarly to seals in southern Australia but no hookings or entanglements of monk seals or any other marine mammals in small-scale jigging gear were reported by a researcher who made several trips on small-scale vessels squid jigging off Kauai and tuna fishing and squid jigging off the island of Hawaii (D. Itano, fishery biologist, pers. comm. to Tony Beeching, NEPA fisheries analyst, WPRFMC, Dec. 7, 2004).

As discussed above, this fishery use a single monofilament handline spooled on a wooden handreel (Itano, 2004), not the multiple rows of automatic jiggers employed by high seas fisheries.

Alternative 3a's federal permitting, reporting and observer requirements would improve documentation of total catch by large vessels and allow collection of additional biological data thereon, including any potential or actual interactions with marine mammals. Alternative 4 would implement a separate FMP and require vessels targeting squid in the U.S. EEZ to participate in local reporting systems, while high seas catches would be reported through

HSFCA logbooks. By establishing pelagic squid as management unit species Alternatives 3, 3a and 4 would all create mechanisms for the implementation of additional control measures should they become necessary, via adaptive management under the MSA process.

Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, none of the action alternatives considered would be anticipated to have any impacts on marine mammal populations.

4.7 Impacts on Fishery Participants and Communities

None of the alternatives considered would have significant impacts on fishery participants or communities as they range from no action to a new requirement for vessels greater than 50 ft in length overall to obtain federal permits, submit federal catch reports, and to carry federal observers if requested by NMFS. These requirements are not expected to have major impacts on fishery participants and communities assuming that the costs of deploying (paying, insuring and feeding) observers will be paid by NMFS (as has been the case in the Western Pacific Region to date). However vessel operators would incur some indirect costs due to the observer requirement. Limited bunk or deck space may require vessel operators to reduce the number of crew in order to accommodate observers, resulting in a decrease in the operating efficiency of the remaining crew. There may be additional costs if vessel operators choose to carry additional liability insurance (beyond that provided by NMFS for its observers). These costs would vary between individual vessels depending on the insurance carriers' minimum allowed coverage period, and the coverage approach that is taken.

Preferred Alternative 3a would carry minor additional regulatory costs for the owners and/or the operators of domestic squid jigging vessels greater than 50 ft in length overall as they would be required to obtain federal permits and to either submit federal logbooks or participate in local reporting systems. The minimum vessel length of 50 feet was selected because this is the approximate lower size limit for commercial squid vessels that fish in the U.S. EEZ and on the high seas, and the smallest size that could readily accommodate observers. Smaller vessels may conduct commercial squid fishing nearer to shore in Hawaii, and their commercial catch is already reported on State commercial catch reports. In other areas, local creel census or commercial sales invoices provide information on the squid catch by smaller vessels. However FMP inclusion of pelagic squid as management unit species under Alternatives 3, 3a and 4 would facilitate the effective management of squid fisheries, thereby contributing to their long-term sustainability and that of the fishery participants and communities that rely upon them. The Pelagics FMP requires that a stock assessment and fishery evaluation (SAFE) report be prepared each year which provides information on the stock status, fishing effort, harvests, bycatch and other factors for each managed species (PMUS). The SAFE reports are intended to summarize the best available scientific information concerning the past, present and future condition of the stocks, marine ecosystems, and fisheries under the Council’s management. This information forms the basis for establishing measures applicable to the fishery which are necessary and appropriate for its conservation and management.

Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, the preferred alternative will provide for the sustained participation of fishing communities by helping to ensure the long-term availability of Pacific pelagic squid.

4.8 Impacts to Administrative and Enforcement Costs

Given the small size of the fisheries involved, additional reporting and permitting costs under all the action alternatives are expected to be relatively low as compared to the No-Action alternative. Alternatives that would implement additional Pelagic FMP federal logbooks for some EEZ vessels, (Alternatives 2 and 3, 3a) would require that appropriate logbooks be designed and distributed, and that the resultant data be collated and analyzed. Alternative 3a would continue to rely on local reporting systems for EEZ squid jigging vessels less than or equal to 50 ft in length overall which would not entail any additional administrative burden. It is anticipated that Pelagic FMP logbooks and permit applications implemented under Alternative 3a would be similar in type to those now in use and that their design would therefore not require extensive resources. Clearly those alternatives that involve voluntary reporting (Alternative 2) would not affect enforcement costs, while those that require mandatory federal reporting (Alternatives 3, 3a) would. Optional electronic reporting has been recommended by the Council in a separate action and is currently in the process of being implemented by the NMFS.

Alternative3a would require that operators of squid jigging vessels greater than 50 ft in length carry federal observers if requested by NMFS (Alternative 2 would make this a voluntary measure). Specific administrative costs are unknown as the appropriate level of observer coverage has not been determined, however they would consist of the costs of deploying and supporting the observer as well as collating and analyzing the resultant data. It has been estimated by NMFS' PIRO (Lewis VanFossen, NMFS PIRO pers. comm.) that observer deployments cost about $400/day.

Alternatives 3, 3a and 4 would involve incorporating pelagic squid into the Council's Pelagic FMP or establishing a new Squid FMP (Alternative 4). Adding species of squid to any FMP would trigger all of the administrative activities and costs required under the MSA including the collection of fishery data discussed above, and inclusion of these data in the FMP's annual SAFE report. Creating a new FMP for squid would incur greater administrative costs than including them in an existing FMP because a new plan team would need to be established and an entire annual SAFE report written for this fishery.

The administrative and enforcement costs of Alternative 5 remain unquantified as they would be determined after agreement on a management regime in a future international forum. Although unquantified, the management of squid under Alternative 5 is not expected to result in significant costs for administration and enforcement because the size of the high seas U.S. squid jigging fleet is relatively small.

4.9 Environmental Justice

Based on the information presented here and in the 2005 FEIS, as compared to the No-Action alternative, none of the action alternatives would have a disproportionately high or adverse impact on minority or low-income populations. All of the action alternatives are intended to promote the long-term sustainability of Pacific pelagic squid and continued opportunities for U.S. squid jigging fishermen to catch pelagic squid. Potential impacts to fishermen are largest for those who own or fish from vessels over 50 ft in length, and these impacts are not considered significantly adverse. Additionally, the provisions for permits, reporting, and observers upon request, would apply evenly to all fishery participants who meet these criteria.

4.10 Climate Change

The global mean temperature has risen by 0.76°C over the last 150 years, and the linear trend of temperature over the last 50 years is nearly twice that for the last 100 years (IPPC 2007a). Ample evidence now exists supporting the wide-ranging ecological impacts of global climate change (Walther et al. 2002). Observed changes in marine systems are associated with rising water temperatures, changes in ice cover, salinity, oxygen levels, circulation, and ocean acidity. Changes to marine systems include shifts in ranges; changes in algal, plankton, and fish abundance (IPPC 2007b); and damage to coral reefs (Scavia et al. 2002), and other impacts.

In general, it has been shown that large scale climate cycles can impact winds, currents, ocean mixing, temperature regimes, nutrient recharge, and affect the productivity of all trophic levels in the North Pacific Ocean (Polovina et al., 1994). These impacts are expressed as variability in stock size, recruitment, growth rates, or other factors. Pelagic squid stocks and the fishery, as well as protected species that interact with the fishery, are currently affected by these large-scale climate fluctuations and would continue to be affected in the same way under each of the alternatives.

This FMP amendment and its alternatives consider a range of management measures that would monitor and manage fishing for pelagic squid stocks. All of the action alternatives, including the preferred alternative, would provide enhanced fishery data to fishery managers which would improve the effectiveness of fishery management. Improved data from the pelagic squid jig fishery would also help managers detect and respond to any changes in target and non-target species, bycatch, and protected resources. Ongoing research on fish stocks and protected species including sea turtles, marine mammals, and seabirds will continue under all of the alternatives, and will help scientists and fishery managers to detect changes in the status, distribution and interactions between the fishery and these resources of management concern. Adjustments to the fishery would be made, as needed, to ensure that the fishery is sustainable.

Climate change would not adversely affect the Council's ability to achieve the management objectives of this proposed amendment. Future impacts of climate change have been considered in view of the potential cumulative impacts on fishery target and non-target species and protected resources. Continuing research, improved fishery data collection and analysis, coordination with NMFS on the impact of fisheries on protected resources, and adaptive fishery management will help to ensure long-term sustainability of the fishery, even in light of potential climate changes.

Chapter 5. Consistency with Other Laws and Statutes

5.1 National Standards for Fishery Conservation and Management

National Standard 1 states that conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

The preferred alternative is consistent with National Standard 1 because it will strengthen current data collection systems and management mechanisms. By including pelagic squid species under the Pelagics FMP, these species will be subject to the same overfishing control rules, reference points and definition of optimum yield (OY) established in the fishery management plan. The FMP recognizes that catches of pelagic species in the U.S. EEZ of the Western Pacific are part of larger pan-Pacific or regional stocks, and defines their OY as the volume of fish that can be harvested within the U.S. EEZ by U.S. fisheries. This applies equally to pelagic squid as to pelagic finfish. In the short-term the preferred alternative is not expected to have a significant impact on fish stocks or optimum yield however in the long-term it will ensure that the fishery achieves optimum yield without overfishing.

National Standard 2 states that conservation and management measures shall be based upon the best scientific information available.

The best available scientific information relative to squid is insufficient to assess current stock status or establish the biological parameters necessary to guide further management. However, existing landings data do indicate an ongoing domestic harvest of the species. As a result, more information is necessary to support an assessment of stock status and guide future management of the species. The preferred alternative is therefore consistent with National Standard 2 because it will strengthen current data collection systems through the use of federal permits, logbooks and the ability to place federal observers on board vessels. The resultant data will increase our scientific understanding of the marine environment, the domestic squid fishery and its impacts.

National Standard 3 states that, to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

The preferred alternative is consistent with National Standard 3 because it will strengthen the coordinated management of Pacific squid fisheries by including squid in the Council's Pelagics FMP. Improved data collection will allow estimates of MSY and improve evaluations of stock status. Both of these will allow improved management of pelagic squid. The preferred alternative is also consistent with National Standard 3 because it would include stocks of fish for which there is not enough information to specify MSY and OSY.

National Standard 4 states that conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be (A) fair and equitable to all such fishermen; (B) reasonably calculated to promote conservation; and (C) carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

The preferred alternative is consistent with National Standard 4 because it does not discriminate between residents of different states, nor does it allocate fishing privileges. However the increased reporting requirements will ensure that all EEZ harvests, as well as high seas harvests, are recorded and this will assist in the equitable distribution of future allocations should such measures become necessary.

National Standard 5 states that conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no measure shall have economic allocation as its sole purpose.

The preferred alternative is consistent with National Standard 5 because it will not alter current fishing operations or affect their efficiency.

National Standard 6 states that conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

This action does not have substantial implications for National Standard 6, because it is not regulating catch, and only establishes permitting and reporting requirements for the domestic squid fisheries, which does not effect variation among fisheries. However, the preferred alternative is consistent with National Standard 6 because it addresses data deficiencies for vessels that target squid which may be used in future actions to address variations and contingencies in, fisheries, fishery resources, and catches

National Standard 7 states that conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

The preferred alternative is consistent with National Standard 7 because it will improve data collection and management mechanisms for these operations with the least duplication of existing systems.

National Standard 8 states that conservation and management measures shall, consistent with the conservation requirements of the MSFCMA (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities.

The preferred alternative is consistent with National Standard 8 because it will not constrain participation in domestic squid fisheries, and its increased data collection and management mechanisms will contribute to the long-term sustainability of Pacific pelagic squid resources.

National Standard 9 states that conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided minimize the mortality of such bycatch.

The preferred alternative is consistent with National Standard 9 because it will have no adverse impact on bycatch, and will establish mechanisms by which such bycatch will be assessed. However, it is important to note that there is no information currently indicating that bycatch is a problem in these fisheries.

National Standard 10 states that conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

The preferred alternative is consistent with National Standard 10 because it will not alter current fishing operations or create situations which would jeopardize human safety at sea.

5.2 Regulatory Flexibility Act

The Regulatory Flexibility Act, 5 U.S.C. 601 et seq. (RFA) requires government agencies to assess the impact of regulatory actions on small businesses and other small organizations. The basis and purpose of this rule are described in Section 1. Under the preferred alternative described in Section 2, this rule is anticipated to potentially apply to the one recently active high seas domestic squid jigging operation as well as the one to three ika shibi operators currently active in Hawaii and the 20-30 participants in the Kauai-based squid fishery (see Section 3.6.1.2 for a description of these fishing operations). Based on the estimated revenues reported for these fisheries, (see Section 3.6.1.2) all these potentially affected operations are classified as “small entities” as their annual revenues are believed to be below the $4 million threshold set for this determination. This is definitely the case for the nearshore fishery, complete information on the revenue of the high seas squid jigging operation is unavailable. Also potentially affected will be an unknown number of future participants in these fisheries.

The largest potential impact to affected participants is the observer requirement for vessels greater than 50 ft in length overall contained in the preferred alternative. The minimum vessel length of 50 feet was selected because this is the approximate lower size limit for commercial squid vessels that fish in the U.S. EEZ and on the high seas, and the smallest size that could readily accommodate observers. Assuming that the costs of deploying (paying and feeding) observers would be paid by NMFS (as has been the case in the Western Pacific Region to date), vessel operators will still incur some indirect costs. Limited bunk or deck space may require vessel operators to reduce the number of crew in order to accommodate observers, resulting in a decrease in the operating efficiency of the remaining crew. There may be additional costs if vessel operators choose to carry additional liability insurance (beyond that provided by NMFS for its observers). These costs would vary between individual vessels depending on the insurance carriers' minimum allowed coverage period, and the coverage approach that is taken. The number of entities that will be required to carry observers is unknown as the appropriate level of observer coverage has not been determined however given that no vessels of this size have fished for pelagic squid in Pacific U.S. EEZ waters to date, this burden may be minimal. It is possible that a squid fishery observer program could operate on an intermittent basis if the low levels of bycatch and protected species interactions believed to occur are confirmed. The remaining aspects of the preferred alternative consist of the requirement for vessels greater than 50 ft in length overall to obtain federal permit and to either complete new federal logbooks or to participate in local reporting systems. Because there are no fishery management controls associated with this measure that affect the operations of the fishery other than potentially carrying observers, significant impacts to the profitability of a substantial number of small entities are not anticipated and there will be no disproportionate impact between gear types, vessels or port of landing.

Based on the minor impact of these measures on potentially affected current and future fishery participants, the Council believes that this action is not significant (i.e. it will not have a significant impact on a substantial number of small entities) for the purposes of the Regulatory Flexibility Act and no Initial Regulatory Flexibility Analysis has been prepared.

5.3 Executive Order 12866

In order to meet the requirements of Executive Order 12866 (E.O. 12866) a Regulatory Impact Review must be prepared for all significant regulatory actions that are of public interest. This review provides an overview of the problem, policy objectives, and anticipated impacts of the proposed action, and ensures that management alternatives are systematically and comprehensively evaluated such that the public welfare can be enhanced in the most efficient and cost effective way. A description of management objectives is found in Section 1.6 of this document, a description of the alternatives is found in Chapter 2, and a description of the fishery is found in Section 3.6.1.2. None of the alternatives are expected to have significant impacts on effort or catches of commercial, recreational or charter fishermen in the Western Pacific region. The no action alternative for this action represents no change to the economy since the status quo would be maintained. Net economic benefits to the economy under the preferred alternative are indeterminate since information obtained from improved data collection could have many applications for management purposes and produce different aggregate benefits depending on its use. The Council believes that the preferred alternative is likely to yield net economic benefits by improving the scope and timeliness of available data on domestic harvests of Pacific pelagic squid. Inclusion of squid in the Council's Pelagics FMP will provide a mechanism for management of the Nation's Pacific pelagic squid resources and contribute to their long-term sustainability. Changes to the HSFCA permit applications and logbooks will increase the available information on high seas domestic squid jigging vessels and on vessels larger than 50 ft fishing that fish in U.S. EEZ waters of the Western Pacific region, as will the observer requirement for both fishery sectors.

In accordance with E.O. 12866, the following is set forth: (1) This rule is not likely to have an annual effect on the economy of more than $100 million or to adversely affect in a material way the economy, a sector of the economy, productivity, jobs, the environment, public health or safety, or state, local, or tribal governments or communities; (2) This rule is not likely to create any serious inconsistencies or otherwise interfere with any action taken or planned by another agency; (3) This rule is not likely to materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights or obligations of recipients thereof; (4) This rule is not likely to raise novel or policy issues arising out of legal mandates, or the principles set forth in the Executive Order. Based on these findings, this rule is believed not be significant under E.O. 12866.

5.4 Coastal Zone Management Act

The Coastal Zone Management Act requires a determination that a recommended management measure has no effect on the land or water uses or natural resources of the coastal zone or is consistent to the maximum extent practicable with the enforceable policies of an affected state's approved coastal zone management program. A copy of this document will be submitted to the appropriate government agencies in the Western Pacific Region for review and concurrence with a determination that the recommended measure is consistent, to the maximum extent possible, with each area's coastal zone management program.

5.5 Endangered Species Act

Species listed as endangered or threatened under the Endangered Species Act (ESA) that have been observed in the area where fishing vessels managed under the Pelagics FMP operate are as follows:

Species listed as endangered
Short-tailed albatross (*Phoebastria albatrus*)

Hawaiian monk seal (Monachus schauinslandi)
Pacific olive ridley turtle *(Lepidochelys olivacea*) –Mexico nesting population
Leatherback turtle (*Dermochelys coriacea*)
Hawksbill turtle (Eretmochelys imbricata)
Green turtle (*Chelonia mydas*) - Florida and Pacific coast of Mexico breeding populations only
Humpback whale (Megaptera novaeangliae)
North Pacific Right Whale (*Eubalaena japonica*)
Sperm whale (Physeter macrocephalus)
Blue whale (Balaenoptera musculus)
Fin whale (*B. Physalus*)
Sei whale (*B. Borealis*)

Species listed as threatened
Loggerhead turtle (*C. caretta*)
Other Pacific nesting populations of Pacific olive ridley (*L. olivacea*) and green turtles (*C. mydas*)

Although blue whales, fin whales, northern right whales, and sei whales are found within the area and could potentially interact with the Pelagics FMP fisheries, there have been no reported or observed incidental takes of these species in these fisheries. Therefore, these species are not discussed in this document.

The only listed species of seabirds that may interact with the fisheries managed under the Pelagics FMP is the short-tailed albatross, however, no interactions have been observed for any fishery sectors. Other listed species known to interact with the Hawaii longline fishery and which may potentially interact with other fisheries managed under the Pelagics FMP are the leatherback turtle, loggerhead turtle, green turtle, olive ridley turtles, and hawksbill turtles. A Biological Opinion completed in February 2004 by NMFS (NMFS, 2004b) concluded that the fisheries managed under the Pelagics Fishery Management Plan are unlikely to jeopardize the continued existence of threatened and endangered species in the Western Pacific. At that time, squid were not included in the Pelagics FMP and thus the near-shore and high seas domestic squid jigging operations considered here have not been considered in any ESA consultations to date. Based on available information (see Section 3.6.1.6), interactions with listed species are low to non-existent in both sectors, and therefore the Council believes that the fisheries and preferred alternatives discussed here will not adversely impact any threatened or endangered species, however NMFS may initiate a consultation on these actions under section 7 of the ESA.

Under the preferred alternatives, domestic squid jigging fishery participants on vessels greater than 50 ft in length will be required to obtain federal permits, report any interactions with listed species, and carry federal observers if requested by NMFS. This would provide researchers and managers with improved data and understanding of the type and frequency of any protected species interactions. However it is anticipated that NMFS will conduct an ESA consultation on the Pacific domestic squid jigging fishery to determine its impacts to protected species under the measures recommended here (NMFS 2006).

5.6 Marine Mammal Protection Act

With the exception of the Hawaii-based longline fishery (Category I), all other fisheries managed by the Pelagics FMP are Category III fisheries under Section 118 of the Marine Mammal Protection Act of 1972 (62 FR 28657, May 27, 1997) effective September 9, 2004 (69 FR 48407, August 10, 2004). This means that interactions between marine mammals and the region's non-longline boat pelagic fisheries are believed to be rare.

Marine mammals not listed as endangered or threatened under the Endangered Species Act that have been observed in the area where fisheries managed under the Pelagics FMP operate are as follows:

Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)
Rough-toothed dolphin (*Steno bredanensis*)
Risso's dolphin (*Grampus griseus*)
Bottlenose dolphin (*Tursiops truncatus*)
Pantropical spotted dolphin (*S. attenuata*)
Spinner dolphin (Stenella longirostris)
Striped dolphin (Stenella coeruleoalba)
Melon-headed whale (*Peponocephala electra*)
Pygmy killer whale (*Feresa attenuata*)
False killer whale (*Pseudorca crassidens*)
Killer whale (*Orcinus orca*)
Pilot whale, short-finned (*Globicephala melas*)
Blainville's beaked whale (*Mesoplodon densirostris*)
Cuvier's beached whale (*Ziphius cavirostris*)
Pygmy sperm whale (*K. breviceps*)
Dwarf sperm whale (*Kogia simus*)
Bryde's whale (Balaenoptera edeni)

Because the preferred alternative focuses on data collection (including data on interactions with marine mammals) and is not anticipated to alter historical fishing operations or patterns, it is anticipated to have neutral to potentially beneficial impacts on marine mammals that occur in the Western Pacific region. However it is anticipated that NMFS will conduct a review of the Pacific domestic squid jigging fishery to determine its impacts to marine mammals under the measures recommended here (NMFS 2006).

5.7 National Environmental Policy Act

Much the information provided in this document is taken from the 2005 EIS and repeated for the reader's convenience. The EA included in this document tiers off of the 2005 EIS in that alternatives to the preliminary preferred alternative (Alternatives 1-5) are described and their environmental impacts are evaluated in the 2005 EIS. Specifically, these alternatives are numbered SQA.2 (Voluntary Monitoring); SQA.3 (Mandatory Monitoring and Manageemnt through the Pelagics FMP); SQA.4 (Mandatory Monitoring and Management Through a New Squid FMP; and SQA.5. Mandatory Monitoring and Management Through International Agreement and can be found in the 2005 EIS (NOAA 2005).

A new alternative for Amendment 15 is presented in this document and its potential impacts on the environment are analyzed. This new alternative (Alternative 3a) is similar to Alternative 3 (SQA.3) of the 2005 EIS, however, the revised alternative now contains provisions for mandatory Federal permits and logbooks for vessels greater than 50 ft in length that fish in U.S. EEZ waters of the Western Pacific region. The minimum vessel length of 50 feet was selected because this is the approximate lower size limit for commercial squid vessels that fish in the U.S. EEZ and on the high seas, and the smallest size that could readily accommodate observers.

5.8 Paperwork Reduction Act

The purpose of the PRA is to minimize the burden on the public. The Act is intended to ensure that the information collected under the proposed action is needed and is collected in an efficient manner (44 U.S.C. 3501(1)).

The preferred alternative would require the owners of all domestic Pacific squid jigging vessels greater than 50 ft in length which are fishing in Pacific waters for pelagic squid, to obtain Federal Pelagic FMP permits and to complete and to submit Federal Pelagic FMP catch reports or participate in local reporting systems if fishing in U.S. EEZ waters. Permit eligibility would not be restricted in any way, and permits would be renewable on an annual basis. NMFS anticipates that initial permit applications would require 0.5 hours per applicant, with renewals requiring an additional 0.5 hours annually. Based on recent participation levels, it is estimated that NMFS may receive and process up to three permit applications each year. Thus, the total collection-of-information burden to fishermen for permit applications is estimated at 1.5 hours per year. The cost for individual Federal permits has not been determined but would represent only the administrative cost and is anticipated to be less than $80 per permit. NMFS anticipates the time requirement for completing Federal catch reports to be approximately 20 minutes per vessel per fishing day. Under the preferred alternative, operators of small-scale near-shore squid jigging vessels less than 50 ft in length would continue to comply with local reporting systems and thus would not be subject to an increased reporting burden.

5.9 Traditional Indigenous Fishing Practices

The potential squid PMUS described in this document were not traditionally targeted in Hawaii, Guam, CNMI or American Samoa. In addition the preferred alternatives discussed here are not expected to have any impacts on either contemporary or traditional indigenous fishing practices.

5.10 Essential Fish Habitat

The preferred alternative is not expected to have adverse impacts on essential fish habitat (EFH) or habitat areas of particular concern (HAPC) for species managed under the Pelagics, Bottomfish and Seamount Groundfish, Precious Corals, Crustaceans, or Coral Reef Ecosystems Western Pacific Fishery Management Plans. EFH and HAPC for these species groups has been defined as presented in Table 11. The preferred alternative will not adversely affect EFH or HAPC for any managed species as it is not likely to lead to substantial physical, chemical, or biological alterations to the habitat, or result in loss of, or injury to, these species or their prey. For the same reason, the preferred alternative is not anticipated to cause substantial damage to the ocean and coastal habitats. Under the preferred alternative, EFH and HAPC for pelagic squid would be the same as that of all other PMUS.

Table 11: Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) for all Western Pacific FMPs

FMP	EFH (Juveniles and Adults)	EFH (Eggs and Larvae)	HAPC
Pelagics	Water column down to 1,000 m	Water column down to 200 m	Water column above seamounts and banks down to 1,000 m
Bottomfish and Seamount	Bottomfish: Water column and bottom habitat down to 400 m	Bottomfish: Water column down to 400 m	Bottomfish: All escarpments and slopes between 40-

FMP	EFH (Juveniles and Adults)	EFH (Eggs and Larvae)	HAPC
Groundfish	Seamount Groundfish: (adults only) water column and bottom from 80 to 600 m, bounded by 29°-35°N and 171°E-179°W	Seamount Groundfish: (including juveniles) epipelagic zone (0-200m) bounded by 29°-35°N and 171°E-179°W	280 m, and three known areas of juvenile *ʻōpakapaka* habitat Seamount Groundfish: not identified
Precious Corals	Keāhole Point, Makapuʻu, Kaʻena Point, Westpac, Brooks Bank, 180 Fathom Bank deep water precious corals (gold and red) beds and MiloliʻI, Auʻau Channel and S. KauaʻI black coral beds	Not applicable	Makapuʻu,Westpac, and Brooks Bank deep water precious corals beds and the Auʻau Channel black coral bed
Crustaceans	Bottom habitat from shoreline to a depth of 100 m	Water column down to 150 m	All banks within the NWHI with summits less than 30 m
Coral Reef Ecosystems	Water column and benthic substrate to a depth of 100 m	Water column and benthic substrate to a depth of 100 m	All MPAs identified in FMP, all PRIAs, many specific areas of coral reef habitat (see FMP)

5.11 Information Quality Act

To the extent possible, the information presented here complies with the Data Quality Act and NOAA standards (NOAA Information Quality Guidelines, September 30, 2002) that recognize information quality is composed of three elements - utility, integrity and objectivity. Central to the preparation of this FMP amendment is objectivity which consists of two distinct elements: presentation and substance. The presentation element includes whether disseminated information is presented in an accurate, clear, complete, and unbiased manner and in a proper context. The substance element involves a focus on ensuring accurate, reliable, and unbiased information. In a scientific, financial, or statistical context, the original and supporting data shall be generated, and the analytic results shall be developed, using sound statistical and research methods.

At the same time, however, the Federal government has recognized, "information quality comes at a cost. In this context, agencies are required to weigh the costs and the benefits of higher information quality in the development of information, and the level of quality to which the information disseminated will be held." (OMB Guidelines, pp. 8452-8453).

One of the important potential costs in acquiring "perfect" information (which is never available), is the cost of delay in decision-making. While the precautionary principle suggests that decisions should be made in favor of the environmental amenity at risk (in this case Pacific pelagic squid), this does not suggest that perfect information is required for any preferred alternative to proceed. In brief, it does suggest that caution be taken but that it not lead to paralysis until perfect information is available. This document has used the best available information and made a broad presentation of it. The process of public review of this document provides an opportunity for comment and challenge to this information, as well as for the provision of additional information.

Chapter 6. Draft Proposed Regulations

PART 665--FISHERIES OFF THE WEST COAST STATES AND IN THE WESTERN PACIFIC

1. The authority citation for part 665 continues to read as follows:
Authority: 16 U.S.C. 1801 et seq.

2. In § 665.12 add a definition for “squid jig fishing” to read as follows: Fishing for squid species that are Pelagic management unit species using a hook or hooks attached to a line that is jerked more or less vertically in the water column by manual or mechanical means.

3. In § 665.12 , in the definition of “Pacific Pelagic Management Unit Species” add the following three squid species to the end of the table, as follows:

Common name	Scientific name
* * * * *	
Neon flying squid	*Ommastrephes bartamii*
Diamondback squid	*Thysanoteuthis rhombus*
Purple flying squid	*Sthenoteuthis oualaniensis*

4. In § 665.14 add new paragraph (i) to read as follows:

(i) *Squid jig fishing.* The operator of any fishing vessel subject to the requirements of § 665.21 that uses a vessel greater than 50 ft (15.4 m) in length overall to squid jig fish in EEZ waters around American Samoa, CNMI, Guam, the Hawaiian Archipelago, or the PRIA must maintain on board the vessel an accurate and complete record of their vessel's EEZ catch, effort and other data on paper logbook report forms provided by the Regional Administrator or electronically as specified and approved by the Regional Administrator, or they must participate in state or territorial reporting systems. If these vessels are also used to fish on the high seas, vessel operators must report their vessel's high seas catch, effort and other data on paper logbook report forms provided by the Regional Administrator or electronically as specified and approved by the Regional Administrator. All information specified by the Regional Administrator must be recorded on paper or electronically within 24 hours after the completion of each fishing day. The logbook information, reported on paper or electronically, for each day of the fishing trip must be signed and dated or otherwise authenticated by the vessel operator in the manner determined by the Regional Administrator, and be submitted or transmitted via an approved method as specified by the Regional Administrator, and as required in paragraph (a). If participating in a state or territorial reporting system, all required information must be recorded and submitted in the exact manner required by applicable territorial or state law or regulation.

5. In § 665.21 add new paragraph (o) to read as follows:
(o) A vessel of the United States must be registered for use under a Pacific squid jig fishing permit if that vessel is more than 50 ft (15.4 m) in length overall and is used to squid jig fish in EEZ waters around American Samoa, CNMI, Guam, the Hawaiian Archipelago, or the PRIA.

6. In §665.22 add new paragraph (zz) to read as follows:

(zz) Use a vessel greater than 50 ft (15.4 m) in length overall to squid jig fish in EEZ waters around American Samoa, CNMI, Guam, the Hawaiian Archipelago, or the PRIA without a Pacific squid jig fishing permit registered for use with that vessel, to in violation of §665.21(o).

7. In § 665.23 revise paragraph (a) to read as follows:

(a) The permit holder for any vessel registered for use under a Hawaii longline limited access permit or for any vessel greater than 40 ft (12.2 m) in length overall that is registered for use under an American Samoa longline limited access permit, shall provide a notice to the Regional Administrator at least 72 hours (not including weekends and Federal holidays) before the vessel leaves port on a fishing trip, any part of which occurs in the EEZ around the Hawaiian Archipelago or American Samoa. The vessel operator will be presumed to be an agent designated by the permit holder unless the Regional Administrator is otherwise notified by the permit holder. Permit holders for vessels registered for use under Hawaii longline limited access permits must also provide notification of the trip type (either deep-setting or shallow-setting). The permit holder of any squid jig fishing vessel greater than 50 ft (15.4 m) in length overall shall also provide a notice to the Regional Administrator at least 72 hours (not including weekends and Federal holidays) before the vessel leaves port on a fishing trip, any part of which occurs in Pacific waters. In all of the above cases, the notice must be provided to the office or telephone number designated by the Regional Administrator. The notice must provide the official number of the vessel, the name of the vessel, the intended departure date, time, and location, the name of the operator of the vessel, and the name and telephone number of the agent designated by the vessel operator or permit holder to be available between 8 a.m. and 5 p.m. (local time) on weekdays for NMFS to contact to arrange observer placement.

Chapter 7. References

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