# THE POPULATION BIOLOGY OF THE BLACK-FOOTED ALBATROSS IN RELATION TO MORTALITY CAUSED BY LONGLINE FISHING

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**Report of a workshop held in Honolulu, Hawaii, 8-10 October 1998 under the auspices of the Western Pacific Regional Fishery Management Council**

**Edited by Katherine Cousins[1] and John Cooper[2]**

WESTERN
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

[1]*Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Suite 1400, Honolulu, Hawaii 96813, USA (Kathy.Cousins@noaa.gov)*

[2]*BirdLife International Seabird Conservation Programme, Avian Demography Unit, University of Cape Town 7701, South Africa* (jcooper@botzoo.uct.ac.za)

April 2000

Cover photo: Black-footed albatross, Midway Atoll, courtesy of Rob Shallenberger

ISBN 0-615-11594-2 20.00

## Executive Summary

The historical record shows that humans have adversely affected the Black-footed Albatross *Phoebastria nigripes* population since the turn of the century when feather hunters raided breeding colonies throughout the North Pacific Ocean for albatross feathers, skins, oil, eggs and guano. To protect the colonies in the Northwestern Hawaiian Islands (NWHI) from further devastation, President Theodore Roosevelt established the Hawaiian Islands Bird Reservation in 1909. In 1941, U.S. Marines in preparation for World War II killed thousands of albatrosses on Midway Atoll. Military activities continued until the Navy ceased its operations in 1993 and in 1996, jurisdiction and control of Midway was transferred to the Department of Interior for inclusion into the National Wildlife Refuge system. Besides past disturbances at breeding colonies, recent threats to the Black-footed Albatross population include plastic ingestion, exposure to contaminants, and mortality from fishery interactions. With the closure of the North Pacific high seas driftnet fisheries in 1992, the primary threat to the Black-footed Albatross at sea is death by drowning on a longline hook. Noting the reported rates of decline in many of the NWHI breeding colonies (where 96% of the world population resides), Croxall and Gales (1998) assigned Black-footed Albatross Vulnerable status under the World Conservation Union (IUCN) criteria.

In the last 60 years ornithologists have been banding and studying Black-footed Albatrosses in the NWHI, but a thorough review of the banding data has not been attempted. In addition, very few papers on this species have been published, although a wealth of information exists in unpublished reports and raw data sets. A lack of a comprehensive understanding of the population dynamics of NWHI Black-footed Albatross and the assignment of an IUCN vulnerable conservation status, coupled with inconclusive albatross mortality figures for the Hawaii-based longline fishery, prompted the Western Pacific Regional Fishery Management Council (WPRFMC), the authority over the fisheries in the U.S. Exclusive Economic Zone (EEZ), to convene a workshop in 8-10 October 1998. The activities of the three-day workshop were to review available information and to generate recommendations for conservation measures and future research. The findings and recommendations from the workshop are especially important because the WPRFMC is in the midst of developing a regulatory framework for seabird bycatch reduction measures in the Hawaii-based pelagic longline fishery.

The Black-footed Albatross Population Biology Workshop brought seabird and fisheries biologists together in a common forum with population modelers. Using data made available at the workshop, the participants investigated the current population parameters, examined changes in parameter rates, such as adult and juvenile survival, and evaluated effects of longlining activity on the Black-footed Albatross population.

Data for the participants to consider in their analyses were collected from several sources. Sixty years of bird-banding data were obtained from the Bishop Museum, Honolulu, the National Bird-banding Laboratory (NBBL), Maryland, and the Pacific Ocean Biological Survey Project, Smithsonian Institution, Washington, D.C. In addition, detailed information associated with bird-banding activities but not required by the NBBL, such as band numbers mated pairs, was obtained from the data sets collected by private researchers and the US Fish and Wildlife Service (FWS), Pacific Refuges Office, Honolulu. The FWS and H. Hasegawa (Toho University, Japan) also provided census and breeding success data sets. Black-footed Albatross sighting records were obtained from R. Pyle at the Bishop Museum, Honolulu, and from private tour guides operating seabird cruises in Oregon and California. At-sea transect sightings and satellite-tagging data sets were supplied by T. Wahl and D. Anderson (Wake Forest University), respectively. The National Marine Fisheries Service (NMFS) supplied information regarding seabird mortality on Hawaii and Alaska longline vessels and from annual pelagic fishery reports.

The first task for the workshop participants was to review these historical records and data sets. The participants learned that the current world population of breeding Black-footed Albatrosses is 61,866 pairs in 12 colonies. Seventy-seven percent of these pairs nest in three colonies in the United States (Laysan Island, Midway Atoll and French Frigate Shoals, NWHI) which are systematically surveyed on an annual basis. Only 3.6% of the population breeds in the Eastern Pacific on the Japanese Senkaku Islands (Kita-Kojima), Bonin Island (Chichijima) and Minami Tori Shima Island.

It was noted that different methods were used to generate counts of the Black-footed Albatrosses. For instance, examination of FWS census data sets revealed that only in the last few years has the FWS been able to complete direct counts of breeding pairs on the larger colonies on Midway Atoll and Laysan Island. Since 1996, direct counts have also been conducted for the smaller colonies at Pearl and Hermes Reef. Prior to conducting direct counts on Midway Atoll and Laysan Island, the FWS used extrapolations from counts of nests within randomly selected small plots or quadrats or from direct counts of chicks. Prior to the 1960s, many of the historical counts in the NWHI were best guesses, especially those from the 1910s to 1930s. It was recommended that a description of the methods used, plus a chronology of activities at the breeding colonies, were needed to understand how and under what circumstances the data set was generated. A detailed chronology and a description of census methods used in the NWHI are included in the report.

During the review of the data sets, workshop participants learnt of a major banding problem. Some birds had their bands replaced, due to band wear, or were double-banded for band-wear studies. At the time of the workshop, the NBBL was unable to export data sets in a format with the bird-band numbers worn by a single bird linked together. Until the NBBL can solve the data export problem, the only way a researcher can create a banding history for double-banded or replacement banded birds is to link manually the record by searching through the original bird-banding schedules. In preparation for the workshop, bird-banding data were entered into a relational database where all the different band numbers worn by individual birds were linked together by searching through the bird-banding schedules on file at the FWS and in archives at the NBBL and the Bishop Museum. Over 116,752 records were recovered (100,862 individual birds) and band-numbers belonging to a single bird linked together in a relational database. However, at the time of the workshop at least 2,000 recapture banding records from the Midway Fuel Farm study area were still missing from the bird-banding database. Fortunately, a workshop participant, C. Robbins (a U.S. Geographical Survey researcher), offered to supply the missing records.

C. Robbins also reported on a cohort of 1,000 chicks color banded in June 1957 on Eastern Island, Midway Atoll, by D. Rice. Participants learned that five Black-footed Albatrosses from this cohort have worn bands for 37 years (birds last seen in 1994). Of the 37 birds from the cohort taken at sea by fishing vessels, most were taken in the first three years. Furthermore, analysis of 255 known-age at-sea Black-footed Albatross bird-banding records show that 114 (44.7 %) were young-of-the-year, 40 were two-year olds (5.7 %), 25 were three-year olds (9.8 %), and 52 (20.4 %) were birds over five-years. These data suggest that the younger and more inexperienced birds are more vulnerable to being caught by longline vessels.

At-sea sightings and fishery observer data sets show that Black-footed Albatrosses range throughout the North Pacific between 20° and 58° N. During the egg-laying and incubation period, December through February, Black-footed Albatrosses are concentrated near breeding islands. During the remainder of the breeding season until the chicks fledge in July, birds range more northward to the area just south of the Aleutian Islands and off the west coast of Canada and the United States, where they remain in July and August. Then, during September, October, and November they gradually return to the breeding colonies. Black-footed Albatrosses demonstrated a pelagic lifestyle and have vast foraging areas that, in their annual cycle, overlap with many of the North Pacific longlining fishing fleets, including the Hawaii-based pelagic longline fishery.

After reviewing data sets containing fishery mortality information, workshop participants commented on the apparent lack of information. The U.S. Hawaii and Alaska longline fisheries are the only fisheries routinely collecting and reporting statistics on seabird interactions in the North Pacific. It is estimated that between 1994 and 1998, on average 1,831 Black-footed Albatrosses were killed by Hawaii-based longline vessels each year. Annual bycatch estimates for Black-footed Albatrosses hooked on Alaska demersal ("groundfish") longline gear were, on average, 28 Black-footed Albatrosses from fisheries operating in the Bering Sea and Aleutian Islands and 588 from fisheries in the Gulf of Alaska. The average annual combined mortality of Black-footed Albatrosses in the Hawaii and Alaska longline fisheries represents about 0.6% and 0.2% of the total estimated population for the species, respectively. Japan, the Republic of Korea and the Republic of China (Taiwan) also operate high-seas pelagic longline fisheries within the range of the Black-footed Albatross. Japan only collects statistics on seabird interactions in her South Pacific longline fisheries for Southern bluefin tuna. Korea and Taiwan apparently do not collect seabird interaction data. Other fisheries known to interact with Black-footed Albatrosses are the demersal longline fisheries off the west coast of Canada, the Pacific Halibut fishery off the U.S., and the Pacific cod fishery off Kamchatka, but for these fisheries information is scant as observer coverage is limited or non-existent.

At the workshop, population modeling experiments were developed to compare the effects of different removal rates of adults and juveniles. According to this model, when removal rates are 10 times higher for juveniles than for adults, the population declines more slowly than if removal rates are equal. The difference is not apparent initially, but accumulates over time due to resulting changes in the population age structure. Due to the gaps in the historical records, as well as missing essential population parameters, such as sex ratios and juvenile survival rates, assumptions were made for the modeling exercises. The experimental models assumed that the population sex ratio was equal and that the juvenile survival rate was constant to age of first breeding, and equal for males and females.

Some of the population parameters used in the modeling experiments, such as the adult survival rate (0.923, range 0.810 - 0.994), were based on data collected in the 1960s, a time when the Hawaii-based domestic longline fleet was virtually non-existent. To address the issue of using past population parameters a simple model was proposed. This model first assumes a steady state, such that the survival and breeding success rates in the population do not change with time and then the model is asked to calculate the sustainable growth rate of the population under a certain set of circumstances. The model predicted that if adult annual survival is 0.93 and fecundity is 0.25 fledglings per adult in a single breeding season, then the juvenile survival must be near 0.86 to maintain a stable population growth. However, in the late 1950s and early 1960s, the mean annual juvenile survival was 0.77, below the models' predictions. The current juvenile survival rate is unknown, and given that juveniles are thought to interact with fishing gear more than adults, it is likely that the juvenile survival is lower than 0.77.

The following recommendations were agreed upon by the participants of the Black-footed Albatross Population Biology Workshop.

1. Complete, develop and manage a relational database for banding records.

2. Encourage further analyses of the existing data sets and conduct further modeling at a population dynamics modeling laboratory.

3. Design and implement a population-monitoring program at breeding sites to address the effects of longlining mortality.

4. Obtain information and make best estimates of fishing effort and mortality of birds from the Pacific Halibut and non-US longline fisheries in the Northern Pacific Ocean.

5. Design, implement and develop a longline fishery-monitoring scheme to test mitigation measures and to gather mortality data.

6. Undertake comparative studies with Laysan and Japanese Black-footed Albatrosses.

7. Hold a follow-up meeting to discuss progress with the above recommendations at the Second International Albatross Conference in Honolulu, Hawaii, 8 - 12 May 2000.

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## 1 Introduction

In the last few decades concern has been expressed on the deleterious effects of longline fisheries on seabird populations (Brothers 1991, Brothers *et al.* 1999a). Previously, the huge numbers of seabird species killed by high-seas drift netting contributed to the worldwide ban of this fishing method in 1993. Current concerns are concentrated on longline fishing, which results in thousands of seabirds being killed throughout the world's oceans. The Food and Agriculture Organization of the United Nations (FAO) has undertaken a consultation which has led to the adoption by its Committee on Fisheries of an International Plan of Action for reducing Incidental Catch of Seabirds in Longline Fisheries in February 1999 (FAO 1999ab), subsequently endorsed by the FAO Council in June 1999.

In the Northern Pacific Ocean the species most at risk from longlining are three species of albatross, the Short-tailed *Phoebastria albatrus*, the Laysan *P. immutabilis*, and the Black-footed *P. nigripes*. The last two species breed on both United States and Japanese islands and are killed by both U.S. demersal longline fisheries in the Gulf of Alaska and the Bering Sea and by U.S. pelagic fisheries operating out of Hawaii. The first species, the Short-tailed Albatross, breeds only on the eastern Pacific Islands of Torishima and Minami-Kojima. The effect of Asian pelagic longline fisheries on seabird populations in the North Pacific Ocean is unknown but very likely significant. The current breeding population of the Laysan Albatross is roughly ten times that of the Black-footed Albatross, yet when considering both the Alaska and Hawaii longline fisheries approximately equal numbers Laysan and Black-footed Albatross have been recorded killed by both the two U.S. fisheries, suggesting that the latter species is more seriously affected.

Over many decades field studies have been undertaken on Black-footed Albatrosses. These include banding programs of both chicks and free-flying birds, leading to information on both breeding parameters and at-sea distribution from recoveries, censuses of breeding birds at most breeding localities, at-sea observations during pelagic research cruises, and more recently, at-sea satellite-tracking of breeding birds and contaminant impact studies. In addition, observer schemes in U.S. longline fisheries in the Pacific Ocean are yielding information on mortality. Even so, it is fair to say that this large body of information has never been synthesized. Indeed, compared to many other species of albatrosses, relatively little has been published on the Black-footed Albatross (Robertson and Gales 1998).

High levels of seabird mortality in the Northern Pacific have led to the adoption of regulations in the U.S. demersal longline fisheries, primarily to reduce incidental catch of the endangered Short-tailed Albatross (National Marine Fisheries Service 1997a,b). Currently, no such regulations exist in the Hawaiian pelagic fishery, although pressure from concerned environmental non-governmental organizations has been growing for their adoption. The Western Pacific Regional Fishery Management Council, the statutory administrative body within the U.S. range of Black-footed and Laysan Albatrosses, has responded to these expressed concerns, and to the FAO initiative, by contracting a research project to assess the efficacy of mitigation measures (McNamara *et al.* 1999) and by sponsoring and hosting a population biology workshop on the Black-footed Albatross.

### 1.1 Objectives and Activities of the Workshop

The primary objectives of the workshop were to characterize the population biology of the Black-footed Albatross and to evaluate the species' resilience to the effects of mortality due to longline fisheries interactions.

Following discussion of the existing data sets, the workshop participants split into working-groups to conduct four separate investigations (Appendix I). One group reviewed the existing data on breeding, at-sea distribution and breeding population sizes and trends. The second group modeled population dynamics, using primarily banding data coupled with information on the breeding biology of both Black-footed and Laysan Albatrosses. The third group considered the available Black-footed Albatross mortality data from longline interactions and, together with longline fisheries statistics, estimated the likely total take of Black-footed Albatrosses by Northern Pacific fisheries. The fourth group considered means to evaluate and monitor both the level of fatal interactions between albatrosses and longline vessels, and the population statistics of albatross breeding colonies, to determine the impacts and efficacy of mitigation methods to lessen fishery related mortalities of the Black-footed Albatross. The findings from each group were discussed in plenary sessions, at which conclusions and recommendations were made.

## 2 Natural History and Geographical Distribution

The life-history of the albatrosses is typical of "K-selected" species. By definition, this means that there is selection pressure for characteristics enabling individuals to maximize their fitness for contributing significant numbers of offspring to a population near its carrying capacity (Pianka 1970). The general characteristics of a "K-selected" species are long lives with a delayed reproductive maturity and low annual productivity. Black-footed Albatrosses are relatively long-lived, as many birds are known to have worn bird-bands for at least 43 years. And although some Black-footed Albatross may return to the breeding colonies at two or three years of age, the average age at first breeding is at least five years and probably averages at seven or eight years (Rice and Kenyon 1962a, Robbins 1966). Black-footed Albatrosses are also iteroparous, meaning that they have repeated reproduction, and lay a single egg during a breeding season.

### 2.1 Distinguishing Characteristics and Molting

The Black-footed Albatross is characterized by a dark bill, legs and feet at all stages of development. Comparatively, the Black-footed Albatross is slightly larger and heavier than the Laysan Albatross (Table 1), but for the same-sex birds there is no significant difference between the two species (Harrison *et al.* 1983, G.C. Whittow pers. comm.). Interestingly, the Japanese Black-footed Albatrosses are reported to be slightly smaller than their Hawaiian counterparts (H. Hasegawa pers. comm.). The plumage coloration for both the immature and adult Black-footed Albatross is extremely similar; brown with a white band at the base of their bill and a white sweep defining their eyes (Fig. 1). One distinguishing feature between adult and juvenile (i.e., young-of-the-year) Black-footed Albatrosses is that the juveniles lack the white plumage at the base of their tail (Fig. 2). In addition, the plumage of the immature birds may be slightly darker than that of adult birds. Generally, as the juvenile Black-footed Albatrosses mature, they tend to become more gray or dusty in appearance (Miller 1940).

This change in plumage coloration first occurs during prebasic I molt at between 16 and 21+ months (Whittow 1993). The definitive white plumage on the head, belly and upper tail coverts increases in size with each successive molt until first breeding at 5 or 6 years of age (Bourne 1982). Interestingly, the Black-footed Albatrosses, like Laysan Albatrosses, show an unusual bidirectional pattern of incomplete molt in their primaries (i.e., the most distal wing feathers). Patterns of molt in these species often reflect tradeoffs between current and future reproduction (Langston and Rohwer 1995). For instance, Black-footed Albatross, as do most seabirds, do not molt during the breeding season, so they have approximately four months to molt while at sea (Payne 1972). The birds may, however, trade the metabolic costs of replacing feathers with the cost of preparing for another breeding season.

Table 1. Morphometric comparisons between Black-footed, Laysan and Short-tailed Albatrosses (Warham 1977, Hasegawa and DeGange 1982, Harrison *et al.* 1983, Whittow 1993).

| | Black-footed Albatross | Laysan Albatross | Short-tailed Albatross |
|---|---|---|---|
| Length (cm) | 64 – 74 | 79 – 81 | ~94 |
| Wing Span (cm) | 193 – 216 | 195 – 203 | ~213 |
| Body Mass (kg) | 2.0 – 3.8 | 1.9 – 3.1 | ~7.0 |
| Bill Length (cm) | 9.4 – 11.3 | 10 – 11 | 12 – 14 |

### 2.2 Reproductive Biology

In late October, Black-footed Albatrosses begin to return to the nesting colonies in the northwestern Hawaiian Islands and on Torishima, Japan. The Laysan Albatrosses tend to return to the Hawaiian Islands a couple of weeks later than the Black-footed Albatrosses. Generally, the Black-footed Albatross males arrive first in the last week of October and await the arrival of the females (Bailey 1952). Both Black-footed and Laysan Albatrosses mate for life, and the same mated pair will return each year to breed (Bailey 1952). Often the males will wait for their mate near the same nest site the pair shared in previous years (Bailey 1952, Fisher 1971).

Interestingly, there is interbreeding between the Black-footed and Laysan Albatrosses that results in hybrid offspring (Fig. 3), but there have been no confirmed reports of hybrids reproducing; however, hybrids have been observed incubating eggs (Fisher 1972, E. Flint pers. comm.). Fisher (1972) observed some "casual social relations" between the two species, such as reciprocal preening and displaying, but he did not observe coition. He believed that hybrids are a result of a mobbing event, where early arriving males will over-zealously attempt coition with any newly arrived individual (Fisher 1971). Fisher (1971) theorized that the hybrids fail at their attempts to find a mate because their breast plumage is unrecognizable by both the Laysan and Black-footed Albatrosses. The breast plumage of the hybrid is a soft gray rather than the pure white of the Laysan Albatross or the grayish-brown of the Black-footed Albatross (Fig. 3). Fisher (1971) believed that the breast plumage coloration was important for the birds to recognize a member of their own species.

Fisher (1972) also believed that, in the majority of cases, bonding between a mated pair was established at least two years previously during the late egg-laying time. Based on these observations, it is possible that if one of the mated pair did not return to breed, the other may wait at the nest site until it is too late to find another mate and lose a breeding season. Once all the other mated albatrosses are incubating and their chicks begin to hatch, the birds that have been "stood-up" join the "unemployed" (Richdale 1950) and the competition for a mate resumes. Clearly then, if a mate fails to return, the surviving mate could lose at least three breeding seasons.

In a successful reunion a female Black-footed Albatross will lay a single egg in mid-November to early December. Both the Black-footed Albatross and the Laysan Albatross lay only one egg in a single season. Although rare, two eggs are sometimes deposited into a single nest. This occurs when two pairs try to use the same nest or a second, and perhaps younger female, adds her egg (Warham 1990). If a second egg is deposited into a nest, usually the first egg is thrown out of the nest and the pair incubates the later egg (Richards 1909). The mean incubation period for Black-footed Albatross eggs is 65.6 days and both adults incubate the egg (Rice and Kenyon 1962b). For a review of petrel egg incubation physiology see Warham (1990, 1996). The adults tend to forage close to the breeding colony during the chick brooding period, taking turns on the nest every two to four days (please see Appendix II for breeding success summaries).

After the chick hatches, between 15 January and 7 February (Rice and Kenyon 1962b), the brooding period lasts between one to two weeks where at least one adult stays with the chick protecting it from the elements and from neighboring adults or predators (Fig. 4). Results from a recent satellite-tracking project, initiated by Dr. David Anderson of Wake University, show that during the brooding period the parents tend to forage close to the breeding colony taking short two to four day trips (Anderson and Fernandez 1998). At the end of the brooding period, however, the adults begin to take longer foraging trips and spend anywhere between 10 -28 days at sea (Anderson and Fernandez 1998). After two to three weeks foraging at sea, the adults return to the nesting colony to feed their chicks regurgitated food (Fig. 5). The regurgitated food consists of, by volume, approximately 10% stomach oil, 50% fish, 32% squid and 5% crustaceans (Harrison *et al.* 1983). The adults stay with their chicks only as long as it takes to regurgitate all of their stomach contents. After the feeding session, the parents often tend to walk over to one or two neighboring chicks and attack them before promptly departing back to sea (Fisher 1904). There does not appear to be any coordination between the parents in terms of a feeding schedule and consequently, chicks must sometimes endure long periods alone between feedings.

After one last feeding in June, the adults depart for the open ocean leaving the young chicks to fledge on their own in late July (Fig. 6). Many of the young fledglings never survive to enter the water as they slowly die of starvation or dehydration waiting for their parents to return. Others drown, or fall victim to waiting Tiger Sharks *Galeocerdo cuvier* (Fig. 7). Successful fledglings disperse over the open ocean of the North Pacific.

### 2.3 Breeding Distribution and Habitat

Historically, the breeding range of the Black-footed and Laysan Albatrosses was extensive, reaching as far east as the Japanese Islands of Torishima and as far south as Taongi Atoll in the Marshall Islands. Today, the Hawaiian Islands are the primary breeding colonies for the Black-footed and Laysan Albatross populations. Apparently, the feather and egg trade in the early 1900s, followed by World War II, destroyed nesting colonies on the Japanese, Wake, Bonin and Marcus Islands, as well as colonies on Johnston and Taongi Atolls (Spennemann 1998). However, a small population of approximately 1,100 – 1,200 Black-footed Albatrosses has recolonized the Japanese Islands of Torishima (Rice and Kenyon 1962a, Hasegawa 1984, Ogi *et al.* 1994) and there have been recent observations of Black-footed Albatrosses visiting Wake Island (M. Rauzon pers. comm.). There have been no reports of recent visits by Black-footed Albatrosses to Johnston Atoll or to Marcus Island (E. Flint pers. comm.); however, a Laysan Albatross was sighted on Johnston Atoll in 1999 (D. O'Daniel pers. comm.).

Although there is some overlap in nesting sites between the two species while they breed in the northwestern Hawaiian Islands, Black-footed Albatrosses prefer open wind-blown beaches whereas the Laysan Albatrosses prefer more sheltered inland sites (Bailey 1952, Fisher 1972, McDermond and Morgan 1993). On Torishima the Black-footed Albatross nesting sites are located on sparsely to richly vegetated wind-blown and exposed volcanic slopes (Ogi *et al.* 1994).

### 2.4 Feeding and Diet

Like other albatrosses, the Black-footed Albatross have well-developed visual and olfactory systems that assist them to locate food sources and these seabirds are predominantly crepuscular in their foraging activities (Warham 1990). The Black-footed Albatross feeds primarily by seizing prey off the ocean surface and by making shallow dives (Harrison 1990). The Black-footed Albatross diet is comprised of crustaceans, squid, fish, flying fish eggs and zooplankton (Harrison *et al.* 1983). Like the Laysan Albatross, the Black-footed Albatross eats squid; however, Black-footed Albatrosses eat 11 times as many flying fish eggs as do Laysan Albatrosses (Harrison *et al.* 1983, Harrison 1990). Black-footed Albatrosses are also highly opportunistic feeders and will scavenge from ship offal as well as from dead carcasses (Harrison *et al.* 1983).

Albatrosses, as well as other seabirds, will also accidentally ingest plastic while they are foraging at sea. Although adults can regurgitate plastic, the chicks do not regurgitate large items, including plastic, until they are ready to fledge. Plastic and oil float on the ocean surface, and the albatrosses being surface feeders are particularly vulnerable to these types of pollution. Older plastics may contain toxic chlorinated hydrocarbons such as PCBs (polychlorinated biphenyls). All plastics absorb compounds like PCBs onto their surfaces and these toxins may leach into a bird's circulation and tissues (Jones *et al.* 1994, Auman *et al.* 1997, 1998). Black-footed Albatrosses are especially vulnerable to the effects of plastic ingestion because flying fish eggs, a large component of their diet, closely resemble small plastic resin pellets. Often, flying fish eggs are deposited on floating items such as plastic, and seabirds mistakenly consume plastic along with the eggs.

## 2.5 Behavior

There is an older literature describing the behavior of Black-footed and Laysan Albatrosses frequenting ships or "racking-up" (i.e., loitering) near floating objects (Miller 1940, 1941, Yocom 1947). This behavior does not seem to have changed in over 50 years as the seabirds are still observed following ships and loitering near floating objects (Fig. 1). Miller (1940) called Black-footed Albatrosses "feathered pigs" because they would eat whatever was thrown overboard, with a preference for bacon fat and cocoa butter.

When the birds do return to land, however, they often promenade about with one purpose, competitive courtship dancing which leads to reproduction (Fig. 8). With this purpose in mind, the birds, for the most part, tend to ignore the presence of humans while they are present in albatross breeding colonies. Still, Black-footed Albatrosses are more aggressive in defense of their nest sites than are Laysan Albatrosses.

Courtship dancing is a critical component in forming a pair bond between a male and female Black-footed Albatross. The Black-footed Albatross dance has been described in detail by many naturalists and researchers (Bailey 1952, Rice and Kenyon 1962b, Harrison 1990) and is composed of various combinations of preening poses, posturing and vocalizations (Fig. 8). Black-footed Albatrosses at sea also display some of the same postures observed by mated pairs at the breeding colonies (Miller 1940, Yocum 1947). Comparatively, the dancing behaviors of the Black-footed Albatross are much more vigorous and synchronized than those of the Laysan Albatross (Fisher 1972).

Figure 1. A Black-footed Albatross landing in the water behind the FRS NOAA *Townsend Cromwell* research vessel (photo courtesy of B. Mundy). Note the white feathers on the base of the tail. Only the young-of-the-year (= first year of a young fledgling's life) lacks white plumage at the base of the tail.

Figure 2. A Black-footed Albatross on Sand Island, Midway Atoll (photo courtesy of C. Swift). Note the defining white plumage around the base of the bill and eyes. Also note that the Black-footed Albatross has dark feet and bill. This particular albatross is wearing two aluminum bands issued by the National Bird-banding Laboratory in Maryland, U.S.

Figure 3. A hybrid Black-footed X Laysan Albatross (on the left) on Sand Island, Midway Atoll (photo courtesy of S. Conant). Note the difference in breast plumage color between the hybrid and Laysan Albatross on the right.

Figure 4. A Black-footed Albatross chick and parent on Sand Island, Midway Atoll, on the left (photo K. Cousins). In the brooding period, at least one parent stays with the chick protecting it from the elements and potential predators or other albatrosses. Note the shallow cup-shaped nest. On the right is a young Black-footed Albatross chick on Laysan Island (photo courtesy of S. Conant).

Figure 5. Like other seabird species, adult Black-footed Albatrosses forage at sea and then return to the breeding colonies to feed their young (Fig. 1). Parent albatrosses feed their chicks by regurgitating the contents of their stomach in a crossed-bill feeding method. With sudden and strong muscular contractions, the parent forces food from its proventiculus (proventriculus is the anterior part of the bird stomach, with the gizzard being the posterior part) to the open mouth of their chick.

Figure 6. Young Black-footed Albatross fledglings on the sandy beach of Pearl and Hermes Reef in the NWHI (photo by E. Kosaka).

Figure 7. A young Black-footed Albatross fledgling is attempting to escape the jaws of a Tiger Shark. This drama is played out each year between the months of June and July as the young birds attempt to take their first flight (photo courtesy of C. Yoshinaga).

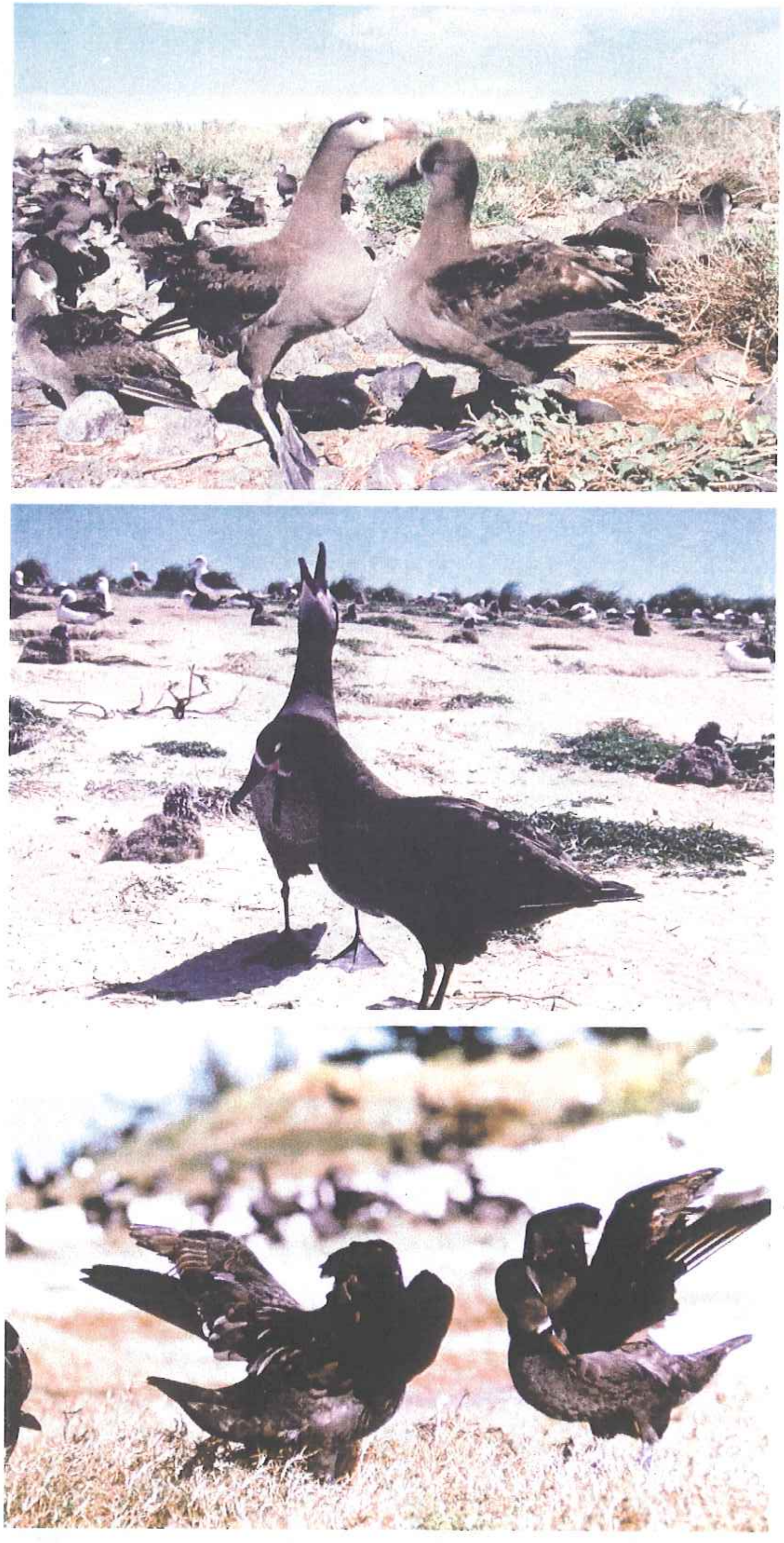


Figure 8. Courtship dancing behaviors of the Black-footed Albatross in the NWHI. Albatrosses often stand on their tiptoes and sky point as shown by the Black-footed Albatrosses displaying on Nihoa Island (photos courtesy of S. Conant). Both the Black-footed and Laysan Albatrosses have a wing lift in their dancing routines, or otherwise known as preening poses; however, Black-footed Albatrosses lift both wings whereas Laysan Albatrosses lift only one wing (photo by E. Kridler).

Figure 9. A Black-footed Albatross in flight behind the FRS NOAA *Townsend Cromwell* research vessel (photo by B. Mundy).

## 2.6 Locomotion

Unlike Laysan Albatrosses, which stand more upright when they walk, Black-footed Albatrosses tend to lower and tuck their neck when walking. All three of the North Pacific albatross species tend to waddle when they walk and engage in elaborate and entertaining nuptial displays which involve several varieties of bobbing motions, wing lifts and rising on tiptoe (Fig. 8).

Even though albatrosses are large birds, they seldom flap their wings in flight (Fig. 9). Black-footed Albatrosses tend to flap their wings every 10 to 45 s while in flight and can reach air speeds of approximately 24 to 32 knots and greater in storms (Yocum 1947, Palmer 1962). The Black-footed Albatross, as well as other albatross species, use forms of flight called slope- and dynamic-soaring (Magnan 1925). This type of locomotion appears relatively effortless and is based on the gradation of wind velocity rate above the ocean surface, and the bird's ability to gain lift from the wind deflected upwards from the ocean surface (Fig. 9). Because dynamic-soaring is dependent upon the ocean winds, the windless doldrums at the equator can hamper the flight of North Pacific albatrosses. There is an extensive literature on the slope- and dynamic-soaring of albatrosses (e.g. Cone 1964, Wood 1973, Wilson 1975, Pennycuick 1982, Warham 1977, and Pennycuick 1987).

## 2.7 Distribution of Black-footed Albatrosses at Sea

In their annual cycle, Black-footed Albatrosses range throughout the North Pacific between 20° and 58° N. Knowledge of their distribution comes primarily from reports of banded birds, from ocean scientific transects and casual observations. A few birds have been followed over long distances by satellites. Nearly all of the encounters of banded birds at sea have come from fishermen, but the reporting rates are unknown; undoubtedly, these varied over time and space.

Compared with the Laysan Albatross, which nests on most of the same islands, the Black-footed Albatross is more eastern in its at-sea distribution and occurs regularly in large numbers off the west coast of Canada and the United States where the Laysan Albatross is rare. Both species occur off the east coast of Japan. Whereas the great majority of pelagic encounters of Laysan Albatross have come from west of the 180° meridian (Sanger 1974), those of the Black-footed Albatross, although strongly clustered, are more uniformly distributed across the North Pacific Ocean (Fig. 10).

During the egg-laying and incubation period, December through February, pelagic records are concentrated near breeding islands (Fig. 11). Records become more widely scattered in March. In April, May, and June (Figs. 11 and 12) the birds move northward to the major summering area just south of the Aleutian Islands and off the west coast of Canada, where they remain in July and August (Fig. 12). Then, during September, October, and November they gradually return to the vicinity of the Hawaiian Chain (Fig. 13).

Banding records of Black-footed Albatrosses caught at sea (1963 to mid-1969) show that young birds, ages zero through five years, tend to occur slightly farther north and east than do older birds, but the differences were not statistically significant (Table 2). The mean locations (weighting months equally) are 38.6° N, 157.1° W for Black-footed Albatrosses 0-5 years old and 37.8° N, 161.4° W for older birds. It was primarily from January through July that the average position of young birds was farther east than the position of the adults. A sample from 5,000 adults and 5,000 chicks banded at Midway from 1941 to 1967 shows nearly identical numbers of adults (54) and young (58) taken at sea in the first 14 years after banding (prior to any significant loss of bands through wear). Both birds banded as adults and those banded as chicks are most vulnerable to capture at sea in the first four years after banding (Fig. 14). The great majority (77%) of albatrosses captured at sea was taken during the six-month period, March through August (Fig. 15). The peak month, with 27% of all captures, was July. There is no significant difference between adults and young (ages 0-5) in the time of year when they were captured.

Table 2. Monthly distribution of at sea encounters of banded Midway Black-footed Albatross, 1963 to mid-1969 (C.S. Robbins unpubl. data).

| Month | N | Latitude | | Longitude | |
|---|---|---|---|---|---|
| | | Mean | S.D.* | Mean | S.D.* |
| January | 24 | 30.4 | 4.3 | 178.2 | 23.8 |
| February | 24 | 29.6 | 5.6 | 167.5 | 24.2 |
| March | 58 | 32.4 | 6.1 | 167.6 | 31.3 |
| April | 35 | 39.1 | 10.2 | 153.2 | 33.9 |
| May | 69 | 42.0 | 9.1 | 149.9 | 30.9 |
| June | 95 | 43.2 | 7.3 | 148.1 | 32.8 |
| July | 120 | 44.3 | 6.5 | 144.0 | 30.0 |
| August | 72 | 45.9 | 6.3 | 158.4 | 34.9 |
| September | 35 | 45.5 | 9.2 | 152.3 | 27.7 |
| October | 34 | 43.7 | 9.1 | 165.7 | 32.7 |
| November | 11 | 31.4 | 9.7 | 165.9 | 24.8 |
| December | 13 | 30.9 | 5.5 | 170.5 | 25.3 |
| Dec-Jan-Feb | 61 | 30.1 | 5.1 | 172.3 | 24.3 |

* S.D. = Standard Deviation

### 2.8 Satellite Tracking of Individual Birds

Black-footed Albatross have been fitted with satellite transmitters at Torishima, French Frigate Shoals, NWHI, and at sea off the coast of California (Yamashina Institute of Ornithology unpubl. data, Anderson and Fernandez 1998, Hyrenbach 1998). Anderson and Fernandez (1998) showed that breeding birds at Tern Island in French Frigate Shoals travel shorter distances near the time of hatching and for a few weeks thereafter, and longer distances all the way to the coast of North America when the chicks get older. Birds tagged at Torishima Island traveled to the east during their foraging trips (Yamashina Institute of Ornithology unpubl. data). In 1997, Hyrenbach (1998) tracked five Black-footed Albatrosses that he captured from a ship in the southern California Bight. His research was oriented toward more fine-scale questions about foraging habitat use.

Anderson and Fernandez (1998) also showed that breeding adult Black-footed Albatrosses from the Tern Island colony covered the entire Northeast Pacific Ocean during foraging activities. They caution, however, that they had only tracked adult birds that were breeding or had bred in the 1997-98 breeding season and non-breeding or juveniles may or may not forage in the same area. Interestingly, Anderson and Fernandez (1998) showed that breeding Laysan Albatrosses primarily fly north to the Gulf of Alaska and the Aleutian Islands whereas breeding Black-footed Albatrosses fly to the west coast of North America.

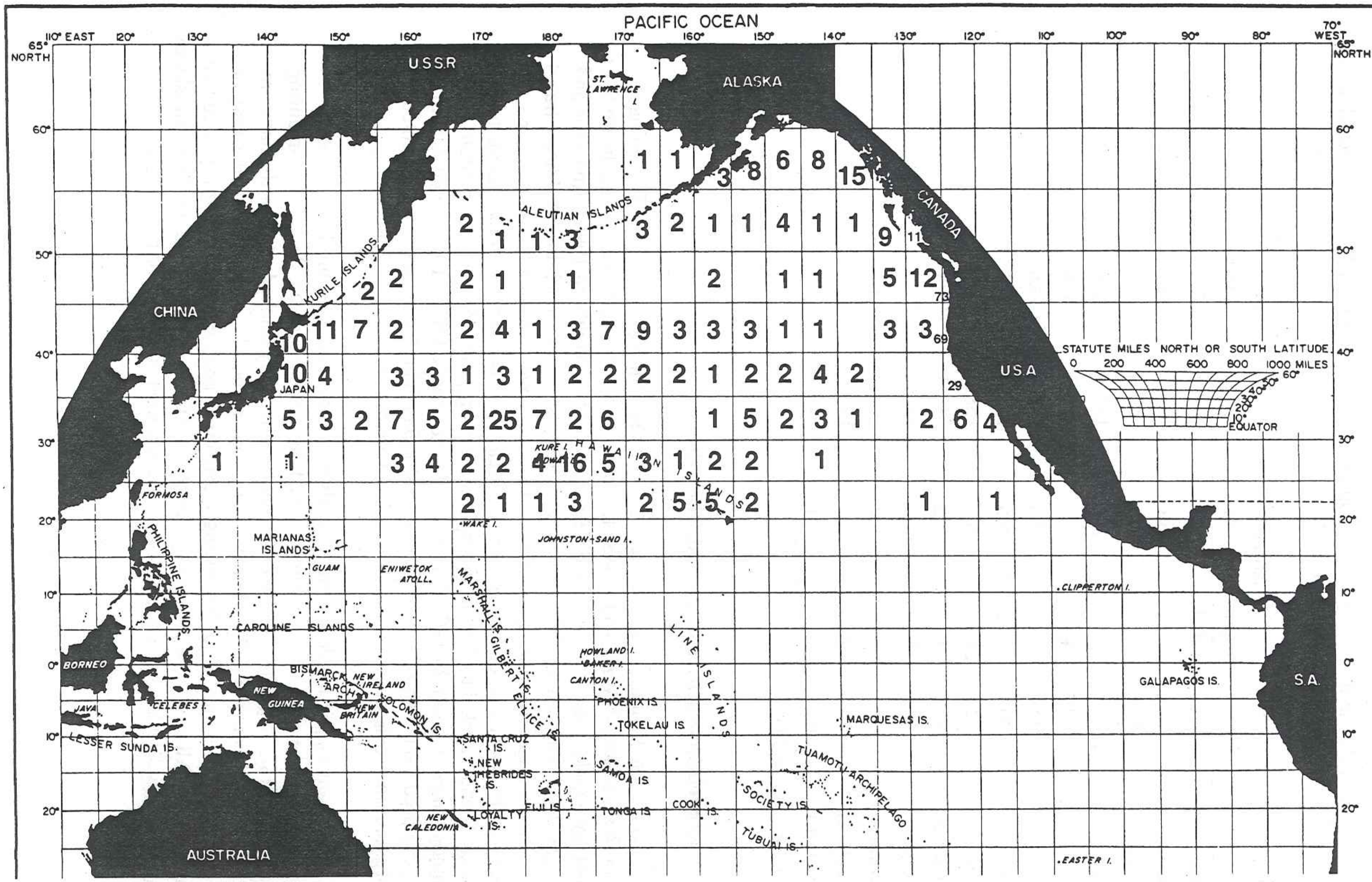



Figure 10. Distribution by five-degree blocks of all at-sea encounters of banded Black-footed Albatrosses processed up to 31 August 1998.

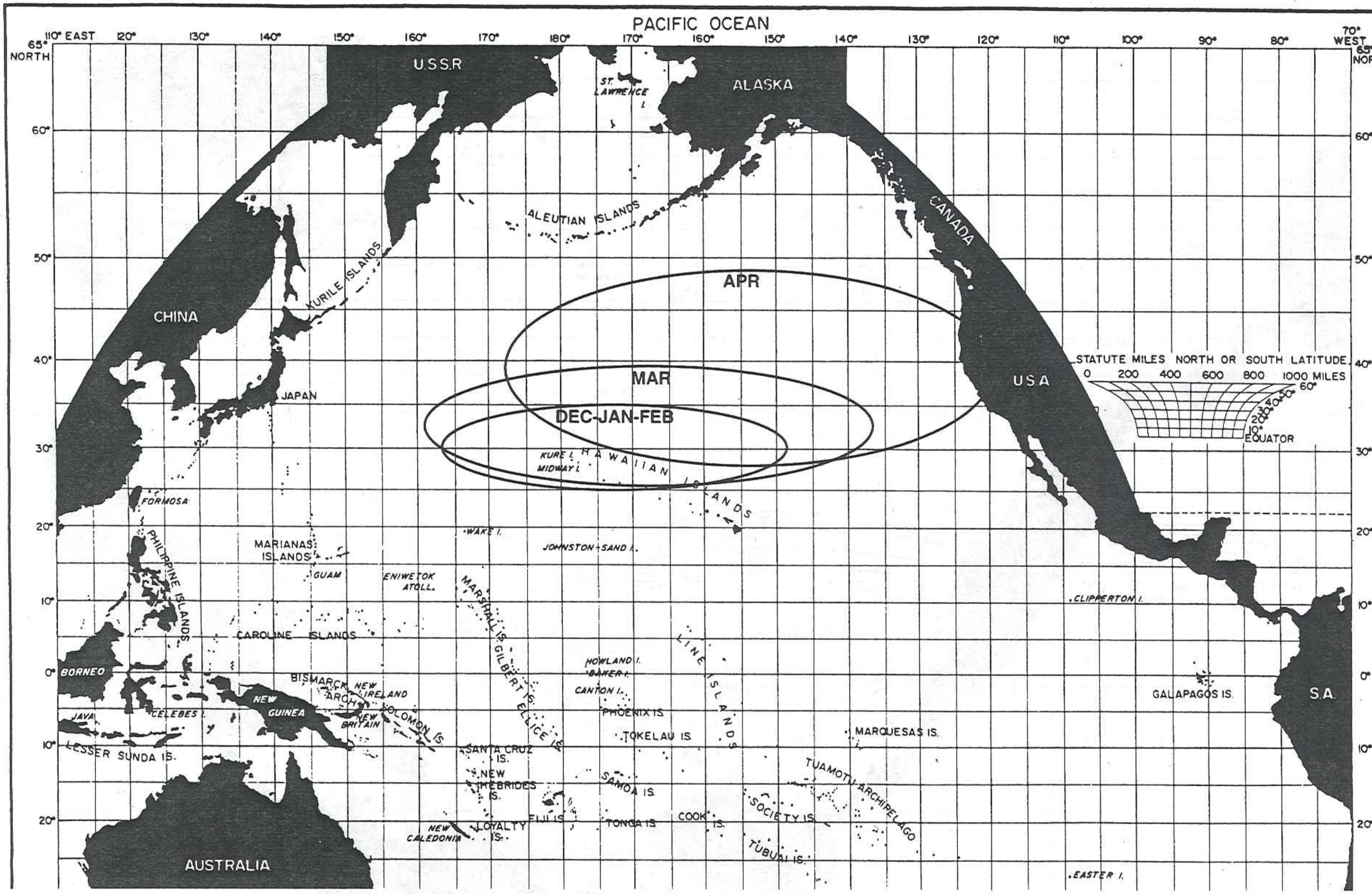



Figure 11. Monthly distribution, December through April, of Black-footed Albatrosses showing approximate area within which two-thirds of the reported encounters of banded birds occurred. Ovals represent one standard deviation around the mean. See Table 2 for means, standard deviation, and sample size.

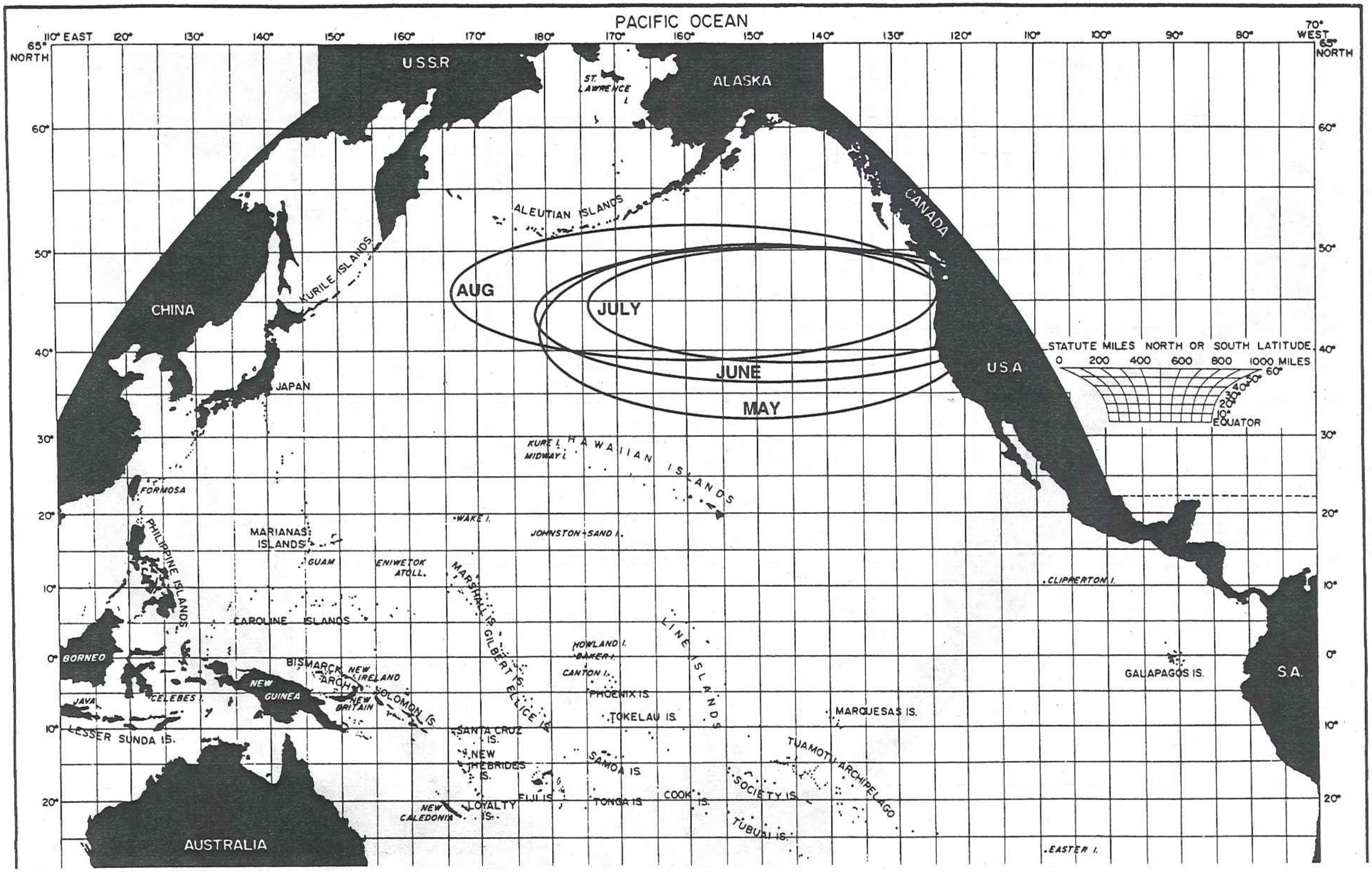



Figure 12. Monthly distribution of Black-footed Albatross band recoveries, May through August.

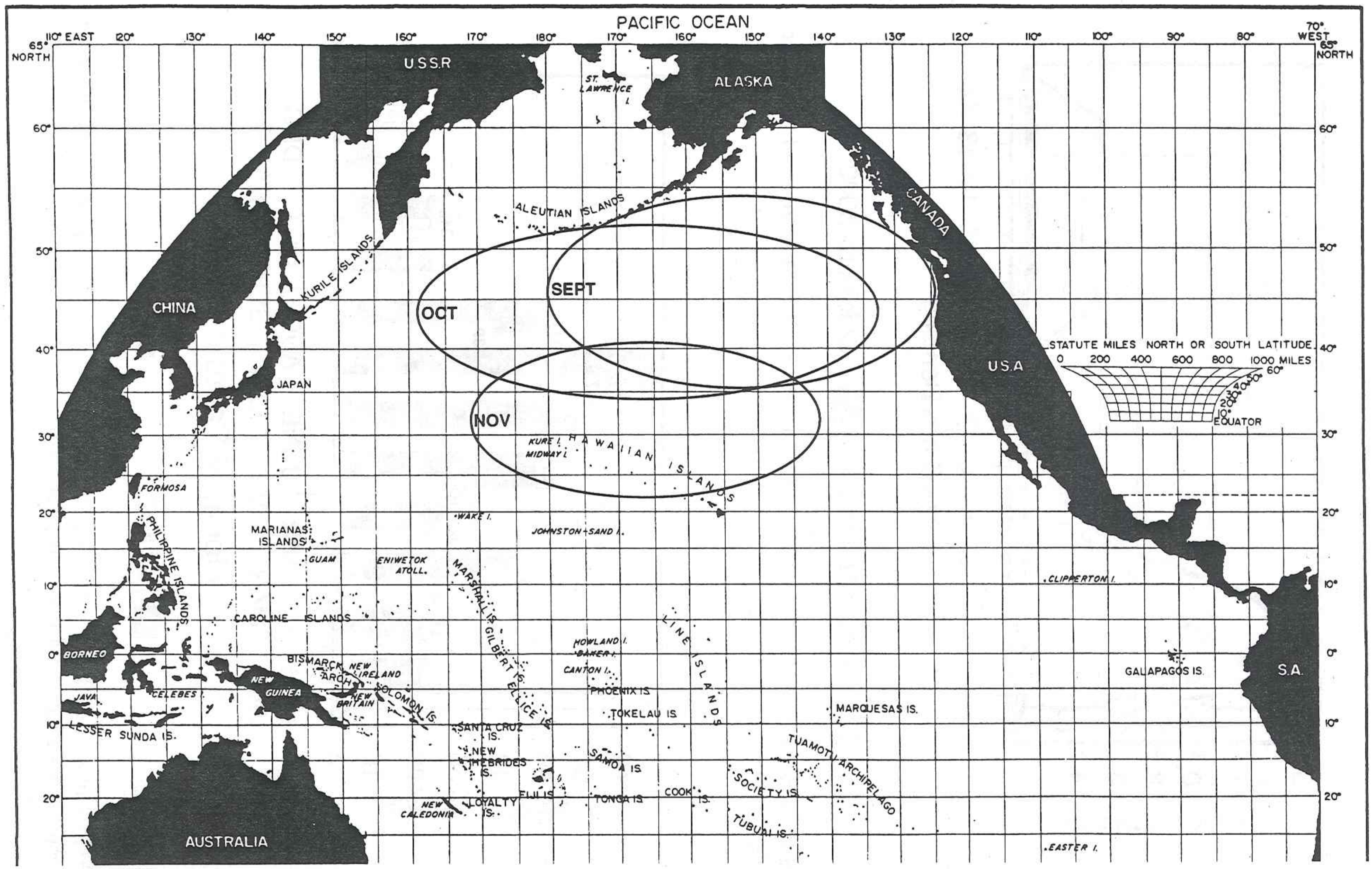



Figure 13. Monthly distribution of Black-footed Albatross band recoveries, September through November.

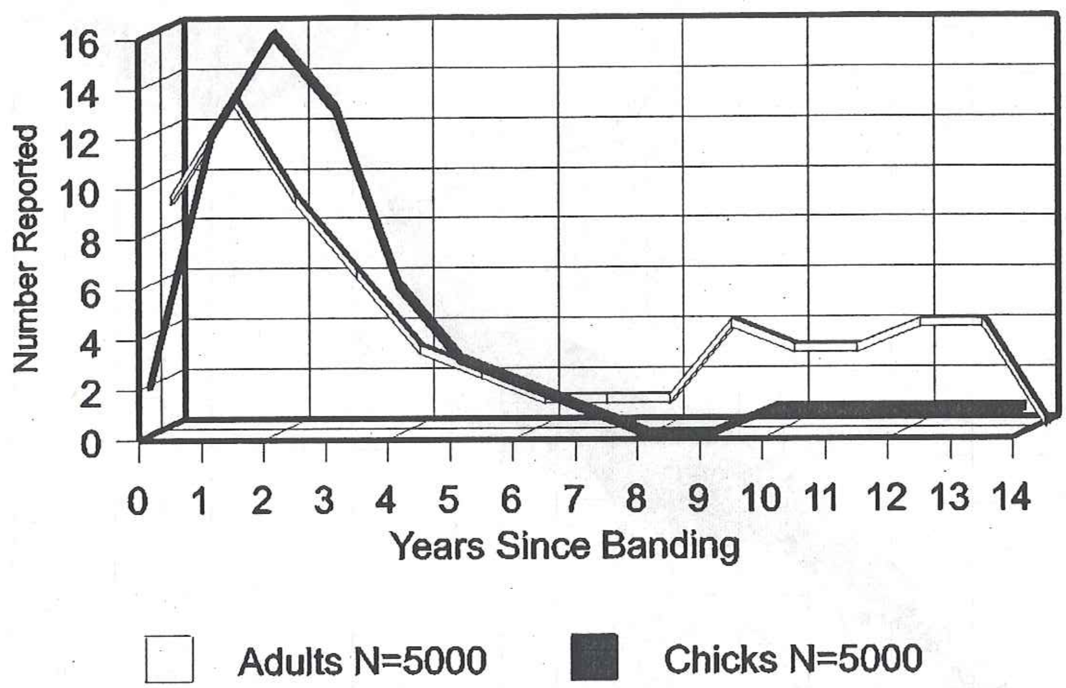



Figure 14. Numbers of banded Black-footed Albatrosses recovered at sea up to 14 years after banding.

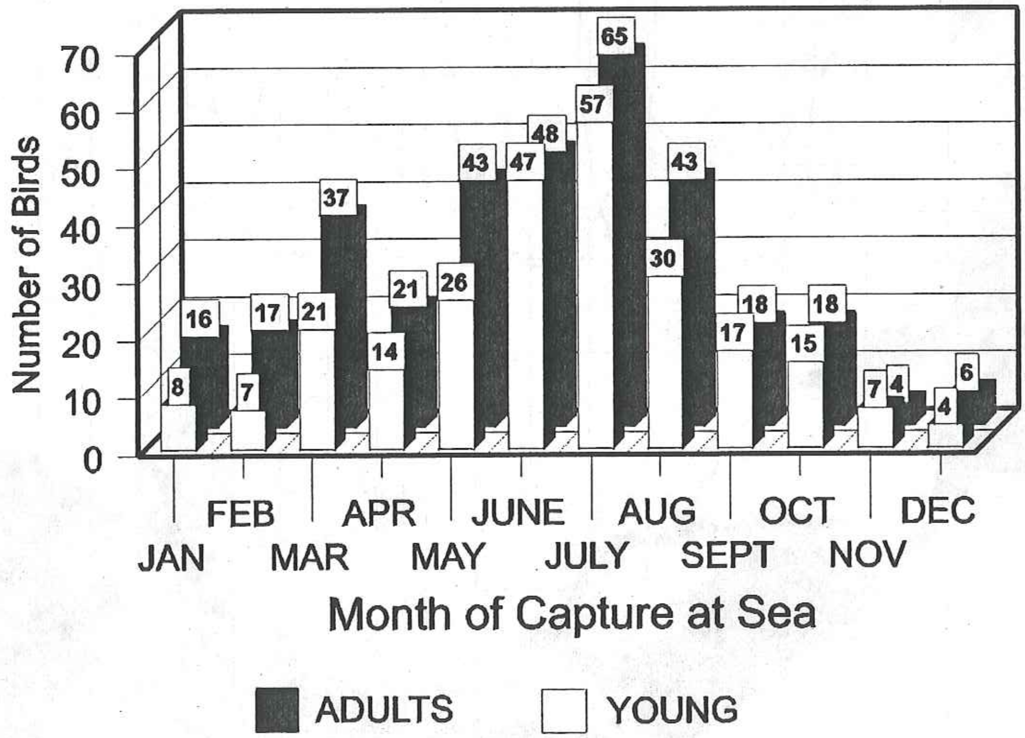



Figure 15. Numbers of Black-footed Albatrosses recovered at sea for a particular month. Note that more birds are recovered June through August.

## 3 Population Size and Trends

Black-footed Albatrosses nest throughout the North Pacific on islands that vary in habitat type and size. The current world population of breeding Black-footed Albatrosses is approximately 62,000 pairs in 12 colonies (Table 3). This means that the current world population of Black-footed Albatross, including both breeding and non-breeding birds, is about 300,000 (see sections 5.6 and 6). Seventy-seven percent of these pairs nest in three colonies (Laysan Island, Midway Atoll and French Frigate Shoals) which are systematically surveyed on an annual basis. Birds at most of the other colonies have been surveyed within the past two years and the rest within five years. Smaller colonies on Necker, Nihoa, Kaula and the Senkaku and Bonin Islands are not visited regularly.

The largest Black-footed Albatross colony, accounting for approximately 38% of world population, is on Laysan Island. Midway Atoll has the second largest Black-footed Albatross colony with 33%. Breeding populations formerly on Johnston Atoll, Wake Island, Taongi Atoll, Marcus Island, Iwo Jima Group (Volcano Islands) and the northern Marianas were extirpated within the last 150 years (McDermond and Morgan 1993). In recent years, Black-footed Albatrosses have made breeding attempts at Wake Island (M. Rauzon pers. comm.) and four birds were sighted on Minami Iwo Jima in 1982 (H. Hasegawa pers. comm.).

Direct counts of active nests during the egg stage have been completed for Midway Atoll from 1991 to 1998, with the exception of the 1993 breeding season, Laysan Island from 1997 to 1998, and French Frigate Shoals since 1979. Trend data from Midway Atoll, Laysan Island and French Frigate Shoals are presented in Figures 16, 17 and 18, respectively. Each shows data for the period that standardized techniques have been used to measure numbers of breeding pairs at the colonies. Together these three sites account for approximately 78% of the entire world population of the species. Figure 19 shows recent trends in the size of those three colonies that are counted each year as well as a composite of the best available information for all other sites each year to illustrate total world population trend.

Using the World Conservation Union (IUCN) criteria for identification of threatened species, the conservation status for the Black-footed Albatross was assessed as Vulnerable (Croxall and Gales 1998). The qualifying criterion was A2b reflecting a projected population decrease of more than 20% over three generations (approximately 45 years).

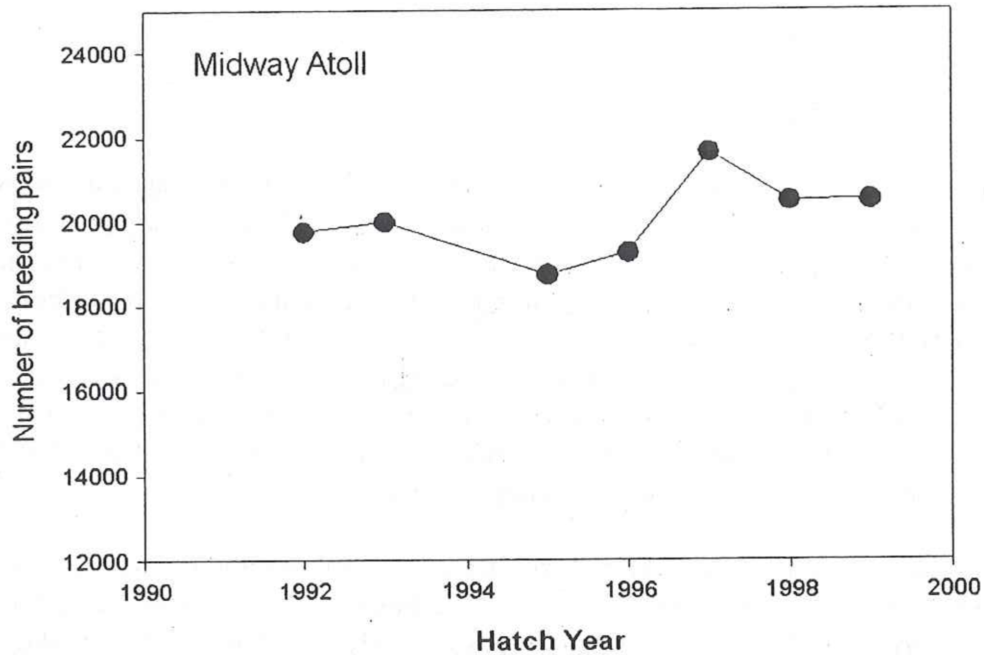



Figure 16. Total number of Black-footed Albatross active nests counted at Midway Atoll during each December between 1991 and 1998. The results are reported as number of breeding pairs during the hatch year. Eggs hatch in January of the year following the year of the December nest count (E. Flint unpubl. data).

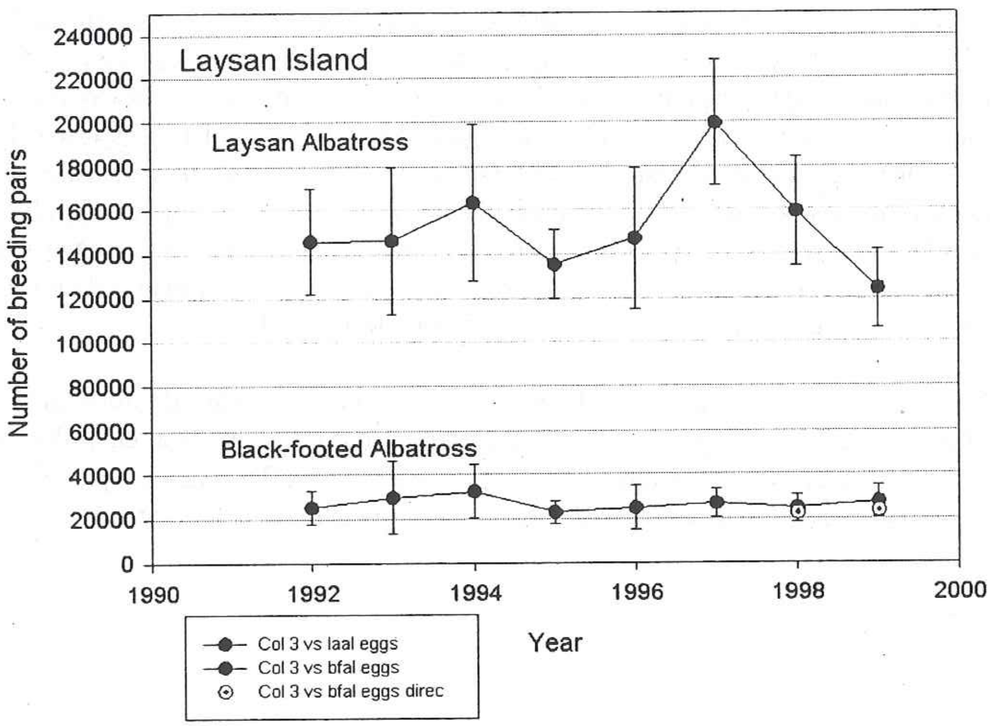



Figure 17. Number of breeding pairs of Laysan and Black-footed Albatrosses at Laysan Island during hatch years 1992 to 1999. Values with error bars represent estimates of total active nests derived by measuring nest density in 106 to 229 quadrats of 500 square meters each on Laysan Island during the month of December each year of the year preceding hatch year. Total population was then calculated by applying density to island area available for albatross nests. In hatch years 1998 and 1999, active nests of Black-footed Albatrosses were also counted directly at about the same time as the density samples were measured (E. Flint unpubl. data).

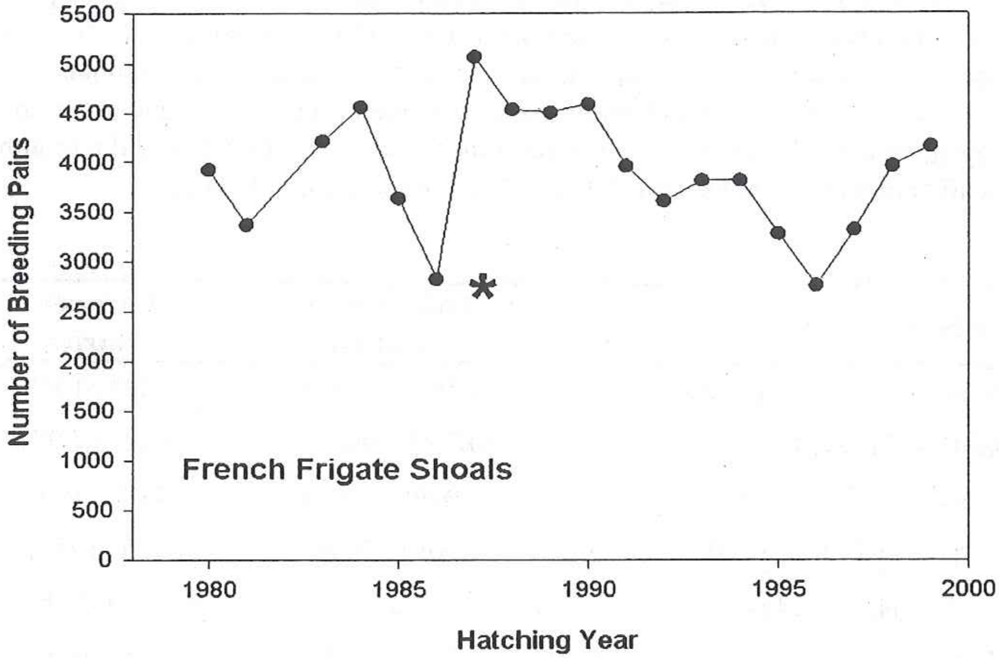



Figure 18. Number of breeding pairs of Black-footed Albatross at French Frigate Shoals during hatch years 1980 to 1999. Values represent a direct count of all active nests during the early egg stage for each year. An asterisk (*) marks the count where large ocean swells destroyed many nests before they could be counted (E. Flint unpubl. data).

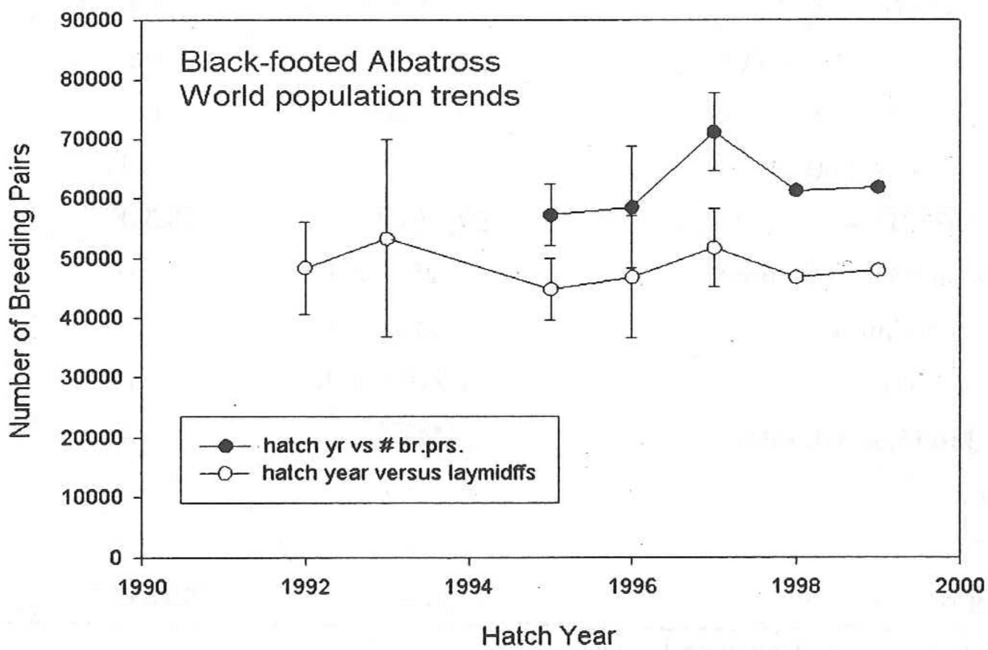



Figure 19. Recent trends in the world population of Black-footed Albatross and the trend at the three most thoroughly monitored colonies, Midway Atoll, Laysan Island and French Frigate Shoals (midlayffs), at which approximately 78% of the world breeding population is now counted annually. The total world population is derived from the most recent count at each of the breeding colonies listed in Table 3 (E. Flint unpubl. data).

Table 3. A summation of current best available figures for the numbers of breeding pairs of Black-footed and Laysan Albatrosses for each breeding locality. A hash mark (#) indicates that breeding is suspected but not confirmed. An asterisk (*) indicates an extrapolation to total eggs from chicks counted between February and July of the indicated year and assuming a 75% breeding success. Values without asterisks indicate nests counted during the month of December while birds are on eggs (E. Flint and H. Hasegawa unpubl. data).

| Breeding locality | Black-footed Albatross | Laysan Albatross |
|---|---|---|
| Kure Atoll 28° 25' N, 178° 10'W | 1,653* (1997) | 5,539* (1997) |
| Midway Atoll 28°12'N, 177° 20'W | 20,510 (1998) | 387,854 (1996) |
| Pearl & Hermes Reef 27° 55'N, 175° 45'W | 6,949* (1998) | 11,429* (1997) |
| Lisianski I. 26° 02'N, 174° 00'W | 2,901* (1999) | 26,500 (1982) |
| Laysan I. 25° 42'N, 171° 44'W | 23,297 (1998) | 124,113 (1998) |
| French Frigate Shoals 23° 45'N, 166° 15'W | 4,164 (1998) | 2,105 (1998) |
| Necker I. 23° 35'N, 164° 42'W | 112* (1995) | 500* (1995) |
| Nihoa I. 23° 06'N, 161° 58'W | 31* (1994) | 0 (1995) |
| Kauai I. 22° 14'N, 159° 24'W | 0 (1995) | 100 (1995) |
| Lehua I. 22° 01'N, 160° 06'W | # | Unknown |
| Niihau I. 21° 55'N, 160° 14'W | Unknown | 175 |
| Kaula I. 21° 40'N, 160° 32'W | 5 (1993) | 63 |
| **Total for NWHI[1]** | **59,622** | **558,378** |
| Senkaku Islands (Kita-Kojima) | 25 (1991) | 0 |
| Bonin I. (Chichijima) | 1,000 (1993) | 14 |
| Izu I. (Torishima) | 1,219* (1998) | 0 |
| **Total for Japanese Islands** | **2,244** | **14** |
| Guadelupe I. | 0 | 10 |
| Mexican I. | 0 | 13 |
| **World Total** | **61,866** | **558,415** |

[1] NWHI = Northwestern Hawaiian Islands

### 3.1 Black-footed Albatross Population History on Torishima

In 1932, fewer than 1,000 Black-footed Albatrosses nested on Minami Tori Shima Island ("Torishima") (30° 29′ N, 140° 19′ E; Fig. 20). The local inhabitants killed these birds for their feathers, although not as highly prized as feathers from the Short-tailed Albatross (Austin 1949). In 1939, the volcano erupted and modified the nesting habitat of the island, thereby reducing the Black-footed Albatross population to a low level. Systematic counts started in 1957 (Table 4) when six Black-footed Albatross chicks were reared. Numbers of chicks reared have increased steadily to 914 in 1998 (H. Hasegawa unpubl. data). The Black-footed Albatross populations on Bonin and Senkaku Islands have also increased (H. Hasegawa pers. comm.).

Table 4. Numbers of Black-footed Albatross chicks reared on Torishima, Japan, 1957- 1998* (H. Hasegawa unpubl. data).

| Year of Fledging | Date of Count | Original Colony At Tsubame-zaki | New Colony At the Northwest Slope | Total Population |
|---|---|---|---|---|
| 1957 | 26 March | 6 | | 6 |
| 1958 | 25 March | 6 | | 6 |
| 1959 | 19 April | 11 | | 11 |
| 1960 | 5 February | 10 | | 10 |
| 1961 | 18 April | 11 | | 11 |
| 1962 | 5 February | 18 | | 18 |
| 1963 | 17 April | 13 | | 13 |
| 1964 | 7 April | 14 | | 14 |
| 1965 | 6 April | 20 | | 20 |
| 1973 | 1 May | 50 | | 50 |
| 1977 | 20 March | 126 | | 126 |
| 1980 | 21 March | 160 | | 160 |
| 1982 | 25 March | 200 | | 200 |
| 1983 | 20 March | 218 | | 218 |
| 1985 | 18 March | 347 | | 347 |
| 1986 | 16 March | 333 | | 333 |
| 1989 | 30 May | 404 | 1 | 405 |
| 1990 | 25 May | 531 | 5 | 536 |
| 1991 | 14 April | 561 | 10 | 571 |
| 1992 | 21 April | 557 | 24 | 581 |
| 1993 | 18 April | 597 | 46 | 643 |
| 1994 | 17 April | 630 | 86 | 716 |
| 1995 | 27 April | 659 | 126 | 785 |
| 1996 | 22 April | 481 | 160 | 641 |
| 1997 | 17 April | 392 | 205 | 597 |
| 1998 | 22 April | 636 | 278 | 914 |

* No counts made in missing years.

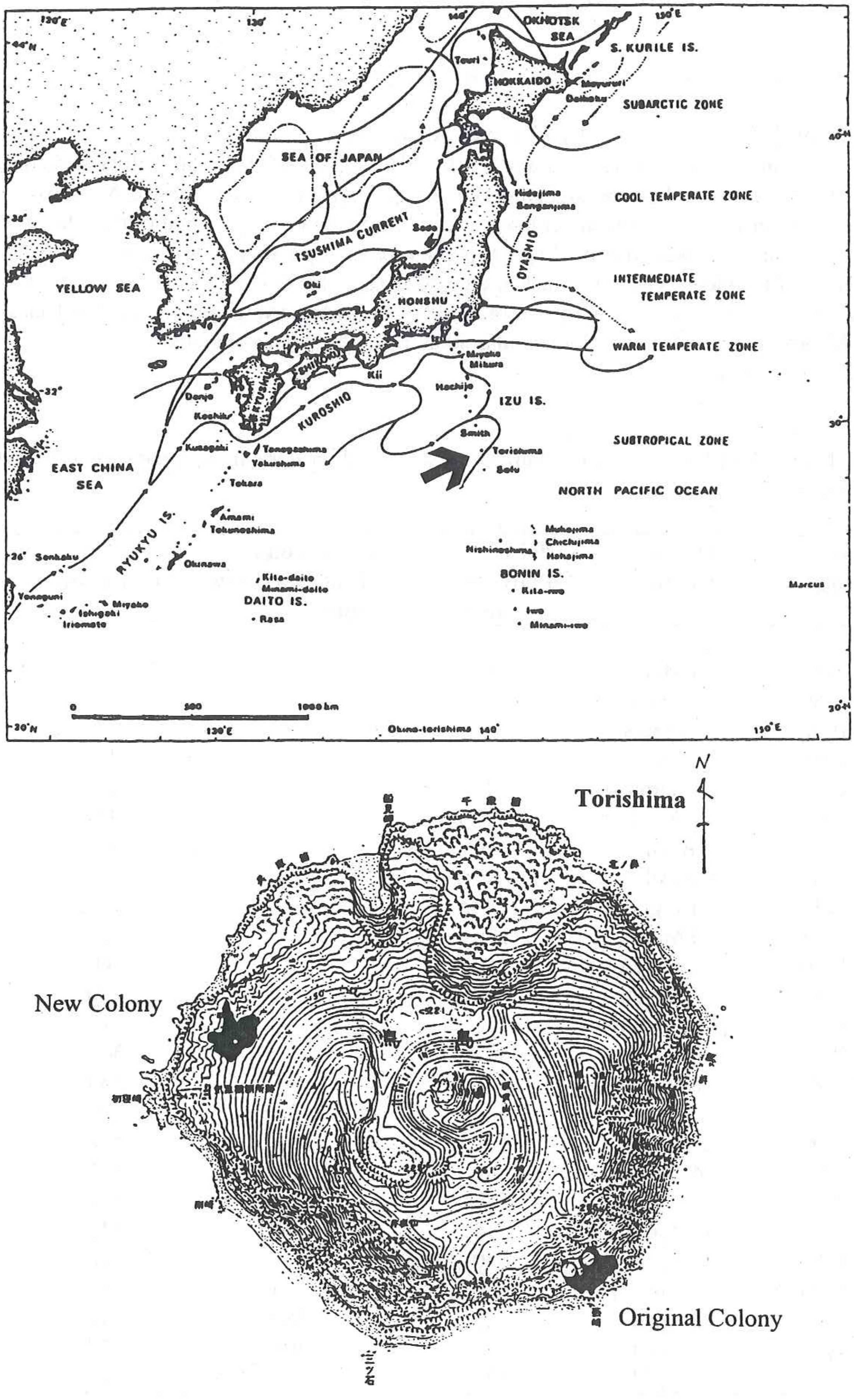



Figure 20. Location of Torishima in the Western Pacific Ocean and the localities of the Black-footed Albatross colonies on the volcanic island.

### 3.2 Black-footed Albatross Population History in the NWHI

The northwestern Hawaiian Islands (NWHI) extend approximately 1,900 km (1200 miles) northwest from Honolulu, from Nihoa, a steep rocky island approximately 190 km (125 miles) northwest of Kauai, to Kure Atoll, whose single low, sandy island is the last emergent land in the chain (Figure 21). Early mariners discovered the islands in the late 1700s through mid-1800s (Berger 1988). Only Nihoa and Necker showed signs of earlier Polynesian habitation, although the presence of Polynesian rats *Rattus exulans* on Kure indicates earlier Polynesian visits (Berger 1988). Devoid of mammalian predators, these islands supported extremely high populations of breeding seabirds, as did the main Hawaiian Islands until the arrival of the first Polynesians around 500 A.D. (Kirsch 1982).

From the late 1800s through the early 1900s, Japanese egg and feather hunters supplying the French millinery trade extirpated or nearly extirpated some seabird colonies throughout the Pacific (Rice and Kenyon 1962a, Berger 1988, Spennemann 1998). To protect the colonies from further devastation, President Theodore Roosevelt established the Hawaiian Islands Bird Reservation on 3 February 1909 (Executive Order 1019). The Reservation initially included all of the NWHI except for Midway Islands, which were under the jurisdiction of the U.S. Navy Department (Clapp and Kridler 1977). Jurisdiction for the Reservation was transferred from the U.S. Department of Agriculture to the Bureau of Sport Fisheries and Wildlife (BSFW) of the U.S. Fish and Wildlife Service (FWS) in the Department of the Interior on 25 July 1940, and its name was changed to the Hawaiian Islands National Wildlife Refuge (Clapp and Kridler 1977). Eugene Kridler became the BSFW's first manager of the Refuge in 1964 (Clapp and Wirtz 1975).

### 3.3 Past Scientific Studies

Unfortunately, there are no records of the Black-footed Albatross population size prior to the egg and feather poaching. The Rothschild Expedition of 1891, with Henry Palmer and George C. Munro, was the first scientific collecting expedition to the Leeward Hawaiian Islands, but they did not make quantitative estimates (Ely and Clapp 1973). Estimates and counts taken since bird harvesting ceased show that populations have generally increased (Gould and Hobbs 1993).

In 1913, a party from the U.S. Bureau of Biological Survey, including George Willet and Alfred M. Bailey, explored the NWHI. Lieutenant William H. Munter, although not an ornithologist, made knowledgeable observations in 1915 while on a cruise of the U.S. revenue cutter *Thetis* (Clapp and Wirtz 1975). The first comprehensive scientific exploration of the NWHI was the Tanager Expedition in 1923, led by Dr. Alexander Wetmore of the U.S. Biological Survey, and sponsored by the U.S. Navy, U.S. Biological Survey, and the Bishop Museum in Honolulu (Clapp *et al.* 1977). Frank Richardson of the University of Washington made observations for several islands in 1954. From 1956 to 1958, Rice and Kenyon (1962a,b) of the BSFW conducted the first systematic attempt to estimate the total numbers of albatrosses in the North Pacific. Robbins (1961) and colleagues of FWS continued the studies of Rice and Kenyon at Midway Atoll through 1969. Meanwhile, the Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institution, conducted from 1963 through mid-1969, was the most intensive scientific study ever undertaken in the NWHI. Few censuses were conducted during the 1970s and 1980s, with the exception of studies done by the FWS

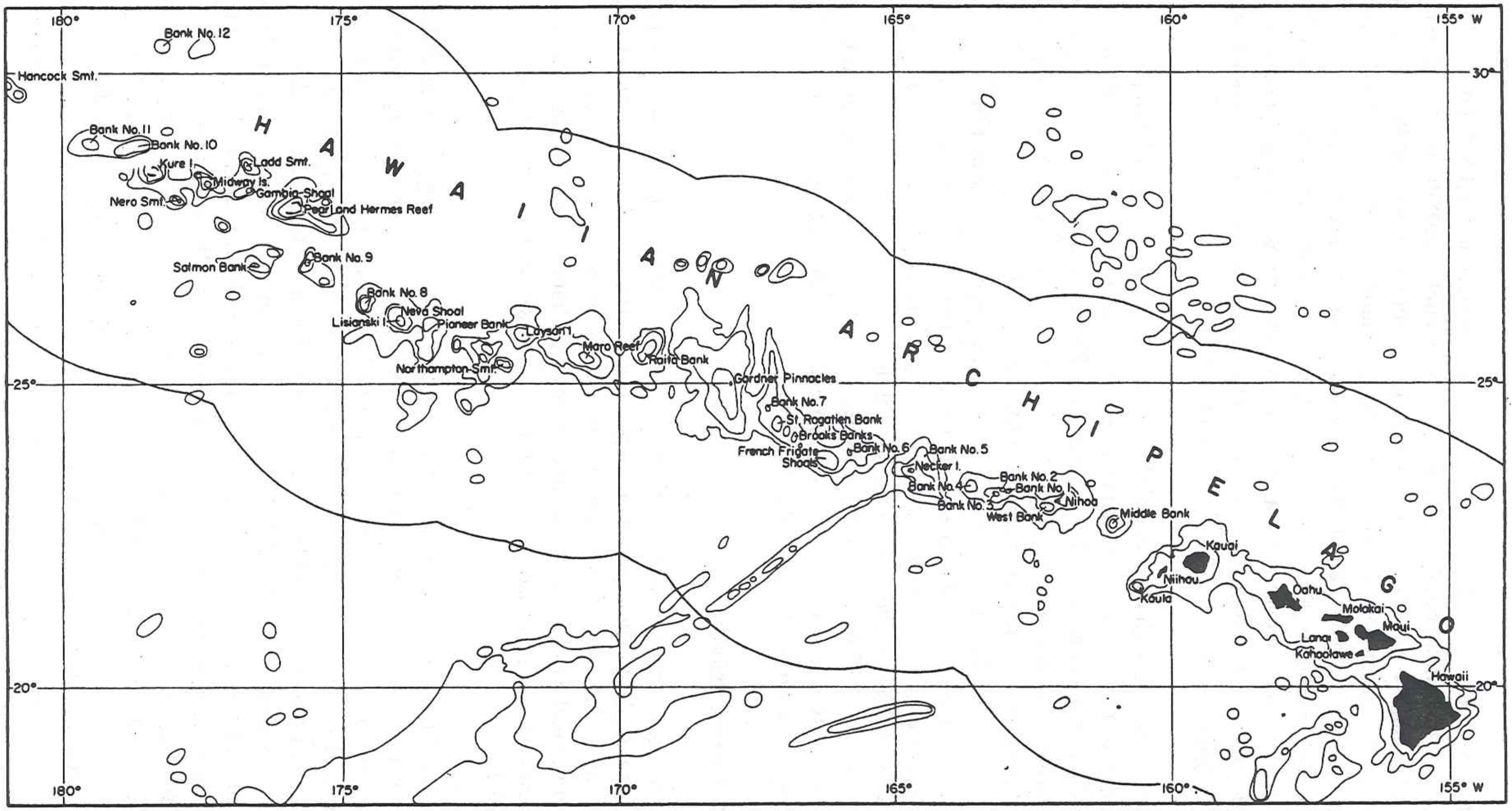



Figure 21. The Hawaiian Archipelago and the 200-nautical mile Exclusive Economic Zone (EEZ) (Figure reproduced with permission from Harrison 1990).

during 1978-1982 (Fefer *et al.* 1984). However, data collected from individual islands during this time remain unpublished and some appears to have been lost. The frequently cited numbers of breeding pairs from Harrison (1990) are taken from a paper by Harrison *et al.* (1984), which in turn were taken from Fefer *et al.* (1984). Some of the numbers cited here were based on counts and quadrat sampling estimates done between 1979 and 1992. Others, such as those for Kure Atoll, are the POBSP numbers from the 1960s. The FWS has maintained permanent field stations on Midway Atoll since 1991 and at Tern Island in French Frigate Shoals since 1979, and a camp on Laysan Island since June of 1991. The remaining NWHI are visited at least once a year by FWS personnel or, in the case of Kure Atoll, by Hawaii State Division of Forestry and Wildlife managers. Counts of albatrosses are not always conducted on these trips. Additional data exist from Tern Island from 1995 onward that will be published as part of a University of Washington graduate thesis (A. Viggiano, University of Washington pers. comm.).

### 3.4 Methodology

Several techniques have been used to arrive at the population figures given in Appendix III. The oldest figures, unless otherwise indicated, were rough guesses. Rice and Kenyon (1962a) conducted complete ground surveys of Kure and Midway Atolls, and estimated populations at other islands using aerial photographs taken in December 1956 and January and December 1957. Based on ground counts done on Midway Islands a few days before the air surveys, they subtracted 25% from the aerial counts for "unemployed" or non-breeding birds to estimate the number of incubating birds.

The reliability of these different census estimates varies. Visual estimates are no longer done because they depended on the skill of the observer, which is difficult to assess. Counts from aerial photographs and surveys, such as Rice and Kenyon's (1962a) and E. Kridler's (BSFW 1967), may overestimate Black-footed Albatross on those islands where might be mistaken for Great Frigatebirds *Fregata minor* (Amerson 1971).

The long incubation and fledging period of Black-footed Albatrosses (7 months) increases the chances that short visits to uninhabited breeding islands will occur during the breeding season and population counts can be made. When these counts occur later in the breeding cycle they must be corrected for egg and chick loss that occurred before the count. Standard refuge protocol for seabird counts at uninhabited albatross breeding sites is to make a direct count of all active nests (those containing an egg and incubating adult or those containing a live chick). These values are then corrected for chick loss prior to the count by using reproductive performance rates for that year measured at more intensively monitored colonies. Reproductive success has been measured through the years at Midway Atoll, Laysan Island, and Tern Island, French Frigate Shoals (Appendix II). These studies indicate that reproductive success varies widely between years, location, and habitat types. This suggests that counts of chicks made late in the breeding season will yield unreliable estimates of the number of pairs that laid eggs that season. Moreover, reproductive success can be negatively affected by the presence of ground contaminants, such as pesticides, PCBs (polychlorinated biphenyls), and lead at the breeding sites. Contaminants such as these have been removed by the Navy from Midway Atoll and by the Coast Guard at Kure and Tern Islands, but are still present at Midway and Tern Island.

The most accurate method for measuring the size of the breeding population in any year is a direct count of active nests immediately after laying has finished in the month of December. This is standard procedure at three sites now, Midway Atoll, Laysan Island, and French Frigate Shoals and accounts for approximately 77% of the world population each year.

Between 1980 and 1996 counts at Laysan Island, the world's largest Black-footed Albatross colony, were done by sampling approximately 200 quadrats for density of active nests and multiplying that density by island area suitable for nesting. The count generated trend data but with wide confidence levels that made small changes in population size impossible to detect. Complete counts of Laysan Island Black-footed Albatross nests were initiated in 1996. At French Frigate Shoals these complete direct counts were started in 1979 and at Midway Atoll complete counts were started in 1991. Unfortunately the variation in methods at most colonies makes comparison Black-footed Albatross population sizes between years and localities troublesome prior to the 1992 hatch year.

Even more difficult than counting breeding birds is the task of estimating the size of the non-breeding population - both birds that are too young to have started breeding and those that simply are not breeding in any particular year. Many of these birds do visit the breeding colonies even if they are not actually breeding. This segment of the population has been more thoroughly studied in the Laysan Albatross (Fisher and Fisher 1969). To estimate the size of the non-breeding population of Black-footed Albatross the FWS is doing a saturation banding and band-reading project at Tern Island where they band and record all individuals that visit during the entire season. All chicks produced at Tern Island have been banded since 1979, and all unbanded adults have been banded and all bands have been read since 1997. This effort will produce better estimates for the demographic parameters of breeding frequency and proportion of pre-breeders in the near future.

## 3.5 Northwestern Hawaiian Islands History

### 3.5.1 Kure Atoll

Kure Atoll (28° 25′ N, 178° 10′ W) is the most northern island of the leeward Hawaiian Islands (Fig. 22). Green Island (about 2.25 km long and 0.60 km wide) is the only permanent land, although two other islets existed in the past (Berger 1988). President Franklin Roosevelt placed the atoll under the juridiction of the Secretary of the Navy on 20 February 1936 (Woodward 1972). During World War II, the U.S. military removed Kure Atoll from the Hawaiian Islands National Wildlife Refuge (Berger 1988). Kure Atoll was placed under the jurisdiction of the Territory of Hawaii in 1952 by President Harry S. Truman (Executive Order 10413). From 1960 through to 1992, a Coast Guard Long Range Aid to Navigation (LORAN) station, consisting of a 1.2-km runway and a 190-m high tower, was maintained by approximately 24 men (Bryan 1978). In July of 1992 the Coast Guard demolished the tower, relinquished its license to the State of Hawaii, and in 1993 completed a cleanup of the atoll. The State of Hawaii's Division of Forestry and Wildlife (DOFAW) now maintains jurisdiction over the atoll and DOFAW personnel visit it about once a year. The most frequent counts of Black-footed Albatrosses took place during the Pacific Ocean Biological Survey Program (POBSP) of the Smithsonian Institute from 1963 to 1969. The POBSP conducted the only breeding success studies done on Kure Atoll (Table 7). Winter storms that washed away or buried nests with blowing sand destroyed many eggs in 1964-65 and 1968-69 and rat predation apparently reduced success in 1966 (Woodward 1972; Appendix III).

### 3.5.2 Midway Atoll

Midway Atoll (28° 12′ N, 177° 20′ W), geographically referred to as Midway Islands, contains three islands: Sand (485.6 hectares), Eastern (138.6 hectares) and Spit (variable) (Fig. 23). Midway has the second largest colony of Black-footed Albatross. Of all the islands and atolls of the NWHI, Midway has had the longest continuous human occupation (since 1903), the largest human population [reaching approximately 15,000 by 1945 (Harrison 1990) —it currently hovers around 200], and the most intense human impact. That any seabirds remain at all is more of a testament to the birds' tenacity and adaptability than to responsible human stewardship. Thousands of albatrosses, mostly Laysan Albatrosses, were deliberately killed by the U.S. Navy in an attempt to reduce bird strike hazards to aircraft (Robbins 1966). Countless birds also fell victim to lethal beatings by vandals (Robbins 1963). During the war years Black-footed Albatrosses, in particular, were killed by entanglement in barbed wire set along the shorelines (Fisher and Baldwin 1946). In addition, residents of Midway on both Eastern and Sand Islands kept dogs as pets (Robbins 1961). The birds have also been exposed to toxic chemical agents such as DDT (Dichloro-diphenyl-trichloroethane), which was sprayed to control mosquitoes (Robbins 1962), and lead paint chips and PCBs (polychlorinated biphenyls).

Albatross habitat has been both destroyed and created on Midway. Large areas (approximately 250 meters on either side) around the runways on Sand Island were paved to prevent albatross from nesting (Robbins 1966). The addition of fill material dredged from the lagoon to create a channel and harbor greatly increased the original area of Sand Island. The presence of Black-footed Albatross nests in the interior areas of Sand Island shows the original location of the pre-fill shorelines (Fig. 24). From 1994 to 1997, the demolition of multiple blocks of military housing, a number of abandoned buildings (including a school, a chapel, and a hazardous materials storage area), as well as the removal of over 150 underground and surface fuel storage tanks, reopened large areas of habitat for nesting birds. One area around former fuel storage tanks is now a major Black-footed Albatross colony; however, Laysan Albatrosses have mostly recolonized other cleared areas. In addition, many unnecessary street and traffic signs and overhead wires have been removed, reducing bird collisions with these obstacles.

In 1996, Executive Order 13022 transferred the administration of Midway Atoll to the Department of Interior to be managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. Limited eco-tourism and public use in the form of sport-fishing, diving and wildlife observation is permitted at the atoll. It also serves as a refueling stop for a limited number of private planes traveling between North America and Asia and the Middle East. Reckless driving by people; collisions with buildings, lights and overhead utility lines; entanglement in *Casuarina litorea* (Ironwood) trees; and introduced *Casuarina* trees falling in windstorms landing on nesting albatrosses or bringing down overhead electrical lines which electrocute nearby birds, continue to claim the lives of a number of albatrosses (mostly Laysan Albatrosses) each year.

The Midway Black-footed and Laysan Albatross populations are the most studied of all the NWHI populations. Breeding success figures exist for a number of years in the 1950s and 1960s and Refuge Staff have conducted breeding success studies and annual complete censuses since 1994.

### 3.5.3 Pearl and Hermes Reef

This atoll comprises a variable number of small islands and sand bars within a reef 69 km in circumference (Amerson *et al.* 1974) (Fig. 25). Island number and size change due to storms, rising sea level, wave action and currents. Grass, North, Seal-Kittery, and southeast are presently the largest, and only vegetated islands. Pearl and Hermes Reef (27° 55′ N, 175° 45′ W) has been occupied at various times by ship-wrecked sailors, Japanese feather harvesters, fishermen, mother-of-pearl harvesters, and the U.S. military. A direct count of all Black-footed Albatross chicks on the islands has been conducted each spring since 1996.

### 3.5.4 Lisianski Island

Lisianski (26° 02′ N, 171° 00′ W), a low sand and coral island with an area of approximately 182 hectares, is the only island in a large reef bank about 170 $km^2$ in area (Clapp and Wirtz 1975) (Fig. 26). Although the Hawaii Kingdom granted leases with rights to remove phosphates and guano from Lisianski Island, no guano mining or military occupation occurred on Lisianski; only ship-wrecked sailors and Japanese feather harvesters in the 1800s and early 1900s have lived on the island for any length of time. In 1977, the Liberian oil tanker *Irenes Challenge* spilled 10.4 million gallons of crude oil 80 km north of Lisianski (200 nautical miles southeast of Midway), but the island was not surveyed at the time. A direct count of all Black-footed Albatross chicks on the island has been conducted each spring since 1997.

### 3.5.5 Laysan Island

Laysan (25° 42′ N, 171° 44′ W) is a stable, coral island approximately 2.25 $km^2$ in area (369.5 hectares), with a saline lagoon in the interior (Fig. 27). It has the world's largest colony of Black-footed Albatrosses. Japanese feather harvesters and a guano-miner named Max Schlemmer all but destroyed the island's unique ecosystem within a thirty-year period spanning the turn of the century. On 21 March 1910, Schlemmer was indicted, but later found not guilty, on charges of poaching on a federal bird reservation and on two counts of illegally importing contract laborers. Schlemmer also introduced rabbits to Laysan Island. The rabbits had virtually devegetated the entire island and were not completely eradicated until the 1923 Tanager Expedition (Ely and Clapp 1973). As late as 1970, the old guano mine was still noticeable as a flattened, partially devegetated area, approximately 274 m in diameter (Ely and Clapp 1973). The FWS has maintained a permanent camp on the island since June of 1991. In May of 1988, researchers surveying Hawaiian Monk Seals *Monachus schauinslandi* noticed an area of about 10 square meters where dead albatross chicks did not decompose normally. Closer examination revealed many dead flies and crabs. Subsequent analysis of the soil from this area, known as the "dead zone", revealed the presence of a carbamate pesticide, Carbofuran, which is highly toxic to invertebrates, fish and birds, but no container was ever discovered nor was there any hint of how the pesticide found its way to the island.

From 1992 through 1995, FWS personnel conducted annual breeding success studies in different habitat types on Laysan Island, and estimated the breeding population. Because the population is so large, the number of breeding pairs was estimated by counting nests within at least two hundred and five 5 x 100 meter quadrats along 38 transects. Since 1997, FWS personnel have also undertaken a complete count of Black-footed Albatross nests in the third week of December. Comparison of the direct counts taken in 1997 and 1998 with the estimates calculated for those years using the quadrat sampling method shows that the quadrat sampling method overestimates the number of eggs. However, the direct counts fall within the confidence intervals of the quadrat sample estimates.

### 3.5.6 French Frigate Shoals

French Frigate Shoals (23° 45′ N, 166° 15′ W) comprises a crescent-shaped reef 31 km in diameter and an ever-changing number of islands (Fig. 28). Island number and size change due to storms, rising sea level, wave action and currents. With the recent disappearance of Whale-Skate Island, there are currently 11 islands: Bare, Disappearing, East, Gin, Little Gin, Mullet, Near, Round, Shark, Tern, and Trig. Mullet, Round, and Shark are awash at high tide. A new island near Gin, dubbed "Tonic", has recently appeared. La Perouse Pinacle is a small, steep-sided volcanic remnant that has never been observed to support nesting Black-footed Albatrosses.

The following history of French Frigate Shoals is summarized from Amerson (1971): The atoll was of great strategic interest to the U.S. Navy and was an important safety station for the U.S. Coast Guard. Starting in June of 1932, and continuing until World War II, it was used for a series of ship and air exercises, with East Island frequently serving as the base of operations. From 12 June 1942 to 21 March 1943, the Navy planned and constructed a land base on Tern Island. The 549- by 137-meter (4.5 hectares) sand island was covered with fill dredged from the lagoon for a ship channel and seaplane landing area, and transformed into a 945- by 107-foot (14 hectares) landing field, supported by a steel sheetpile sea wall. Eight buildings, both above and below ground, 21 fuel tanks, and a 27-m radar tower were built, with 118 men stationed on the island. In 1944 new barracks and galley facilities were added to accommodate a total of 127 men. After the war ended, it was placed in caretaker status on 7 October 1945, and disestablished on 9 June 1946. From that point through the 1950s, Hawaiian commercial fishermen used the facilities, including for a base to fly fish to Honolulu from November 1946 until August 1949.

The U.S. Coast Guard constructed a LORAN station on East Island in June of 1946, comprising seven Quonset huts, six smaller buildings, a distillation plant and storage, and a seven-pole antenna network, with 27 men stationed there. On 24 October 1952, the station moved to the old Navy facilities on Tern Island, leaving the East Island facilities to fall to ruins (Berger 1988). In 1958, when Kenyon and Rice (1962) conducted their survey, 13 men and a dog lived on Tern Island. On 2 December 1969 the men and three dogs were rescued after the island was completely over-washed by high waves. A Pacific Missile Range Facility was constructed on Tern Island in December of 1960, further increasing human activity in the atoll, but it was removed in August of 1963. From April through August 1964, the Coast Guard substantially renovated the Tern Island facilities and sea wall. The island was occupied by U.S. Coast Guard personnel until 1979, when it was finally returned to the FWS (McDermond and Morgan 1993), which has since maintained a permanent field station there.

During its tenure, the Coast Guard destroyed many bird nests on Tern Island to reduce the hazard of bird-strikes for the C130 planes that frequently used the island's landing strip. Since 1979, Black-footed Albatrosses have moved to Tern Island as other islands within the atoll have disappeared or become over-washed. Direct counts of Black-footed Albatrosses are conducted annually for all islands in the shoals while breeding success is measured only on Tern Island. At present, the steel sheetpile seawall that contains Tern Island is seriously deteriorated and unless it is repaired the continued existence of the island is questionable.

### 3.5.7 Necker, Nihoa and Kaula Islands

Necker (23° 35´ N, 164° 42´ W; approximately 17 hectares) and Nihoa (23° 06´ N, 161° 58´ W; approximately 63 hectares) are small volcanic island remnants (Fig. 29). They rise so steeply from the ocean that landings are extremely difficult and dangerous in all but the most calm conditions (Clapp and Kridler 1977, Berger 1988). Kaula (21° 40´ N, 160° 14´ W; approximately 51 hectares) is also a small island remnant 37 km west-southwest of the main Hawaiian island of Ni`ihau (Berger 1988). Visits to these islands have been infrequent, and the FWS usually surveys the islands between the months of May through September. The Navy has used Kaula as a bombing target and strafing target since 1952 (Harrision 1990), and it is infrequently visited by biologists. Although the Black-footed Albatross colony on Kaula represented only a tiny fraction of the total population, it appears to have been all but obliterated.

Black-footed Albatross populations on Necker and Nihoa have been estimated based upon the number of chicks that have survived and have not yet fledged (Table 3). Since no one has studied the breeding success of Black-footed Albatross on these islands it is inappropriate to extrapolate to a breeding population estimate. A more accurate estimate of the population on Necker and Nihoa requires censuses of nesting birds taken in December or January and preferably several years of breeding success data. However, this may not be feasible for Necker and Nihoa due to the difficulty of landing on the islands in the winter months.

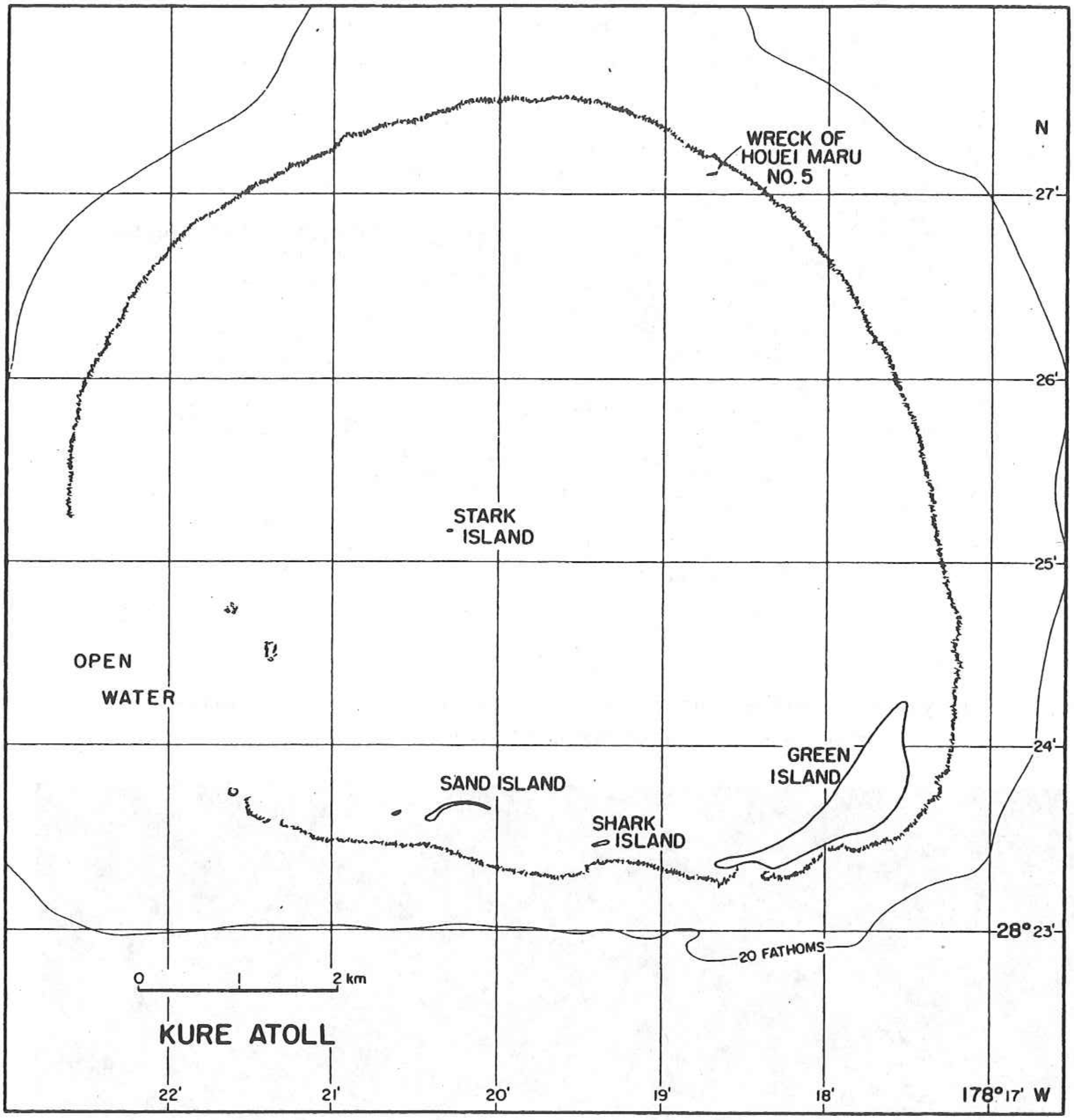



Figure 22. Kure Atoll (adapted from National Ocean Service chart 19483). The only permanent land in the atoll is Green Island.

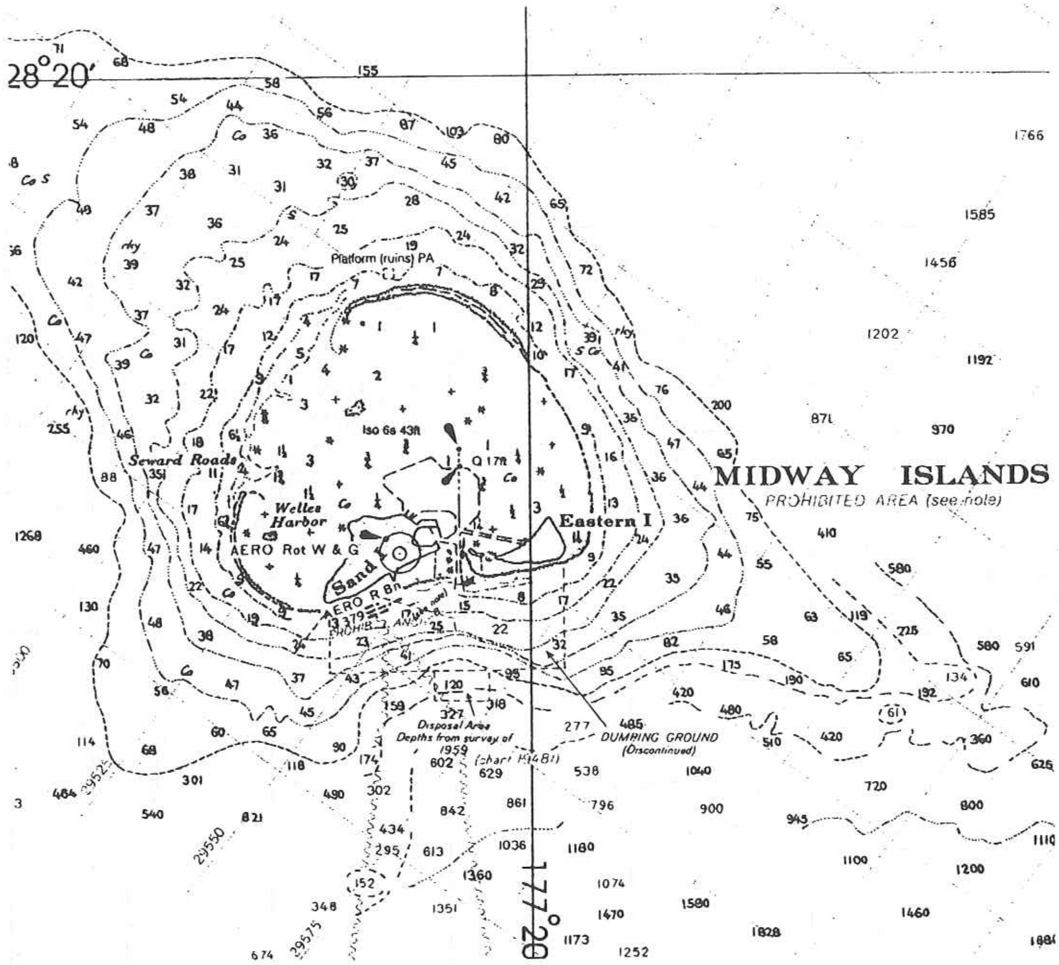



Figure 23. Midway Atoll. The atoll is comprised of three islands, with Sand and Eastern Islands being the permanent islands. Spit Island, more of a sandbar, lies between Sand and Eastern.

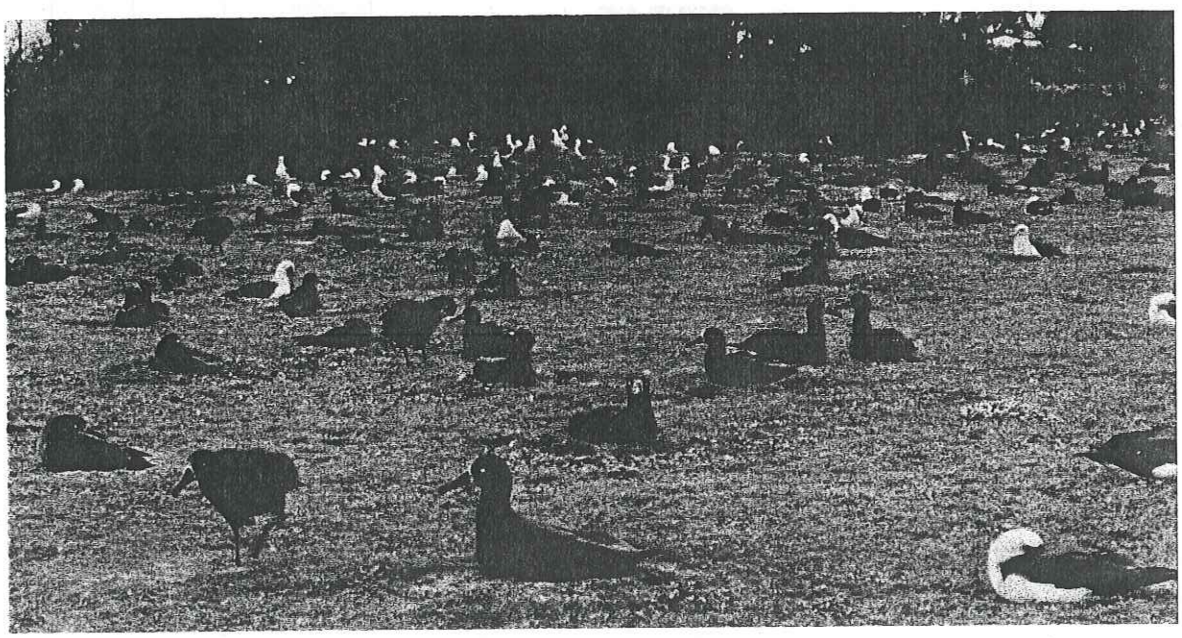


Figure 24. One of the inland Black-footed Albatross colonies on Sand Island, Midway Atoll. Prior to the addition of fill material from dredging operations to create a channel in the atoll and the construction of the Midway airstrip, this colony was located on a sandy shoreline. Because Black-footed Albatrosses are nest-site specific, like many other albatross species, the birds are breeding where their nests were originally located rather than moving to their preferred habitat of exposed sandy beaches.

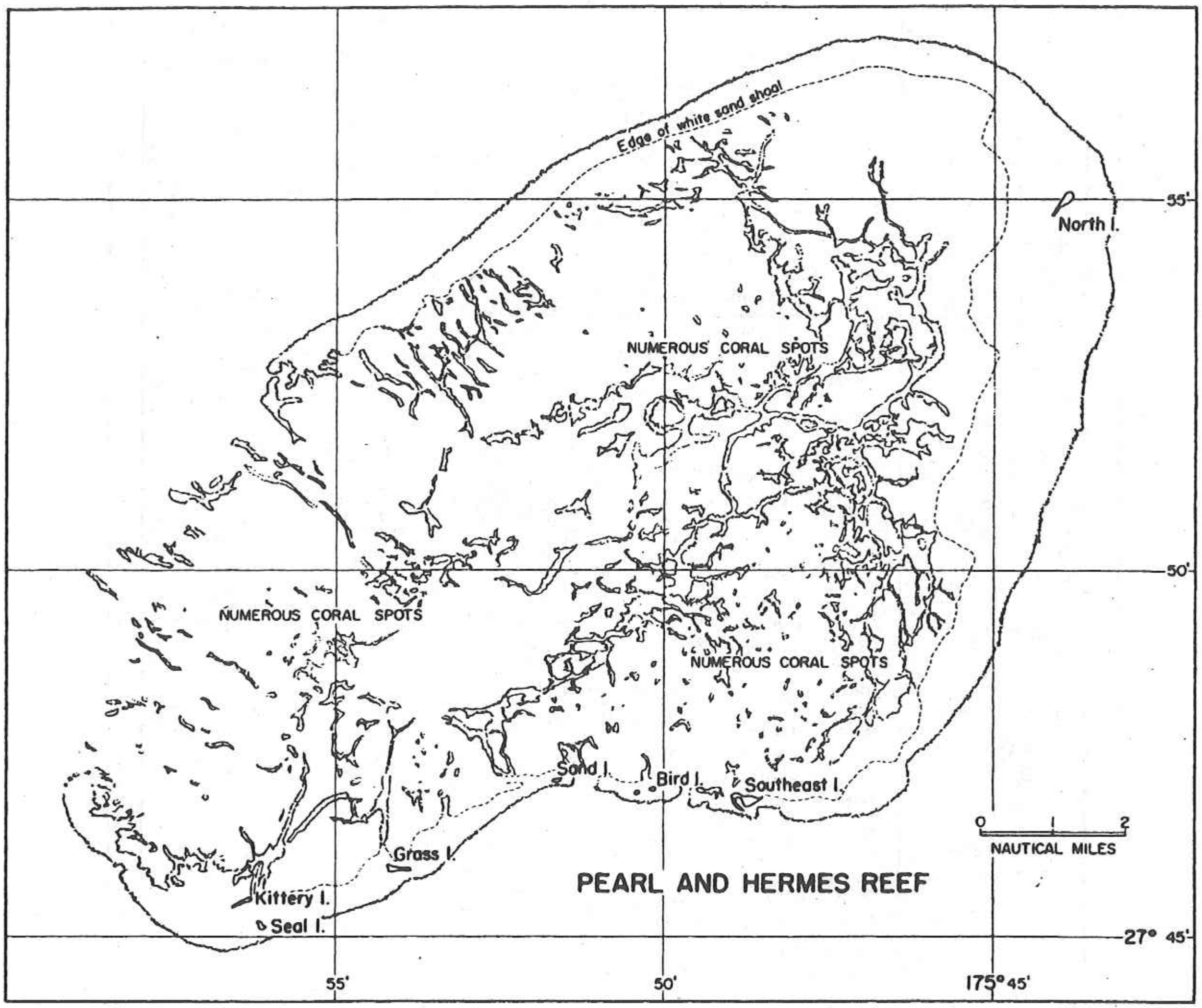



Figure 25. Pearl and Hermes Reef (adapted from National Ocean Service chart 19461).

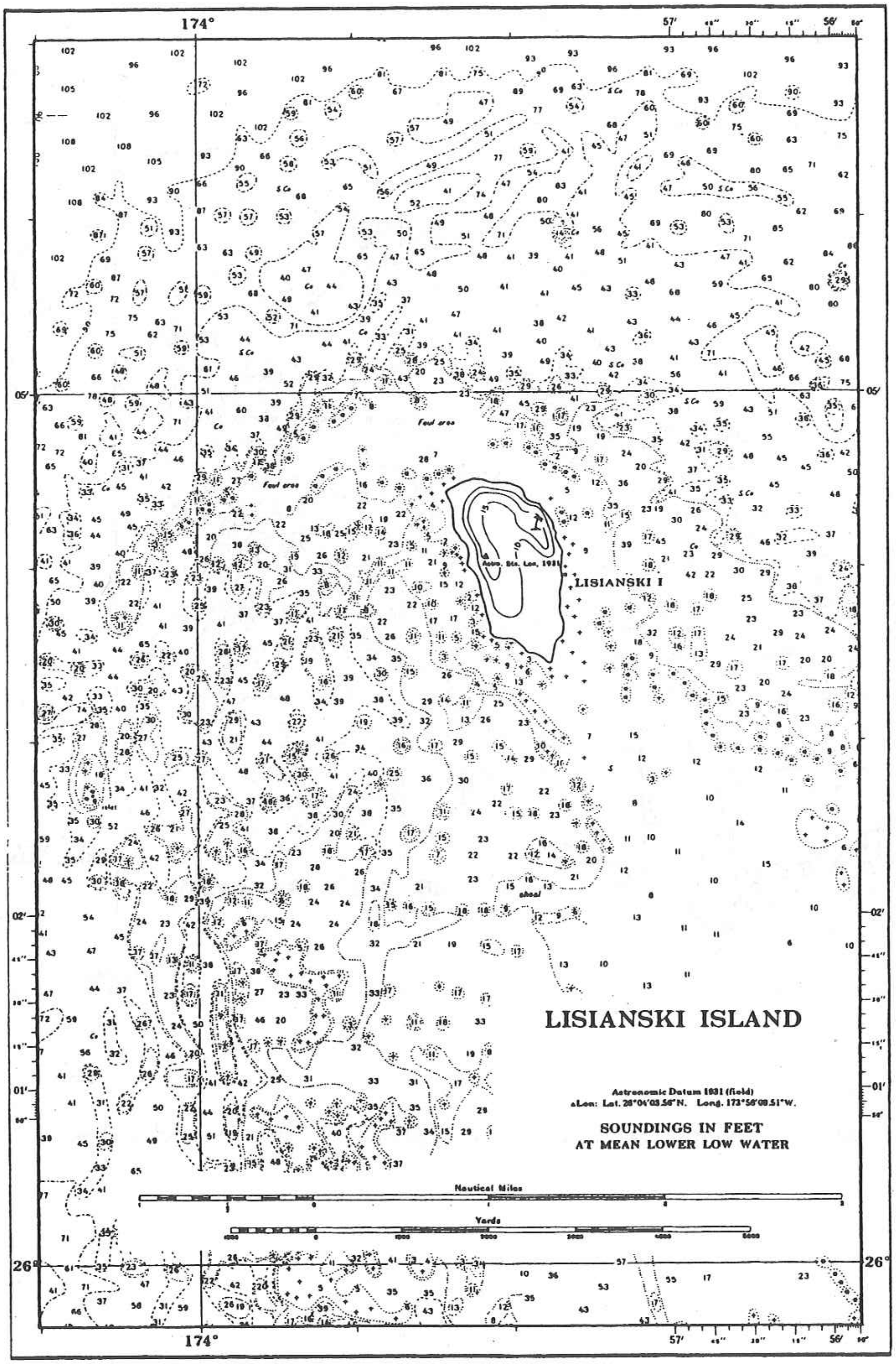



Figure 26. Lisianski Island (adapted from National Ocean Service chart 19442).

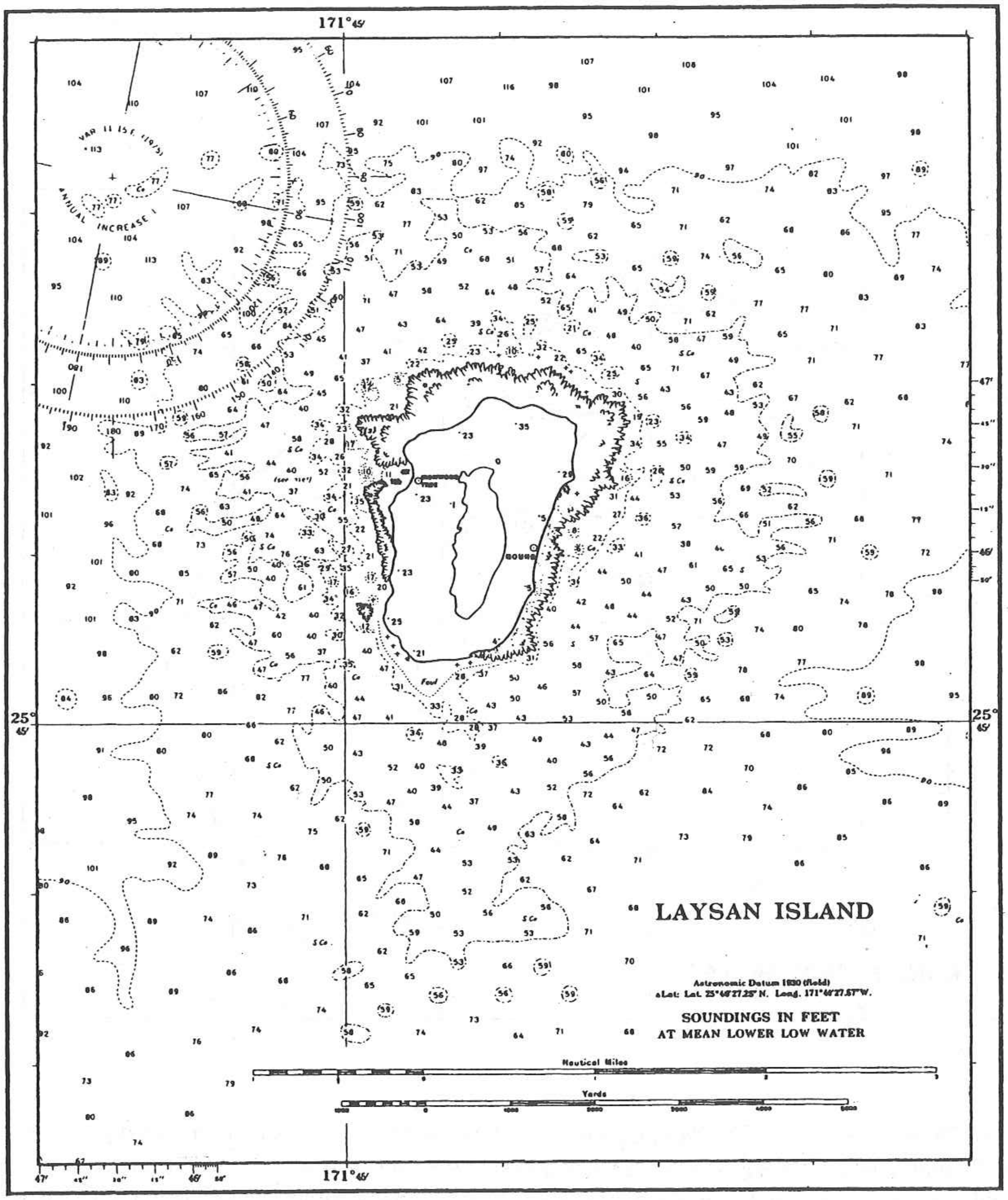



Figure 27. Laysan Island (adapted from National Ocean Service chart 19442). Laysan is the largest island of the NWHI.

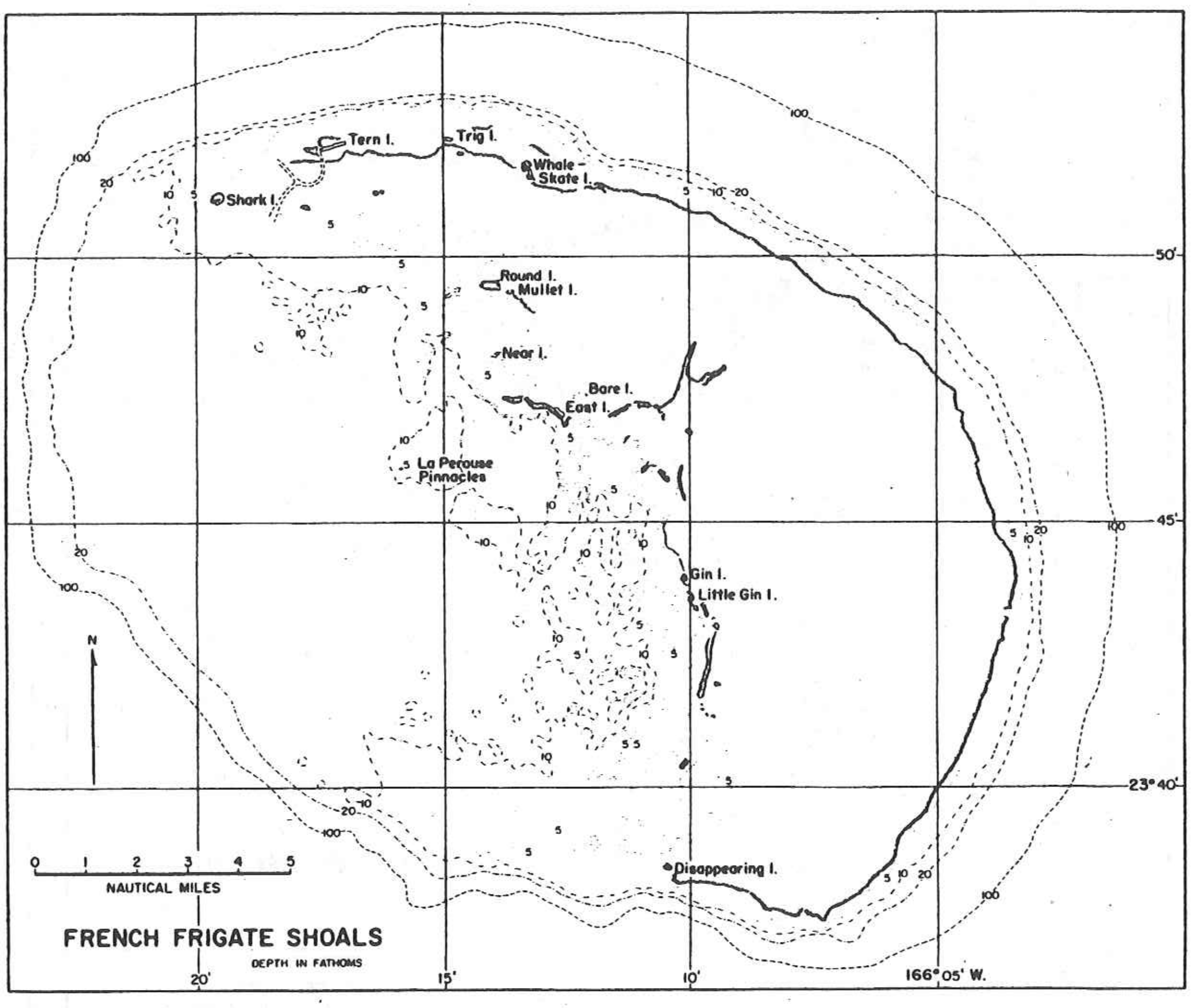



Figure 28. French Frigate Shoals (adapted from National Ocean Service chart 19401). There are 13 small islets in the lagoon, 12 are low and sandy with sparse or no vegetation and one island, La Perouse Pinnacles, is a volcanic rock. Some of the smaller islands are sandbars that shift continuously and/or are submerged during periods of high tide.

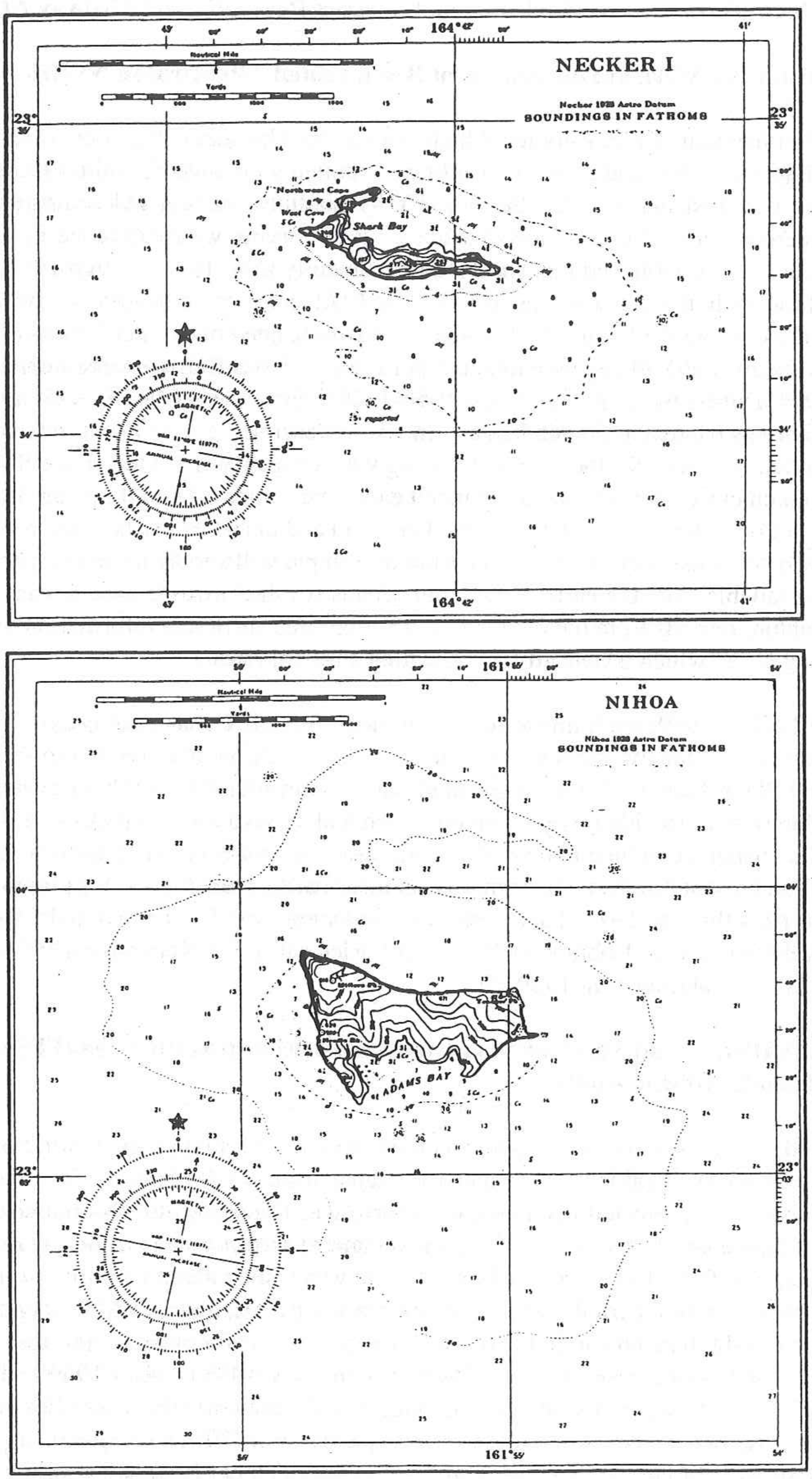



Figure 29. Necker and Nihoa Islands (adapted from National Ocean Service chart 19416).

## 4 Demographic Information of Black-footed Albatross Population on Midway Atoll

### 4.1 History of Marked Populations of Black-footed Albatross on NWHI

The first banding of Black-footed Albatrosses in the Hawaiian chain occurred on Midway Atoll in the 1940s, and sporadic banding continued there until the mid-1950s, at which time the U.S. Fish and Wildlife Service (FWS) initiated surveys and banding on both Sand and Eastern Islands, Midway Atoll (Table 5). These surveys were expanded in 1960, when study sites were established that were studied annually from 1961 through 1967. There was some follow-up in these study sites in 1971 and 1972 and then no banding activity on either island on Midway Atoll until 1979 when J. Ludwig banded both chicks and adults. Banding was resumed at Midway on a much larger scale by FWS Refuges personnel and J. Ludwig in 1992. During the years 1963, and 1966-1969, there were 4,049 Black-footed Albatross fledglings banded at French Frigate Shoals representing over 70% of the entire atoll's production of chicks for the period. Banding was resumed at French Frigate Shoals in 1981, where all chicks on Tern Island are banded each year. Since 1997, all the bands of both breeders and non-breeders that visit Tern Island are read and entered into the band recovery database. Ultimately this recent much larger banding sample will supply more comprehensive data than are available from the earlier years, but because of the birds' delayed sexual maturity, recapture records from the 1990s do not yet provide sufficient information on the return of young birds, which is needed for estimating survival rates.

From 1962 to 1969, the Smithsonian Institution's Pacific Ocean Biological Survey Project conducted an intensive survey of seabird populations throughout the North Pacific and banded 16,950 Black-footed Albatrosses throughout the Hawaiian Chain. That project was of insufficient duration to provide information on return and survival of the chicks, but the large number of birds banded continue to provide information on longevity, adult survival and movements. The present report relies primarily on information from the FWS program at Midway from 1954 through 1972. This work was conducted by P.A. DuMont and J. Neff in 1954, J.W. Aldrich and C.S. Robbins in 1956, D.W. Rice and K.W. Kenyon in 1956-58, and C.S. Robbins and collaborators in 1959-72.

### 4.2 Life History and Survival Data from the Fuel Farm Study Area (FFSA), Sand Island, Midway Atoll

In 1960, a study site was established on the Fuel Farm located on the North Shore of Sand Island, as one of several long-term sites for intensive study (Robbins 1966). The site was selected because it was protected from human disturbance. The study plot was bounded on two sides by a high chain-link fence, limiting movement of birds on and off the site on those two sides. Each year from 1961 through 1967 this site was visited about six times during the latter part of the incubation period and early chick-rearing period, and all adults attending eggs or chicks were caught, banded and marked with spray paint or nail polish to indicate they had been captured. All chicks within the study site were banded in 1963 through 1969 and also in 1971 and 1972. The site was not visited late enough in the season in 1961 and 1962 to band the chicks for those two years, and no observer was present in 1970. The numbers of pairs with active nests in February of each year and the number of chicks banded are shown in Figure 30.

Table 5. Numbers of chick and adult Black-footed Albatrosses banded in the Leeward Hawaiian Chain, 1941 – 1998 (National Bird-banding Laboratory and FWS unpubl. data). Values in parentheses are the number of birds banded at a particular locality.

| Year | Number | | Locality |
|---|---|---|---|
| | Chicks | Adults | |
| 1941 | 0 | 400 | Midway |
| 1944 | 100 | 116 | Midway |
| 1945 | 100 | 1 | Midway |
| 1946 | 22 | 109 | Midway |
| 1947 | 21 | 9 | Midway |
| 1951 | 100 | 105 | Midway |
| 1952 | 0 | 806 | Midway |
| 1955 | 252 | 100 | Midway |
| 1956 | 0 | 254 | Sand Is., Midway |
| 1957 | 1,209 | 646 | Midway except 200 chicks at Laysan |
| 1958 | 1,519 | 41 | Midway except 900 chicks at Laysan |
| 1959 | 235 | 5 | Midway |
| 1960 | 1,084 | 100 | Midway except 8 chicks at Kure |
| 1961 | 41 | 2,569 | Midway and Kure |
| 1962 | 18 | 1,880 | Midway except 48 adults at Kure |
| 1963 | 4,951 | 5,457 | French Frigate, Pearl and Hermes Reef, Midway, and Kure |
| 1964 | 2,815 | 3,672 | Nihoa, Lisianski, Pearl and Hermes Reef, Midway, and Kure |
| 1965 | 4,678 | 1,530 | Nihoa, Necker, Laysan, Lisianski, Pearl and Hermes Reef, Midway, and Kure |
| 1966 | 4,553 | 747 | French Frigate Shoals, Pearl and Hermes Reef, Midway, and Kure |
| 1967 | 5,760 | 745 | French Frigate Shoals, Laysan, Lisianski, Pearl and Hermes, Midway, and Kure |
| 1968 | 1,316 | 91 | French Frigate Shoals, Midway, and Kure |
| 1969 | 2,582 | 152 | French Frigate Shoals, Midway, and Kure |
| 1971 | 191 | 1 | Midway |
| 1972 | 147 | 0 | Midway |
| 1978 | 51 | 0 | Sand Is., Midway |
| 1979 | 2,090 | 2,424 | Oahu (5 adults), French Frigate Shoals, Laysan, Midway, Kure |
| 1980 | 267 | 65 | French Frigate Shoals |
| 1981 | 325 | 180 | Oahu (5 adults), Nihoa, French Frigate Shoals, Midway, Kure |
| 1982 | 98 | 5 | French Frigate Shoals, Midway (1 chick on Sand Is.) |
| 1983 | 325 | 75 | French Frigate Shoals, Midway |
| 1984 | 145 | 130 | Nihoa (38 chicks), French Frigate Shoals |
| 1985 | 124 | 0 | French Frigate Shoals |
| 1986 | 386 | 352 | French Frigate Shoals, Laysan, Midway |
| 1987 | 462 | 210 | Nihoa (22 chicks), French Frigate Shoals, Laysan, Midway |
| 1988 | 342 | 10 | French Frigate Shoals |
| 1989 | 351 | 28 | Kauai (1 chick), French Frigate Shoals |
| 1990 | 443 | 64 | French Frigate Shoals, Midway (5 chicks, 4 adults) |
| 1991 | 539 | 140 | French Frigate Shoals |
| 1992 | 764 | 1,262 | French Frigate Shoals, Laysan, Midway |
| 1993 | 3,409 | 8,016 | French Frigate Shoals, Laysan, Midway |
| 1994 | 3,812 | 3,512 | French Frigate Shoals, Laysan, Midway |
| 1995 | 1,108 | 83 | French Frigate Shoals, Laysan, Midway |
| 1996 | 2,260 | 65 | French Frigate Shoals, Midway |
| 1997 | 2,619 | 1,434 | French Frigate Shoals, Midway |
| 1998 | 1,038 | 2,368 | French Frigate Shoals, Midway (3 adults) |

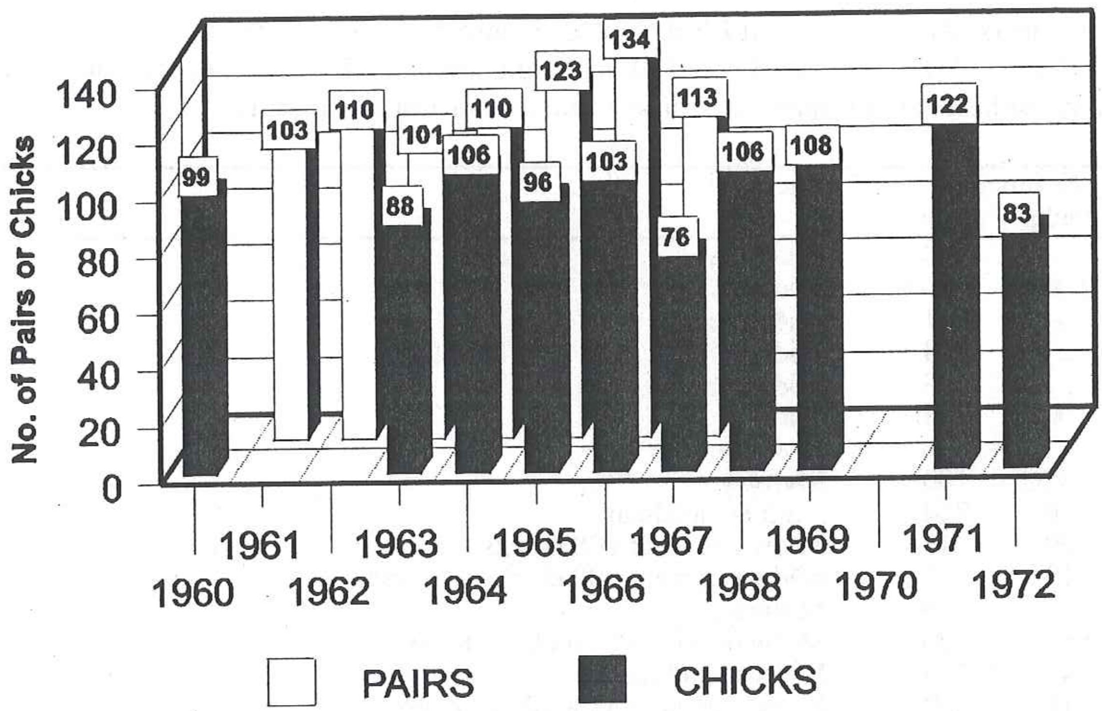



Figure 30. The numbers of Black-footed Albatross breeding pairs and chicks banded at the Fuel Farm Study Area, Sand Island, Midway Atoll, between 1960 to 1972.

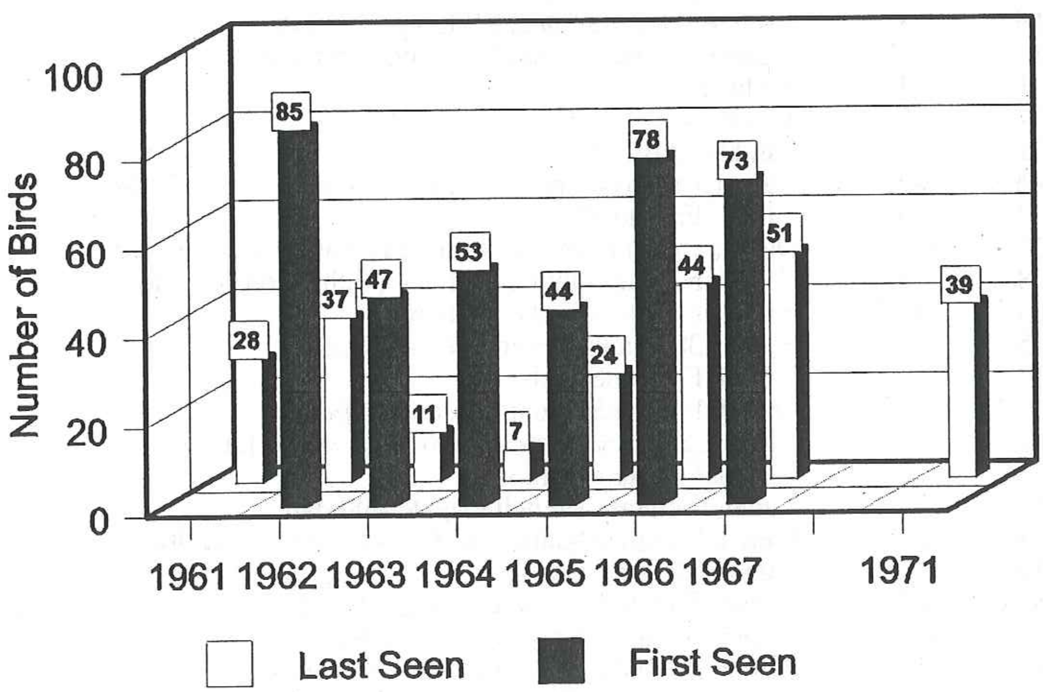



Figure 31. The numbers of Black-footed Albatross first and last seen at the Fuel Farm Study Area, Sand Island, Midway Atoll, between 1961 to 1971.

### 4.2.1 Annual Turnover

The degree of annual turnover can be estimated by capture-recapture methods (Pradel 1996). In Figure 31, the stability of the Black-footed Albatross Midway FFSA population is indicated by the number of birds first seen and last seen for each breeding season. Note that many birds were last seen in 1962, indicating the loss of a substantial number of breeding birds from this population during the ENSO (*El Niño*-Southern Oscillation) event of 1963. The steady increase in number of last-seen birds in 1965, 1966 and 1967 simply reflects the absence of observers during the years 1968 through 1970.

### 4.2.2 Mate Retention

Observations at the breeding colonies suggest that Black-footed Albatrosses, like Laysan Albatrosses, retain the same mate for life and seek a new mate only if a mate is lost (Bailey 1952). Mated pair data were collected for the FFSA Black-footed Albatross and an example of the length of time a mated pair nests together is shown in Figure 32. One histogram shows pairs that nested for consecutive years, and the other shows the number of pairs that were still resident in these study plots even though they had not produced chicks in all the years. Note the drop in number of pairs that occurred during the ENSO event of 1963.

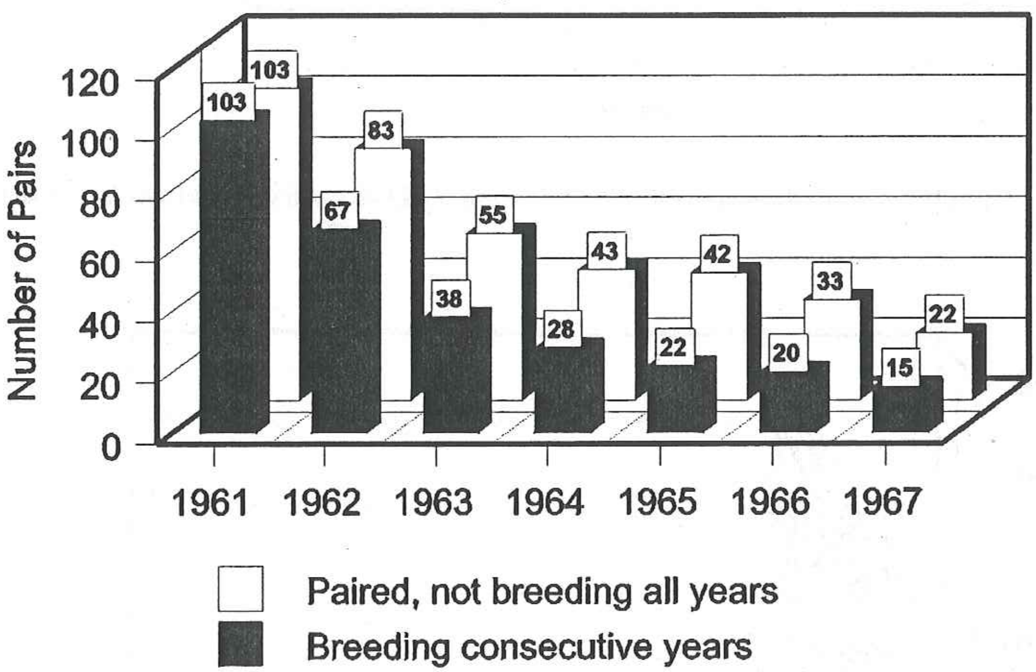



Figure 32. The number of Black-footed Albatrosses that retain their mate for consecutive breeding seasons.

### 4.2.3 Nesting Seasons Missed After Loss of Mate

Often, birds that have lost a mate obtain a new one and nest without losing a year. More frequently for the FFSA Black-footed Albatross one reproductive year is lost and occasionally two to four years are lost (Fig. 33). The mean number of years missed by birds that lost a mate was 0.98 years (SD = 0.991, n = 59).

### 4.2.4 Distance Bird Moved Nest from Year-to-Year

Black-footed Albatrosses at the FFSA showed high site fidelity and generally returned to nest within about 5 m of the previous year's nest (Fig. 34). One or two percent moved as far as 30-35 m. The mean distance moved was 4.7 m (SD = 5.08, n = 111). This

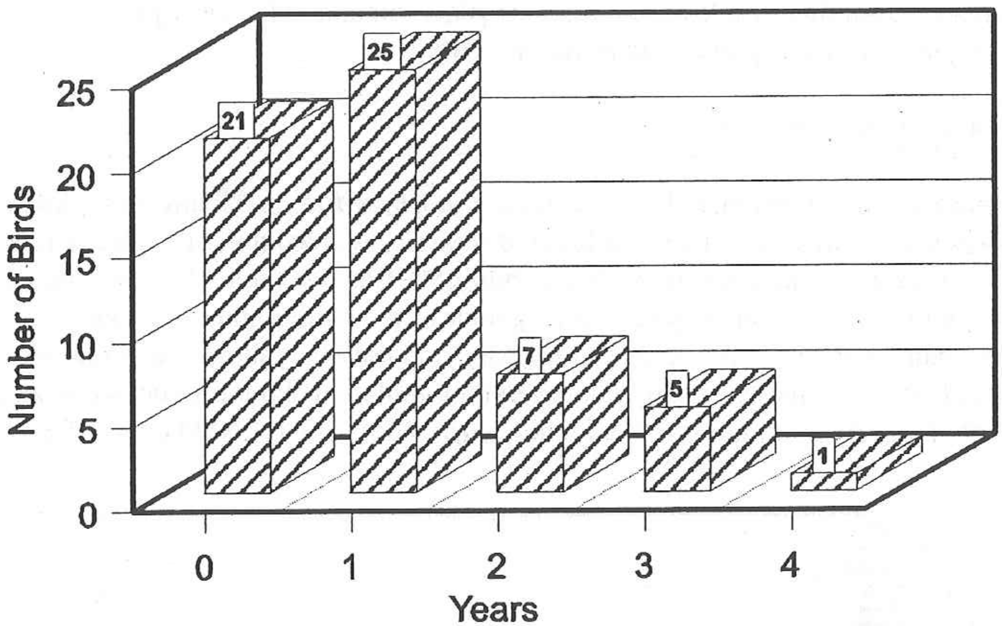



Figure 33. The number of breeding seasons missed when Black-footed Albatrosses lose their mate.

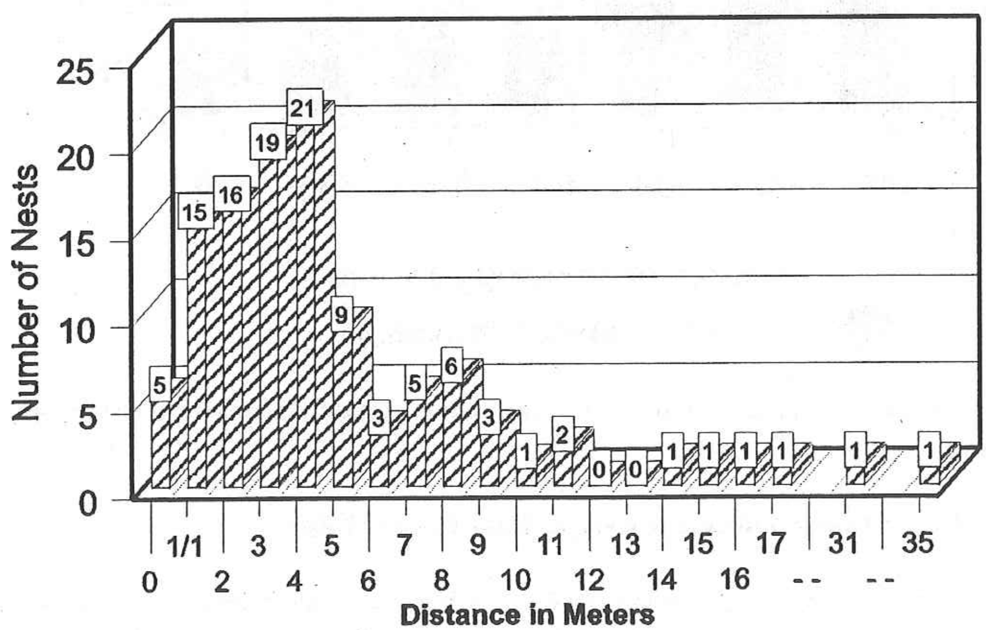



Figure 34. The distance (in meters) that Black-footed Albatrosses move a nest each breeding season.

movement of birds in and out of the study site must be considered when establishing study sites and when evaluating continuity of nesting. In the Midway Fuel Farm study, adults and chicks throughout the fenced fuel farm were banded and searched for bands each year of the study, but nest positions outside the study area were not mapped and searches were less frequent.

### 4.2.5 Origin of the Breeding Population

Most Black-footed Albatrosses breeding on Sand Island, Midway, FFSA in a given year were birds that had bred there previously or were banded there as chicks. The percentage of birds banded as chicks that returned to nest in the FFSA in 1972 ranged from four to seven percent for birds that were six to ten years old, compared with zero to four percent for chicks that were raised a few meters away but outside the study plot (Fig. 35). In comparison, the percentage of chicks that had come from remote sites on Sand Island ranged from only 0.2 to 0.6% of the number banded. The percentage from Eastern Island was even less. The origins of known-age birds in the same study site in 1971 were similar to those in 1972.

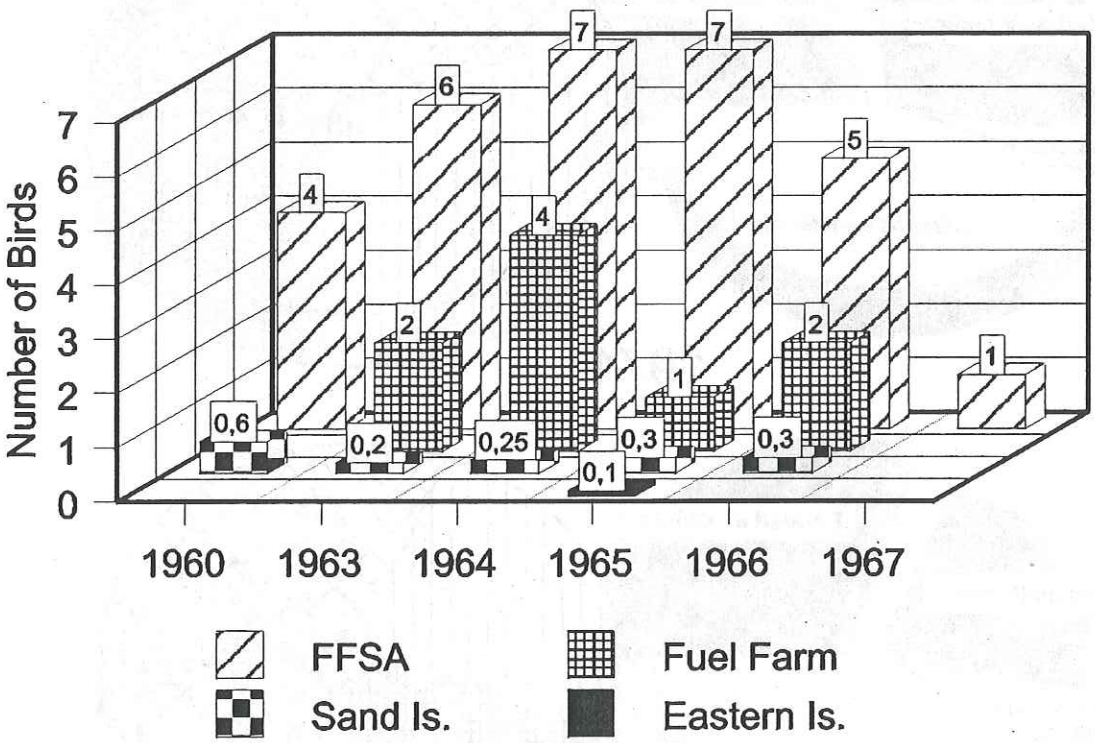



Figure 35. The origin and number of Black-footed Albatrosses breeding in the Fuel Farm Study Area, Sand Island, Midway Atoll.

### 4.2.6 Composition of the Breeding Population

Nearly half of the birds that nested in the Midway Fuel Farm study site in 1971 were birds that had been breeding there for at least eight years. The other half, primarily those banded as chicks and "walkers," had been nesting there for only four to eight years (Fig. 36). FFSA walkers are those birds not on eggs or chicks when captured for banding. They include young pre-nesters, mates of incubating birds, and birds that had lost mates, eggs or chicks. In

1967, 45% of the FFSA walkers were current or former nesters, 23% were previously banded walkers of unknown age, 18% were birds of known age banded as chicks (mostly three- and four-year old birds), and 14% were unbanded birds. Probably many of the unbanded birds were five- and six-year olds from the unbanded 1961 and 1962 cohorts.

One quarter of the 1971 FFSA nesters were known-age birds, aged 4 to 26 years, with the largest number, constituting one third of the total, of age 7 followed by ages 11, 6 and 8 (the ENSO year cohort), and with progressively smaller numbers of ages 5, 12 and 4. (No 9- or 10-year cohorts had been banded.) For comparison, in 1972 the largest sample was of 8-year-old birds followed by 6-, 7-, 9- and 12-year cohorts (Fig. 36).

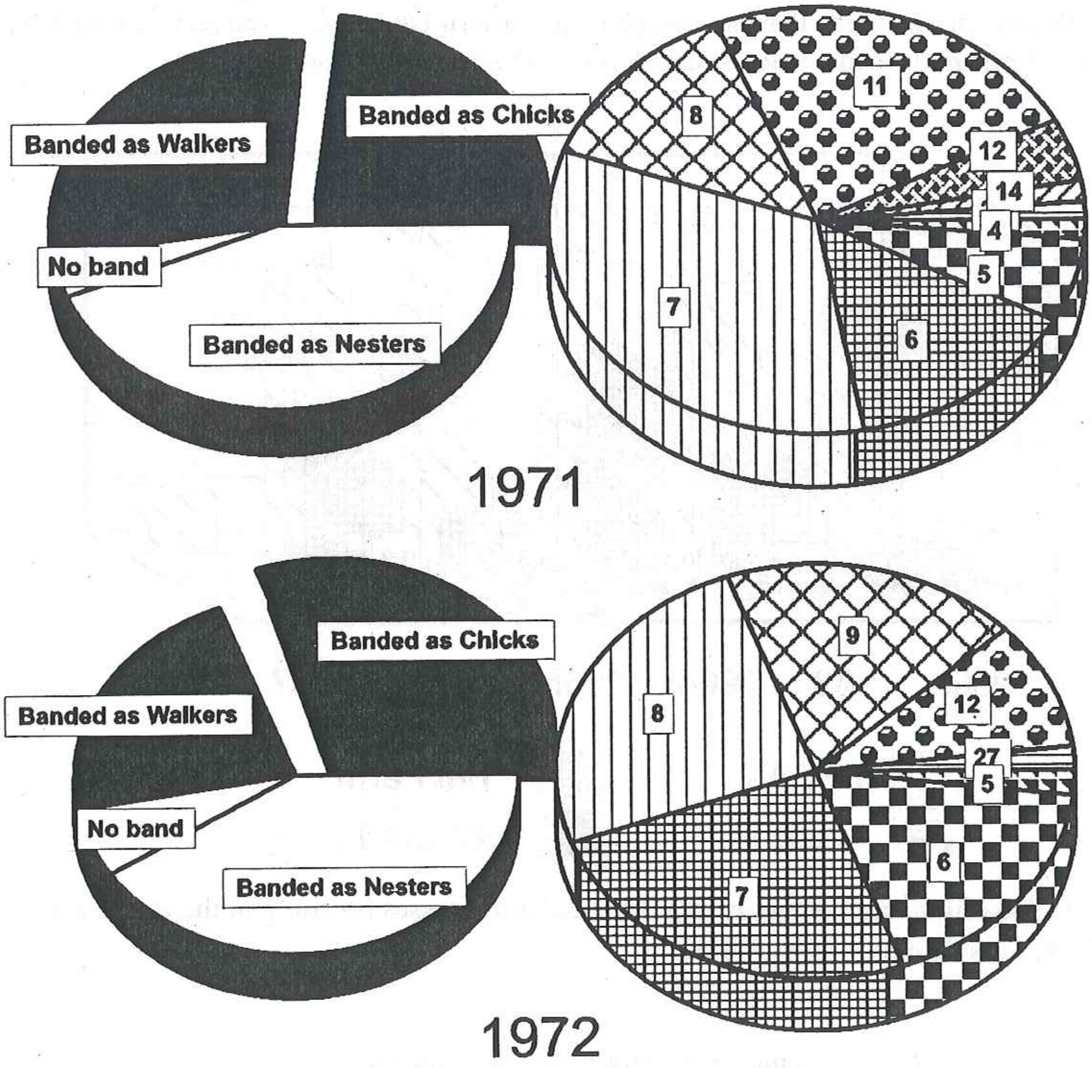



Figure 36. The composition by age of the 1971 and 1972 Fuel Farm Study Area Black-footed Albatross nesters. A "walker" is a bird that is not incubating eggs or caring for chicks.

### 4.2.7 Survival of Adults

Of the 224 breeding birds (112 pairs) in the Midway FFSA in 1961, 96 individuals (42.9%) are known to have survived until 1971. Beyond that year, inconsistent coverage and inability to identify rebanded birds have prevented good estimates of the number of survivors. The sharpest drop in population occurred in the ENSO year, 1963 (Fig. 37).

Annual survival of adult breeding birds in the FFSA for the period 1961-67 was estimated using binomial proportions. Survival estimates ranged from a high of 0.994 (S.D. 0.047) from 1961 to 1962 to a low of 0.810 (S.D. 0.031) from 1962 to the ENSO year of 1963. The estimate for a constant annual survival, based on the binomial proportion 96 individuals/244 breeding birds is 0.919 and it should be noted that this assumes a probability of recapture equal to one. The mean annual survival for the period, however, was 0.923.

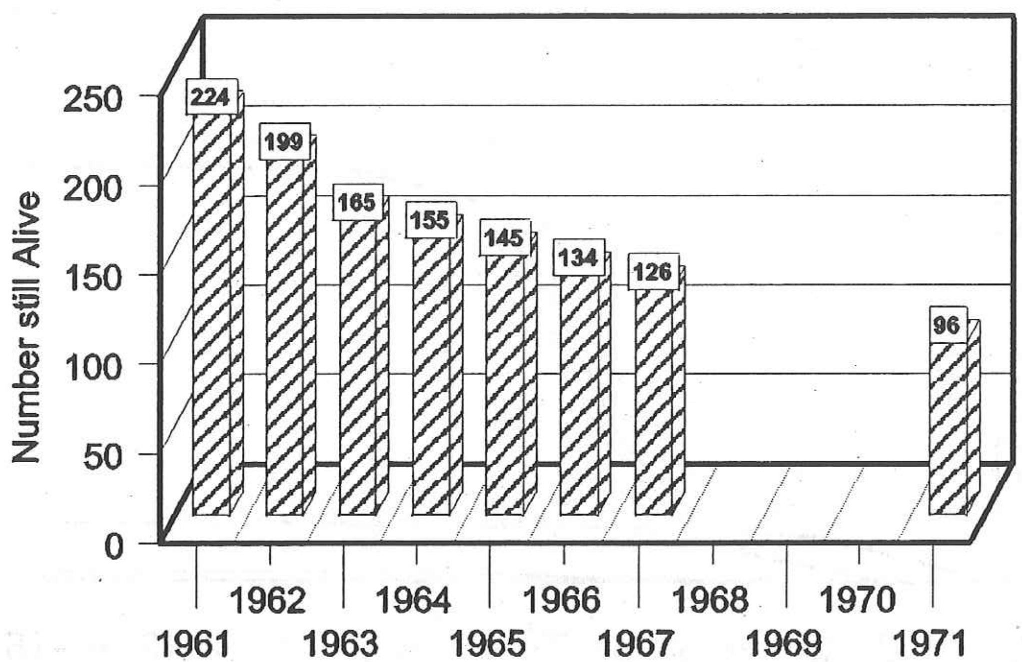



Figure 37. The number of Black-footed Albatrosses surviving in the Fuel Farm Study Area, Sand Island, Midway Atoll.

### 4.2.8 Survival of Black-footed Albatross Chicks in their First Five Years

Survival of chicks until breeding age is a critical component of population dynamics. The best sample from the research of the 1950s and 1960s comes from a cohort of 1000 chicks color-banded around the perimeter of Eastern Island on 3-4 June 1957 by D. Rice of FWS and recaptured in subsequent years. A concerted effort was made to recapture these birds at Midway and Kure Atolls during the breeding seasons of 1959-60 through 1966-67. The birds were wary in their first two winters on shore (1959-60 and 1960-61), at ages three and four, and many escaped capture. Although the peak of encounters at sea occurred in the first three years, the great majority (85%) of first recaptures on land occurred at ages five through eight (Fig. 38). All but two of the birds (ages 12 and 15) that were recaptured on Midway (n = 279) had been caught by age ten.

None of the thousand chick cohort was reported to have died at Midway prior to fledging, but 313 were subsequently encountered: 262 back on Eastern Island, Midway Atoll; 37 were reported taken at sea (four of which had also returned to Midway); 12 were captured four or five kilometers away on Sand Island, Midway; 11 at Kure, about 150 km to the west (including six that were also caught at Midway), and one at Pearl and Hermes Reef, about 150 km to the east. Although 313 birds had been encountered since their first flight from Eastern Island, only 273 (27.3%) were known to have survived to breeding age (considered as five years). Most (all but three) of the 37 encounters at sea occurred before age five, and eight of the birds captured on land as three- and four-year olds were not subsequently encountered and are assumed to have died. At least five of the 1000 birds were back on Eastern Island in November-December 1994 at age 37.

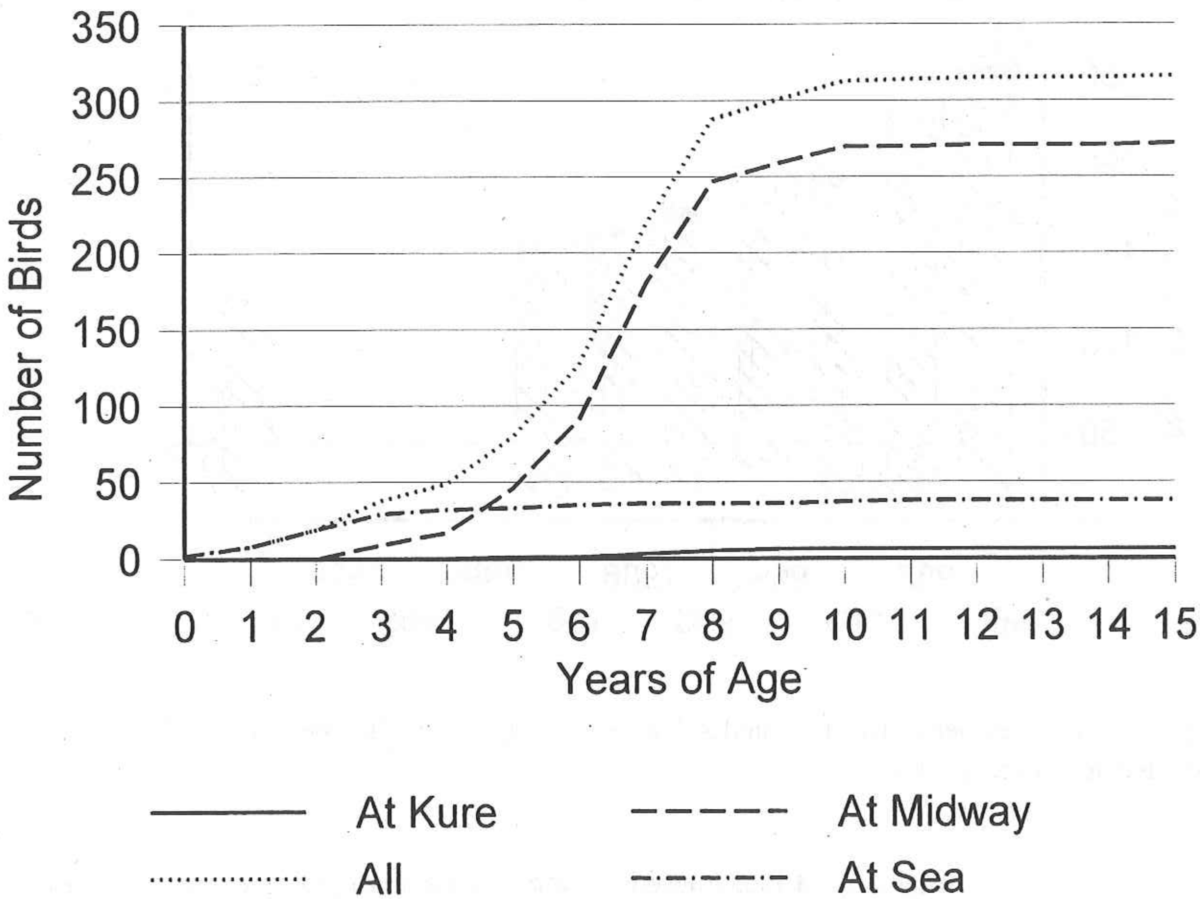



Figure 38. The cumulative number of Black-footed Albatrosses recaptured after they were first banded in 1957.

## 5 Characterization of Population Dynamics and Estimates of Population Parameters

The primary variables essential to the characterization of the population dynamics of albatrosses are:

- Adult survival
- Age of first breeding
- Proportion of adult population breeding each year
- Breeding success (total number of chicks fledged per total number eggs laid)
- Juvenile survival (recruits per chick fledged)

For initial modeling purposes at the workshop, and pending the calculation of appropriate values for Black-footed Albatrosses, published values for the Laysan Albatross were used (Table 6). A comprehensive analysis of the bird-banding data for Black-footed Albatrosses will most likely be undertaken by D. Anderson and K. Burnham (Colorado Cooperation Fish and Wildlife Research Unit, Colorado State University) once the appropriate capture-mark recapture statistical matrixes have been generated. At the workshop we were able to examine interim results from the analysis of parts of the data sets, notably those prepared by Chandler Robbins.

Table 6. Values of demographic variables for Laysan Albatross at Midway Atoll. Single asterisk (*) = to age 8 years; double asterisk (**) = in constant pair bonds.

| Demographic Variable | Mean | Range | Data Source |
|---|---|---|---|
| Adult Survival | 0.947 | 0.915 - 0.981 | Fisher 1975 |
| Juvenile Survival* | 0.57 | ? | Fisher 1975 |
| Proportion of Adults Breeding** | *c.* 0.80 | 0.43 – 1.0 | Fisher 1976 |
| Breeding Success (fledglings/egg) | 0.55 | 0.49 - 0.78 | Fisher 1975 |
| Mean Age of First Breeding (yrs) | 8.6 | 5 – 16 | Van Ryzin and Fisher 1976 |

### 5.1 Adult Survival

Data from the FFSA (*c.* 100 pairs) on Midway Atoll, 1961 - 1967, provide seven estimates of year-to-year adult survival. Omitting the last year of the series (because *c.* 20% of breeding birds do not breed in consecutive years and are therefore unavailable for capture) gives a mean value of 0.923 (range 0.810 - 0.994). It should be noted that the value of 0.810 obtained in the same study was for an ENSO year and that this year is also represented in the data series for

Laysan Albatross used in Table 6. The mean value of 0.923 may be an underestimate because it does not allow for all birds that moved outside the study plot during the observation period (C. Robbins pers. comm.). Pending checking and recalculation of the above data a value of 0.93 is probably the most realistic representation of the mean adult survival prevailing during the period 1961 - 1967 at Midway Atoll. (Note that this is 0.02 less than the value used in the initial model based on Laysan Albatross data in Table 6). Estimates of current Black-footed Albatross survival, derived from preliminary analysis of the Tern Island data 1991- 1997 were in the range 0.90 - 0.94.

### 5.2 Juvenile Survival

It is probable that three existing data sets could likely produce accurate estimates of survival of fledged chicks to recruitment to the breeding population. The first is the cohort of 1,000 color-banded chicks fledged at Eastern Island, Midway Atoll, in 1957 (see section 4.2.8). The second data set is the cohort of 2,000 chicks banded on Sand Island and 90 chicks on Eastern Island, Midway Atoll, by J. Ludwig and D. Williamson in 1979. The third data set is a cohort of 2,090 chicks banded on Midway Atoll by J. Ludwig in 1994 to 1995. From the first data set survival of 273 birds to age five years equates to a mean annual survival of 0.771. The remaining two data sets require further analysis, although preliminary analysis shows that survival of chicks banded in 1979 and the 1990s was somewhat lower than for birds banded in the late 1950s.

It is important to note, however, that there are serious biases between the three data sets. For instance, chicks banded in the second and third data sets were from study plots spread across Midway Atoll, whereas chicks banded in the first data set originated from one study plot on Eastern Island, Midway. Also, the time spent searching for banded birds differs greatly between the data sets such that a concentrated effort was spent to find all the banded birds from the 1957 cohort whereas less effort has been spent to find the birds banded in 1979 and the 1990s.

### 5.3 Proportion of Adult Population Breeding

Rice and Kenyon (1962a) recorded 644 birds returning to breed in 1957 from 820 birds which bred in 1956 (78.5%). This is very close to the value of 0.80 for Laysan Albatross used in the present model. Data from the FFSA on Midway Atoll 1961 - 1967 will provide estimates of the average proportion of birds breeding in several consecutive years. Recent data from Tern Island 1994 to present will also provide good estimates of breeding frequency.

### 5. 4 Breeding Success

Available data in the workshop documents for Black-footed Albatross breeding success are presented in Table 7 and in Appendix I. In addition to the values in Table 7, Rice (1959) reported a value of 0.49 for Midway Atoll. The lower values for Laysan Island may reflect the difficulty of re-sighting chicks during weekly checks, such that when the chicks reach fledging age they become very mobile and evade being detected by refuge staff (E. Flint pers. comm.). Nevertheless, efforts should be made to gather standardized breeding success information for as many colonies as possible on an annual basis because this variable can differ greatly among sites, islands and years.

### 5.5 Age of First Breeding

The minimum recorded age of first breeding is four years of age, both at Torishima (H. Hasegawa pers. comm.) and at Midway Atoll (C. Robbins pers. comm.). From the FFSA on Midway Atoll, retrapping in 1971 and 1972 of chicks ringed between 1958 and 1967 provides two cross-sectional samples of the age of breeding birds in the adult population. Pending appropriate analysis, inspection of these data suggests that the modal age of first breeding is probably seven years (i.e., one year earlier than the value for Laysan Albatross used in the interim model).

Table 7. Breeding success (fledgling/egg) data for the Black-footed Albatross in the northwestern Hawaiian Islands (see Appendix II).

| Site | Years | No. of Years | Mean | Range | Data Source |
|---|---|---|---|---|---|
| Kure Atoll | 1964 - 1969 | 4 | 0.44 | 0.34 - 0.46 | Woodward 1972 |
| Laysan Island | 1992- 1995 | 4 | 0.40 | 0.38 - 0.42 | FWS unpubl. data |
| Sand Island Midway Atoll | 1994 – 1995 | 2 | 0.63 | 0.53 - 0.70 | Ludwig *et al.* 1998 |
| Midway Atoll | 1987, 1992, 1993 | 3 | 0.77 | 0.64 - 0.86 | FWS unpubl. data |
| Tern Island French Frigate Shoals | 1980 – 1996 | 18 | 0.69 | 0.45 - 0. 78 | FWS unpubl. data |

### 5.6 Estimating the Total Number of Black-footed Albatross

Multiplying the current number of known breeding pairs of Black-footed Albatross (Table 3) by two results in 123,732 breeding adults. According to C. Robbins, breeding frequency in Midway Atoll is 78.5% (Section 5.3). Therefore the actual adult population is equal to 1/0.785 x 119,968 = 157,620. For this exercise, the mean breeding success is 0.69 (range 0.45 to 0.78) fledglings per nesting attempt (Section 5.4, Table 7). The number of non-breeding birds in the population, such as the juveniles and sub-adults, is the product of the 61,866 breeding pairs and the mean breeding success giving a total of 42,687 fledglings/year. The total number of Black-footed Albatrosses in the non-breeding segment of the population for each breeding year is reduced by known survival rates as shown in Table 8.

Table 8. The total number of Black-footed Albatrosses in the non-breeding segment of the species' population.

| Age | Survivorship Rate | Number Alive at Start of Interval | Number Alive at end of Interval |
|---|---|---|---|
| At Fledging | | | 42,687 |
| 1 year | 0.60 | 42,687 | 25,612 |
| 2 year | 0.82 | 25,612 | 21,002 |
| 3 year | 0.90 | 21,002 | 17,012 |
| 4 year | 0.93 | 17,012 | 15,821 |
| 5 year | 0.93 | 15,821 | 14,714 |
| 6 year | 0.93 | 14,714 | 13,684 |
| 7 year | 0.93 | 13,684 | 12,726 |
| Totals | | 148,432 | 163,258 |

Assuming that all Black-footed Albatross mature at age seven, then there are 148,432 breeding birds in the population. Thus, the total number of birds in the population is the sum of 157,620 breeding and 148,432 non-breeding birds, which equals 306,052 birds. If all birds nest at age eight, then the population is 318,778 individuals.

## 6 Black-footed Albatross Population Modeling

During the workshop, Black-footed Albatross population dynamics were explored with simplified computer models. Basic modeling exercises addressed two questions: (1) what is the potential sustained growth rate of Black-footed Albatross in the absence of anthropogenic (human-caused) mortality; and (2) what is the growth or decrease in the population given different combinations of adult and juvenile mortality rates? The models used were a simple, deterministic simulation model and an analytical, matrix model. Since the models use approximations for long-term average demographic rates and contain many simplifying assumptions about population behavior, the simulation results should be considered for general conclusions only and not be taken as precise predictions.

The estimated, average fecundity and survival rates for the population as described previously in this report were used to simulate the population in the computer models. The following assumptions were made in developing the age-structured simulation model, which was implemented in a spread sheet:

- The population sex ratio is equal
- Mean age of first breeding is eight years and maximum life span is 50 years
- Fecundity is the product of the average proportion of the adult population that breeds each year times the average number of chicks fledged per breeding adult

- Fecundity begins at a single age (first breeding) and is constant over age

- Juvenile survival rate is constant to age of first breeding, and equal for males and females

- Adult survival, also equal between sexes, is a constant rate from first breeding to a maximum age, when all birds die.

In experiments with take removals (i.e., an event that results in the death of the seabird), this mortality is added to baseline mortality rates and parameter values (survival, fecundity) are held constant in each scenario. Reported growth rates are from a steady state (after population age structure is stable).

Both simulation and a matrix model were used to explore the relationship between basic demographic rates and population growth—what modelers call "model sensitivity analysis." By experimenting with a range of basic rates in the simulations, modelers assessed which factors most influence population trends. The results were compared with analytical (mathematical) sensitivity analysis. Plausible ranges for experimental rates were chosen from the limited data available on Black-footed Albatross and from information on related species such as Fisher's (1975) data on Laysan Albatross.

Figure 39 illustrates the sensitivity of population growth to changes in the parameter rates in the simulation model. Typical of relatively long-lived species with low reproductive rates, Black-footed Albatross population trends were more sensitive to changes in survival than to changes in fecundity rates. This result was not surprising since many investigators, using a variety of age-structured models (e.g. Mertz 1971, Cochrane and Starfield 1999), have observed the low sensitivity of long-lived species to birth rate changes. In a Leslie matrix model, the elasticity (Caswell 1989) of the population multiplication or growth rate to changes in fecundity is equal to the inverse of the population's generation time (the mean age of females at reproduction) (Lebreton and Clobert 1991). Thus, the influence of fecundity on population trend decreases very rapidly as the generation time (T) increases. With a generation time of about 25 years in the Black-footed Albatross, the model elasticity will be around 0.04. This means that a 10% change in fecundity will induce approximately a 0.4% change in population growth or multiplication rate. As in the simulation model, changes in the matrix model survival rate have a strong influence on population trends. The elasticity for survival remains equal to one across all age classes and explains the prominent role of changes in survival on the population dynamics of long-lived species.

The first simulation experiment probed more deeply into survival rate influences on the population. This experiment estimated the juvenile survival rates (average annual rate from fledging to eight years) needed to produce a stable population (no growth), given adult survival rates between 90% and 96% per year at four fecundity rates. Fecundity rates ranged from 0.10 to 0.25 fledglings produced per adult bird per year. This range encompassed the average percent of adults breeding between 0.60 and 0.80 combined with 0.30 to 0.60 chicks fledged per breeding adult mated pair. Given the best, single estimates for Black-footed Albatross adult survival (93%) and fecundity (0.25 fledglings/adult) developed at the workshop, this simulation experiment indicated that juvenile survival has to be 86% or higher to prevent a population decrease (Fig. 39).

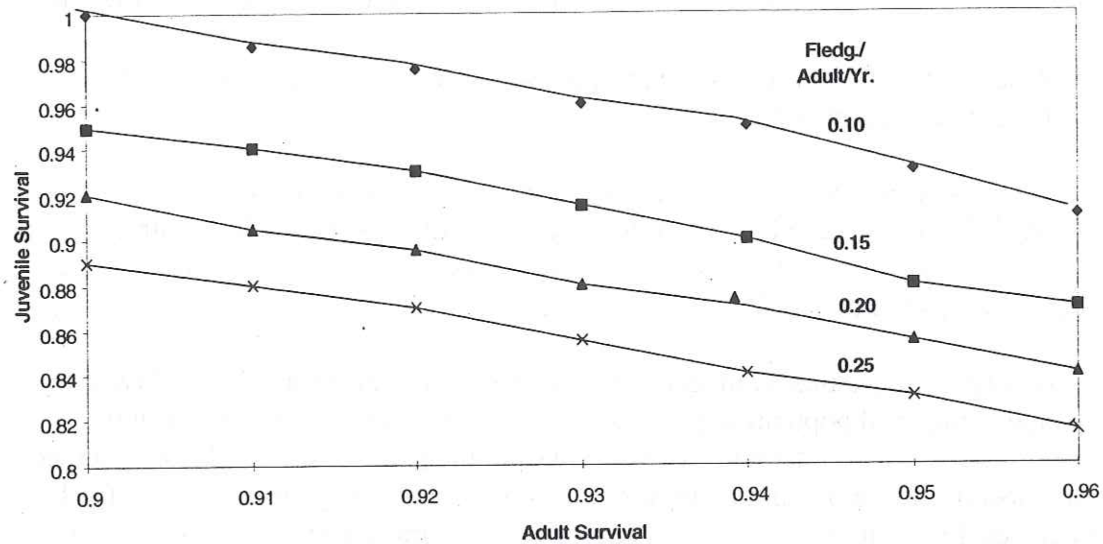



Figure 39. Combinations of adult and juvenile survival rates needed to produce a stable population illustrated for four fecundity rates. Fecundity is the average number of fledged chicks per adult bird in the entire population. For example, if adult survival is 0.93 and fecundity is 0.25, juvenile survival must be near 0.855 for a stable population, given the model assumptions stated in the text. First breeding is assumed at eight years and the maximum age at 50 years.

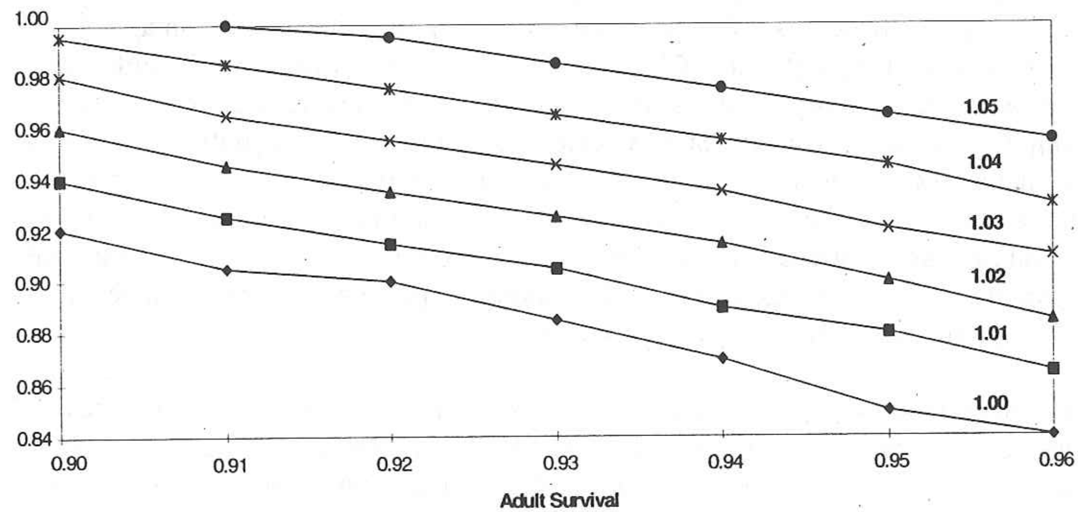



Figure 40. Combinations of adult and juvenile survival rates needed for population growth rates between 1.0 (stability) and 1.05 (5% average annual increase), assuming 0.20 chicks fledged/adult bird/year, first breeding at 8 years and maximum age at 50 years in all cases.

In the next experiment, fecundity was held steady at 0.20 fledglings/adult while determining the combinations of adult and juvenile survival rates needed for population growth rates between zero (no annual change) and five percent per year (a reasonable maximum rate attainable for Black-footed Albatross in the long term). Survival rate combinations for stable and increasing populations are illustrated in Figure 40.

To consider the impact of bycatch mortality on Black-footed albatross more specifically, the third simulation experiment removed birds from the population in addition to baseline mortality and measured the resulting population growth rates (Fig. 41). The experiment showed how different juvenile and adult removals would affect population trend, given preliminary indications that most Black-footed Albatross bycatch is of juvenile birds. The simulations used two baseline or pre-bycatch population growth rates (1.01 and 1.04), three ratios for juvenile:adult removal rates (1:1, 4:1, and 10:1) and three removal quantities (2,500, 5,000, and 7,500) from a total population of 300,000 birds. Scenarios were created from plausible breeding, fledging and survival rates that produced the desired population growth rates of 1.01 and 1.04. The observed declines in population growth for the different removal ratios are shown in Table 9. The results show that population growth rate is quite insensitive to whether juvenile or adult birds are taken, for the ratios tested. Small differences in growth rate accumulate over time, however (Fig. 41). In all the scenarios tested, removing one percent of the population—roughly 3,000 birds at today's estimated population size—results in about one percent lower annual growth regardless of the pre-removal growth rate (Table 9).

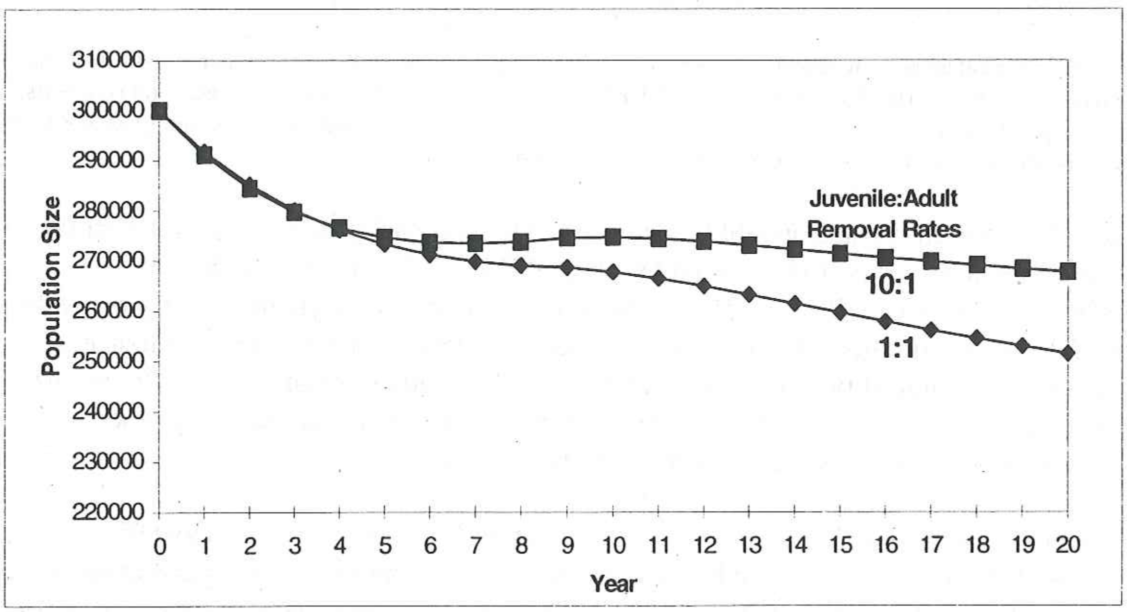



Figure 41. Comparison of removals taken at an equal rate among adults and juveniles with removals at a rate ten times higher for juveniles than for adults. If juveniles are removed at a greater rate than adults, then the population decreases more slowly than if removal rates are equal. The difference is not apparent initially, but accumulates over time due to resulting changes in the population age structure.

Table 9. Experiment with juvenile bias in additive removals or bycatch. Pre-removal growth rates were estimated with plausible parameter values in steady state. Birds were then removed from juvenile and adult age classes as a proportion of each age class population size (thus, as a rate) added to the baseline mortality rates.

| Pre-Removal Growth Rate[1] | Ratio of Juvenile:Adult Removal Rates[2] | Removals (from 300,000 Total Population) | | | Post-Removal Growth Rate |
|---|---|---|---|---|---|
| | | Target | Juvenile | Adult | |
| 1.04 | 1:1 | 5,000 | 2,818 | 2,192 | 1.023 |
| 1.04 | 4:1 | 5,000 | 4,147 | 846 | 1.025 |
| 1.04 | 10:1 | 5,000 | 4,625 | 383 | 1.026 |
| 1.01 | 1:1 | 5,000 | 2,807 | 2,203 | 0.993 |
| 1.01 | 4:1 | 5,000 | 4,144 | 847 | 0.995 |
| 1.01 | 10:1 | 5,000 | 4,619 | 387 | 0.996 |
| 1.01 | 1:1 | 2,500 | 1,391 | 1,099 | 1.001 |
| 1.01 | 1:1 | 7,500 | 4,216 | 3,284 | 0.984 |
| 1.01 | 10:1 | 7,500 | 6,198 | 1,300 | 0.987 |

[1] Model parameter values used to attain pre-removal growth rates were:

- 1.04 growth: 81% adults breeding/year, 0.25 fledglings/breeding adult (0.5 pair), 93% juvenile survival, 96% adult survival, first breeding at 8 years and maximum age at 50 years.
- Growth: 79% adults breeding/year, 0.24 fledglings/breeding adult (0.5 pair), 91% juvenile survival, 93% adult survival, first breeding at 8 years and maximum age at 50 years.

[2] The ratio is between rates (percentage of each age class taken), not numbers of birds taken per age class. Ratios of the removal rates were varied from 1:1 to 4:1 and 10:1. The rates were set to attain the target total removals, given a total population of 300,000 birds. The actual number of juveniles and adults removed and resulting long-term population growth rate for each scenario were then recorded.

Ideally, bycatch impacts would be determined by comparing demographic information for populations in areas or periods with and without fishing-related bycatch. Since comparative data are not available, general principles of population dynamics can provide an estimate of the maximum growth rate of a Black-footed Albatross population and hence, the impact of additional mortality. These analytical results (or mathematical solutions to simple equations representing population dynamics) are then compared or combined with the simulation results to look for robust conclusions about bycatch impacts.

By analyzing various bird populations, population ecologists have previously demonstrated that the maximum population growth or multiplication rate per generation is severely limited in bird populations by various constraints and rarely exceeds three (Lebreton 1981). This led to the approximation:

$$\lambda_{max} \approx 1 + 1/T$$

where $\lambda_{max}$ = the maximum multiplication rate, and T = generation time. In Black-footed albatross, T is between 20 and 30 years and the approximate, maximal multiplication rate is around 1.04.

Fisheries bycatch combines with other natural and anthropogenic mortality sources to decrease the population growth rate. The estimated total mortality in a stable population would be:

$$\text{Deaths}_{\text{stability}} \approx 1/T \times \text{Population Size}$$

Thus, to maintain a stable or increasing population the total number of deaths per year from bycatch and all other sources combined should be held at or below this maximum. The current world population size estimate for Black-footed Albatross is 59,984 pairs. Based on the Leslie matrix model, the total population number is five to six times the number of breeding pairs (also see section 5.6). Using population size (300,000 birds) and generation time (30 years) estimates that give a low or precautionary estimate of total deaths in a stable population, bycatch mortality must be lower than:

$$\text{Deaths}_{\text{stability}} \approx 1/30 \times 300{,}000 = 10{,}000$$

Clearly, this estimate depends critically on the estimate of population size and indicates only the order of magnitude for maximum sustainable mortality. Bycatch levels well below 10,000 may still cause population declines, as indicated by the previous simulation experiments in which bycatch was additive to natural mortality (i.e., the population was growing at less than 4% before bycatch was added; see Table 9).

### 6.1 Preliminary Conclusions from Population Modeling

Models use precise numbers, however, it is unrealistic to expect, in practice, to be able to obtain sufficiently accurate parameter estimates. It follows, therefore, that the models are developed for those broad conclusions that are valid despite the uncertainty in parameter values. We call these robust conclusions. The following are robust conclusions from the modeling exercises described in this report:

1. The models suggest that within the range of plausible parameter values, the sustained growth rate of the population (without any bycatch loss) is in the range of zero to about four percent.

2. If the total number of birds killed in the longline fishery each year is of the order of one percent of the total population, then the growth rate of the population will be reduced by slightly more than one percent. This significant reduction in growth is a robust estimate; it is not sensitive to the ratio of juveniles to adults lost, nor is it sensitive to whether the population was growing previously at zero or four percent. If the total number of birds killed in the fishery each year equals two percent of the total population, then the growth rate of the population would be reduced by somewhat more than two percent.

3. A total population of 300,000 birds could withstand, at the very most, a loss of 10,000 birds per year to all mortality sources including combined natural and anthropogenic sources. This is an upper limit for total mortality—the population should decrease at lower annual mortality due, for example, to indirect effects of mortality such as mate loss and lower net reproduction.

## 6.2 Recommendations for Future Population Modeling

Population models help managers identify the components significantly influencing population dynamics and explore the possible consequences of various management actions. Thus, future modeling directions should evolve from on-going population management concerns. Modeling should proceed iteratively and interactively with data collection and analysis, and in synchrony with evolving management concerns. In addition to using relatively simple simulation models to investigate specific questions as they arise, so too should models be used to evaluate the implications of new data as they are collected. Models can also be used to explore how useful it would be to collect new data or to partition a monitoring budget in alternative ways.

Workshop participants recommended that the simulation model developed at the workshop be modified to make comparisons between Black-footed and Laysan Albatross populations. These related species co-occur on nesting and foraging sites, yet have distinct population dynamics and different fishery-interaction histories. It would be illuminating to explore how the demographic differences between species affect the impact of bycatch on their populations.

During the workshop, modeling experiments assumed that parameters (survival and fecundity rates) remain constant with time and also that the rate of bycatch mortality, in any one scenario, remains constant with time. It would be useful to model scenarios when both parameters and mortality can change from one year to the next. These modeling exercises should be designed to address specific questions, such as:

(a) what would be the consequence of sustained bycatch mortality over a period of reduced breeding success,

(b) how is the population growth rate reduced by episodic catastrophic mortality, and

(c) what are the indirect effects of mortality on population growth, such as reduced fecundity due to mate losses?

## 6.3 Recommendations for Estimating Demographic Parameters and Abundance Indices

Population modeling helps to identify which elements of albatross demography are potentially most sensitive to impacts of human activities. Modeling results, however, may be sensitive to the estimates for vital population rates used in the model. In some cases, direct estimation of various modeling parameters may not be practical, and proxies may be required. In addition, models are not static, but should be changed to reflect new information. The simulation model used at the workshop is a first approximation; it considers primarily the influences of survival and basic fertility to produce an order-of-magnitude estimate of mortality rate impacts on the population. Several measures of reproductive performance and survival may be needed to help tune or revise the model and provide more specific or precise answers to management questions.

Two primary data types are generally relevant to constructing and using different population models: (1) the underlying parameters, which define the processes leading to variation in abundance (survival and fertility), and (2) the variation in population abundance itself (the ultimate reference against which model performance may be compared). In this section, we briefly describe the recommended methodologies for parameter estimation, and describe indices of population variation that could be collected for Black-footed Albatrosses.

Modern methods for the analysis of individually marked birds have progressed significantly over the past decade. Ad hoc methods have largely been replaced by a more robust statistical formalism that explicitly models the uncertainty in the data. The most obvious source of uncertainty is irregular encounters with marked individuals. During observation periods, presence or absence of marked birds may become confounded with temporary departure from the sampling area, permanent departure (either through death or emigration), or combinations of the two. Live mark-recapture and dead recovery models can together provide robust estimates of the primary parameters in population models.

The same statistical formalism can also provide strong inferential tests for the relative influence of bycatch on Black-footed Albatross dynamics, although this would necessarily require data sets contrasted by periods (or localities) where intensity of fishing impact is measurably different. One potential avenue that should be explored is to compare Laysan and Black-footed Albatross data collected over the same period. These two species appear to have significant differences in susceptibility to bycatch mortality. Direct comparison of estimates of the two species derived from equivalent ranges of years/locations should be useful.

Analysis of the standard encounter history of individual birds can yield estimates of age-specific 'apparent' survival ($\phi$). The qualifier 'apparent' is necessary since mark-recapture estimates of survival confound permanent emigration with true mortality. Differentiating these two events is possible either by (1) direct estimation of emigration rate by searching for individuals that have been recruited into other breeding colonies, or (2) use of data on dead recovered birds (since individuals recovered dead reflect outright mortality). Comparison of separate estimates of survival between the two approaches provides an ad hoc estimate of emigration rate and recent work by Burnham (1993) has shown that it is possible to separately estimate mortality from emigration rate through simultaneous analysis of recapture and recovery data. Variation in observer effort (or, equivalently, intensity of the marking effort) is modeled explicitly as a separate parameter.

Recruitment to the population can be estimated through the analysis of the encounter histories of individually marked birds. Recording observations from the time of marking through each subsequent encounter yields an estimate of $\phi$, the probability of leaving the sample permanently. Analysis of the same encounter history, by writing in reverse time sequence ('backwards'), provides estimates of the probability ($\gamma$) that a given individual entered the population permanently. Estimation of $\gamma$ can provide estimates of recruitment to the population by immigrants in addition to the rate of ascension to reproductive maturity (age-specific recruitment rates).

Recently, Pradel (1996) has shown that the geometric rate of growth of a population can be estimated as the ratio:

$$\lambda_t = \phi_t / \gamma_t$$

where $\phi_t$ = probability of leaving the population and $\gamma_t$, = the probability of entering the population. Geometric growth ($\lambda$) is of considerable utility for our purposes. When $\lambda$=1.0, the population is not changing over time. Traditionally, realized $\lambda$ is estimated as the ratio of successive estimates of population abundance. Unfortunately, abundance estimation can be fraught with logistical and analytical difficulties, and the estimates of abundance (and as a result any parameter estimated from them) typically have such large estimation errors that they may not be useful to managers. In contrast, the approach suggested by Pradel (1996) is both simpler and less costly to implement than methods relying on abundance estimates, as well as providing more precise estimates of $\lambda$. Statisticians attended the workshop recommended using estimates of the multiplication rate $\lambda$ as a robust proxy for actual abundance estimates (since, in effect, $\lambda$ is a precise index of relative abundance between years). However, in order to make specific recommendations about allowable bycatch, estimates of true abundance will be periodically required (say, for example, on a rotating 5-year cycle). Whether these abundance estimates are derived from intensive census, or estimated from recapture or recovery data, remains to be explored.

At present, it seems as if most of the data that are needed for these analyses are available, or could be easily collected with little additional cost. In particular, data from birds banded as chicks, and from adults that are known to be reproductively mature, are important. Data from birds banded opportunistically between fledging and recruitment are problematic analytically. It is possible to assess formally the number of birds that would be required to estimate a specific magnitude of change in $\lambda$ or adult survival. Further analyses of existing data would provide such guidance. In general, given the high survival rate of adults expected in this species and the high sensitivity of population dynamics of this species to even small variations in adult survival, either sample size will need to be large or recapture rate will need to be very high.

Recruitment is the number of chicks fledged and later "recruited" into the population. Typically, it is estimated from intensive breeding studies, combined with mark-recapture based estimates of pre-breeding survival. However, while these data provide the most precise estimates of recruitment, acquisition of these data are time-consuming and expensive in the long-term, especially breeding studies. While the infrastructure exists to maintain such studies, it is prudent to consider alternative modes to estimate of fertility. Pradel's (1996) approach provides an interesting alternative approach to estimating recruitment.

Some additional demographic measures that might be useful for assessing population dynamics and bycatch impact in Black-footed albatrosses include:

a) Counts of breeding pairs. This is the measure of population state that is typically used in marine bird studies.

b) Measurements of breeding frequencies from repeated reproductive assessments. This index requires very detailed work since it is difficult to determine whether birds are missing due to mortality or skipped breeding (i.e., due to mate loss).

c) Counts of juveniles in colony. The relative numbers of young juveniles and older birds that are found in the colony in March could provide a valuable index of recruitment. This measure can provide an early, but only partial, measure of effects of bycatch on juvenile survival.

d) Take of albatrosses per unit of effort in longline fisheries. The number of albatrosses taken per unit of effort in longline fisheries provides an additional index of abundance. The use of this index must be standardized for different effects, such as season, geographic location and fleet/boat characteristics and for mitigation measures.

## 7 Mortality of Black-footed Albatrosses in North Pacific Fisheries

Part of the human-caused mortality of Black-footed Albatrosses results from fishing gear interactions. The likelihood of such interactions varies in time and space depending on the seasonal patterns of Black-footed Albatross distribution and fishing effort. Sightings and band returns indicate that Black-footed Albatrosses are broadly distributed in the subtropical and temperate North Pacific Ocean between Asia and the North American continent, but are most abundant in the eastern Pacific (McDermond and Morgan 1993). In the central Pacific, the southern edge of their marine distribution is approximately 15° N (south of the main Hawaiian Islands). In the western Pacific Ocean, Black-footed Albatrosses range from the Ryukyu Islands in southern Japan northward to China and Russia (Sea of Okhotsk). In the eastern Pacific Ocean, Black-footed Albatrosses occupy oceanic waters from Baja California northward, and during late summer are distributed throughout the Gulf of Alaska and along the Aleutian chain, with some birds moving into the Bering Sea (Figs. 10 - 13). Given this wide distribution, the fisheries with a potential to take (i.e., a hooking or entanglement event resulting in the death of the seabird) the species are numerous and diverse. The fisheries of primary interest are longline and gillnet fisheries. They include a few fisheries in which takes of Black-footed Albatross and other seabirds are routinely monitored and several for which seabird takes are unknown (Table 10).

### 7.1 Longline Fisheries

#### 7.1.1 Demersal Longline Fisheries

The U.S. demersal longline fisheries operating in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands Area (BSAI) consist of the groundfish longline fishery targeting sablefish, Pacific cod, Greenland turbot, rockfish and other species, and the halibut longline fishery targeting Pacific halibut. Seabirds are usually hooked or entangled as the gear is being set. In the groundfish longline fishery, the industry funds an observer program coordinated by the National Marine Fisheries Service (NMFS), which places observers on 100% of the trips by large vessels [>124 ft (37.8 m) length overall (LOA)] and 30% of the trips by medium size vessels (60-124 ft or 18.3-37.8 m). Trips by smaller longliners (<60 ft or 18.3 m) are not covered. In the halibut fishery, there are no specific requirements for observer coverage unless the vessel also participates in the groundfish fishery and is required to carry observers according to groundfish longline regulations.

Table 10. Principal fisheries that take Black-footed Albatrosses (BFAL) or with the potential of such takes, monitoring status, and average take levels. EEZ = Exclusive Economic Zone; NPTZ = North Pacific Transition Zone. (Sources: Brothers *et al.* 1999a, Morgan *et al.* 1999, Yamada 1999.)

| Country | Fishery | Target | Region | Status of take monitoring | Average annual take of BFA L (range) |
|---|---|---|---|---|---|
| Japan | Drift gillnet | Swordfish, striped marlin | Japan 200-mile EEZ | None | Unknown |
| | Longline; distant-water | Albacore, bigeye tuna | North Pacific (outside Japan EEZ) | None | Unknown |
| | Longline; offshore | Tuna, swordfish | North Pacific (outside Japan EEZ) | Unknown | Unknown |
| | Longline; coastal | Tuna, swordfish | Japan 200-mile EEZ | None | Unknown |
| Taiwan | Longline; distant-water | Albacore | NPTZ | None | Unknown |
| | Longline; offshore | Tuna | East of Taiwan | None | Unknown |
| Russia | Longline; offshore | Pacific cod | Offshore Kamchatka | None | Unknown |
| United States | Alaska longline | Groundfish | Gulf of Alaska, Bering Sea/ Aleutian Islands | Since 1993 | *c.* 150 - 1,000; see Table 11 |
| | Alaska longline | Pacific halibut | Gulf of Alaska, Bering Sea/ Aleutian Islands | None | Unknown |
| | California drift gillnet | Swordfish, sharks | U.S. 200-mile EEZ | Since 1990 | None |
| | California set gillnet | California halibut, angel shark | U.S. 200-mile EEZ | Since 1990 | None |
| | California longline | Swordfish, tuna | NPTZ, E. Pacific (outside U.S. EEZ) | None | Unknown |
| | Hawaii longline | Swordfish, tuna | NPTZ, East Pacific | Since 1994 | *c.* 1,600-2,000; see Table 12 |
| | Troll | Albacore | NPTZ, East Pacific | None | Unknown |
| Canada | Hook and line | Groundfish | Northwest coast of British Columbia | Limited | Unknown |
| | longline | Halibut, Sablefish | Queen Charlotte Sound, Hecate Strait, Vancouver I. | None | Unknown |
| | Gillnet | Salmon | Northwest coast of British Columbia | Since ?? | Unknown |
| | Seine | Salmon, Herring | Northwest coast of British Columbia | None | Unknown |

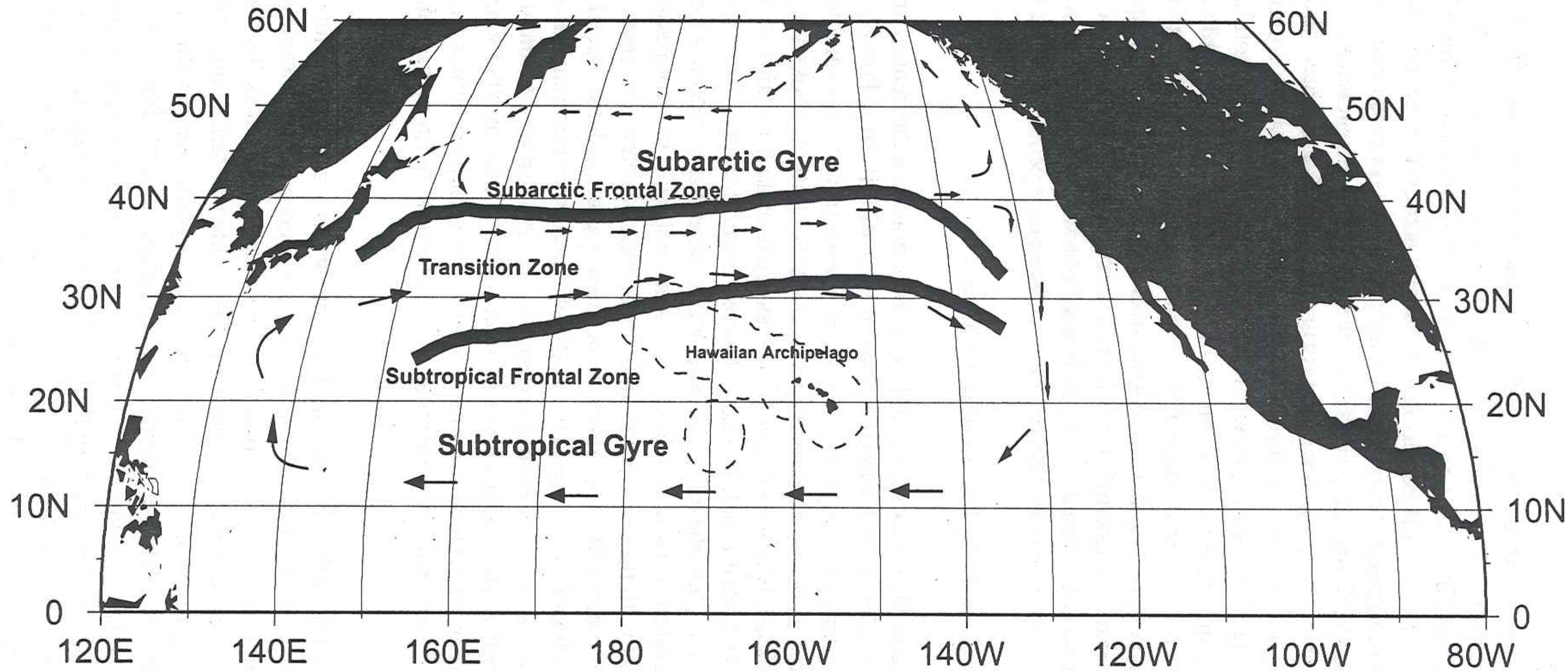



Figure 42. Predominant currents in the North Pacific Ocean. The North Pacific transition zone (NPTZ) is the region between the subarctic and subtropical frontal zones. Dashed lines (---) show the U.S. EEZ around the Hawaiian Archipelago and Johnston Atoll (figure was adapted from Roden 1991 by D. Foley of Hawaii Coastwatch).

NMFS began monitoring seabird/fishery interactions in the groundfish longline fishery in 1990 and added species-level identification to the observer protocols in 1993. Within each monitored vessel class, seabird take data are collected from samples of retrievals on samples of fishing trips. Estimates of total Black-footed Albatross take within each vessel class and management area are computed by combining sample statistics on catch rates of fish and Black-footed Albatross (from the observed hauls) with information on total fish catch (from the NMFS "blend program"); data is not currently entered into a database. Take estimation methods are still under development, but provisional estimates have been computed using ratio estimators (Stehn *et al.* 1999 in review). These estimators regard the total take of Black-footed Albatross as the sum of three components: (1) the total number of birds identified as Black-footed Albatross on observed hauls; (2) the total number of unidentified birds on observed hauls estimated to be Black-footed Albatross (based on species composition data); and (3) the total number of unidentified birds on unobserved hauls estimated to be Black-footed Albatross. Provisional estimates of total Black-footed Albatross takes during 1993-1997 range from 12-46 per year in the BSAI and 120-940 per year in the GOA (Table 11).

### 7.1.2 Hawaii Pelagic Longline Fishery

The Hawaii-based U.S. domestic longline fleet operates in the central and eastern North Pacific, targeting swordfish *Xiphias gladius* in the North Pacific Transition Zone (NPTZ) (Fig. 42) and primarily bigeye tuna *Thunnus obesus* in waters south of the Subtropical Front. Total nominal effort by the Hawaii fleet was about 15 million hooks in 1997. As in the demersal longline fisheries, Black-footed Albatrosses are usually hooked or entangled as the gear is being set. Most takes of Black-footed Albatross occur during swordfish fishing operations in the NPTZ with highest rates of interaction near Black-footed Albatross breeding colonies in the northwestern Hawaiian Islands. The seasonal peak in swordfish fishing effort (March-May) coincides with the seasonal peak in local Black-footed Albatross density in the fishing area. A small number of U.S. longline fishermen operate at least part of the time out of southern California ports and fish outside the 200-mile Exclusive Economic Zone (EEZ); most of these vessels are based in Hawaii. Systematic observation of incidental hooking and entanglement of seabirds in the Hawaii longline fleet began in March 1994 when NMFS implemented an observer program to monitor longline interactions with sea turtles. Currently, turtle observations are given priority over other data collection, but increased attention is being given to seabirds.

Pierre Kleiber of the NMFS Honolulu Laboratory has estimated the total Black-footed Albatross take by year, 1994-1998, as the sum of the take recorded on observed longline sets (assumed to be without error) and the estimated take on unobserved sets. To estimate the take on unobserved sets, Kleiber developed regression-tree models (Clark and Pregibon 1993) that predict Black-footed Albatross take as a function of key explanatory variables. The best-fitting model was found by evaluating numerous alternative regression trees based on a wide range of candidate explanatory variables, including the year of fishing, the number of hooks set, the geographic location of the set (latitude and longitude), oceanographic conditions, and other information collected by observers and also routinely recorded by longline vessel captains in their logbooks. In addition to factors directly measured by observers or longline fishers, the analysis incorporated factors calculated from ancillary data (e.g. proximity of the fishing operation to the nearest Black-footed Albatross breeding colony and distance from particular surface isotherms). The response variable in the regression trees was the untransformed take rate (early provisional regression-tree results based on log-transformed take rates were shown to be biased). The best-fitting regression-tree model predicts Black-footed Albatross takes as a function of proximity of the fishing operation to the albatross nesting grounds and, for fishing locations within a certain radius of the nesting area, the longitude of the operation. Because year of fishing was not a significant explanatory variable, the same regression-tree model was used to predict takes for the unobserved sets for all years. Estimates of the annual Black-footed Albatross takes are given in Table 12, along with 95% confidence intervals. The confidence intervals were estimated by bootstrap methods. Point estimates of total annual take range from approximately 1,600 – 2,000 Black-footed Albatrosses. Although moderate interannual differences among the point estimates of total take are evident, they are masked by the large variance of the annual estimates.

### 7.1.3 Other High-seas Pelagic Longline Fisheries

In addition to the U.S. longline fishery, Japan and the Republic of China (Taiwan) operate high-seas pelagic longline fisheries within the range of the Black-footed Albatross. Japan's offshore and distant-water longline fisheries target primarily albacore and bigeye tuna in international waters south of the Subarctic Boundary from the western Pacific to the 200-mile EEZ of the continental U.S. Some targeting of swordfish occurs in the western Pacific along the Kuroshio Extension. Initially confined to Japanese coastal waters, the fishery expanded across the Pacific in the early 1950s. The total North Pacific nominal effort in this fishery was about 132 million hooks in 1997 (Yamada 1999). Information on the spatial distribution of the 1997 effort is unavailable, but past data suggest that about 10% of the North Pacific effort is exerted in the eastern Pacific north of 20° N, where Black-footed Albatross appear to be most abundant. In this region the primary target is bigeye tuna.

Taiwan's distant-water longline fleet in the Pacific generally has fished in the Southern Hemisphere or equatorial regions, but increased its operations in the NPTZ in 1993, targeting albacore. Effort in the NPTZ has continued to increase, with about 18 million hooks deployed in 1995 and eight million hooks in 1996 (Sun et al. 1999). In addition to the distant-water fishery, Taiwan's offshore tuna longline fleet operates in the southwestern extreme of the Black-footed Albatross range around the Southern Ryukyu Islands breeding colony.

Longliners from the Republic of Korea once fished for bigeye tuna in NPTZ waters north of Hawaii (Anon. 1990). Although Korean fishery authorities have not published detailed longline statistics recently due to budget limitations, recent data indicate that their vessels now fish primarily in equatorial waters and the South Pacific, with little or no activity in the range of the Black-footed Albatross (Anon. 1990). Fishing effort and fish catch of all high-seas longline fleets are monitored by the flag country. Availability of this information may be limited by lack of funds for regular publication (e.g. Korea) or restrictive distribution policies (e.g. Japan).

Apparently, in the North Pacific Ocean, the U.S. is the only country routinely collecting statistics on seabird interactions. Japan so far does so only in her South Pacific longline fisheries for southern bluefin tuna (Takeuchi *et al.* 1998, Uozumi *et al.* 1998).

Table 11. Preliminary estimated total number of Black-footed Albatrosses caught by region in the Alaska groundfish longline fisheries, 1993-1997, and associated standard errors (Stehn *et al.* 1999 in review).

| Year | Bering Sea/ Aleutian Islands Total | Bering Sea/ Aleutian Islands Standard Error | Gulf of Alaska Total | Gulf of Alaska Standard Error | Combined Regions Total |
|---|---|---|---|---|---|
| 1993 | 12 | 2.7 | 626 | 88.6 | 638 |
| 1994 | 37 | 5.8 | 767 | 141.9 | 804 |
| 1995 | 46 | 5.8 | 940 | 118.8 | 986 |
| 1996 | 21 | 4.0 | 485 | 78.6 | 506 |
| 1997 | 21 | 4.6 | 120 | 32.4 | 141 |
| Average | 28 | 2.1 | 588 | 44.4 | 616 |

Table 12. Estimates of total incidental take of Black-footed Albatross in the Hawaii-based longline fishery, 1994-1998, derived from regression-tree model (P. Kleiber, NMFS Honolulu Laboratory, unpubl. data).

| Year | Take Estimate | 95% Confidence Interval |
|---|---|---|
| 1994 | 1,994 | 1,508 – 2,578 |
| 1995 | 1,979 | 1,439 – 2,497 |
| 1996 | 1,568 | 1,158 – 1,976 |
| 1997 | 1,653 | 1,243 – 2,102 |
| 1998 | 1,963 | 1,479 – 2,470 |
| Average | 1,831 | --- |

### 7.1.4 Pelagic Longline Fisheries in Coastal and Inshore Waters

In addition to the high-seas longline fisheries, a variety of pelagic longline fisheries are carried out in coastal and inshore waters. In the eastern Pacific, part of the fishing effort by Hawaii-based longline vessels is exerted within the U.S. 200-mile EEZ around the Hawaiian Archipelago, targeting primarily bigeye tuna. NMFS observers are deployed on a sample of tuna longline trips and incidental takes of Black-footed Albatross are estimated for the fleet as a whole (see above). Pelagic longline fishing is not permitted in the U.S. EEZ off California. In the western North Pacific inshore longline fisheries include Japan's tuna fishery operating within its 200-mile EEZ. Likewise, some of the effort of Taiwan's "offshore" fishery occurs within 200 miles of the Taiwanese coast. Information on seabird takes in the Asian coastal and inshore longline fisheries is apparently not available, nor is it likely that such data have been collected on a systematic basis. However, in the opinion of a Japanese seabird expert, interactions of Japanese fisheries with Black-footed Albatross are insignificant (H. Hasegawa; this workshop).

## 7.2 Gill Net Fisheries

### 7.2.1 High-seas Driftnet Fisheries

Driftnet fishing has not been permitted in international waters of the North Pacific since 1992, in accordance with the Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean and the U.N.-sponsored high-seas driftnet moratorium (UNGA Resolution 46/215). Prior to these actions, high-seas driftnet fisheries operated over wide areas of the temperate North Pacific, targeting salmon, squid, tuna and billfish. Japan's high-seas driftnet fisheries for salmon began in 1952 and operated in the western Pacific and Bering Sea where Black-footed Albatross densities were relatively low. These fisheries involved both mothership-based and land-based fleets. Data from the mothership-based operations (including data collected by U.S. observers within the U.S. 200-mile EEZ) show that this fishery took primarily shearwaters and puffins, and that Black-footed Albatrosses were not taken (e.g. Jones and DeGange 1988, DeGange *et al.* 1993, Ogi *et al.* 1993). Similarly, data from Japanese research vessels indicate that in the land-based salmon gillnet fishery the Black-footed Albatross was not a component of the incidental seabird take. Before their operations were halted by UNGA Resolution 46/215, high-seas driftnet vessels from Japan, Taiwan, and the Republic of Korea fished in the NPTZ targeting neon flying squid, *Ommastrephes bartrami*, (all fleets) or tuna and billfish (Japan and Taiwan).

The Japanese squid driftnet fleet began operations in 1978, the Korean fleet in 1979 and the Taiwanese fleet in 1980. All fleets targeted the neon flying squid in the NPTZ as far eastward as 145° W. and as far northward as the Subarctic Boundary. Beginning in 1986, Taiwan's driftnet vessels also targeted albacore using large-mesh gear. Japan's large-mesh fishery for tuna and billfish began in the $19^{th}$ century in Japanese coastal waters (Nakano *et al.* 1993). In the early 1980s larger vessels in the fleet expanded operations offshore into the NPTZ, targeting albacore with a comparable catch of skipjack tuna *Katsuwonus pelamis*. From June-December the Japanese large-mesh vessels fished in the western Pacific. During January-May their effort was concentrated in the Subtropical Frontal Zone as far eastward as 145° W. Following a pilot scientific observer program in the 1989 Japanese squid fishery, in 1990 observers were deployed in all North Pacific high-seas squid and large-mesh driftnet fisheries under international agreements. The programs led to a sampling of fishing trips during one full year of operations, from May 1990 through April 1991. Combining the observer data with fleet effort statistics, Johnson *et al.* (1993) estimated a total take of 4,420 Black-footed Albatrosses during this year of comprehensive monitoring. Using data from similar sources, Ogi *et al.* (1993) reported an estimated total take of 3,669 Black-footed Albatrosses for the same period. In recent years several vessels, primarily stateless or registered in the People's Republic of China, have been caught on the high-seas driftnet fishing in violation of the salmon treaty or the U.N. driftnet accord (USCG 1997). The take of Black-footed Albatross by such illegal driftnet operations is unknown but probably negligible in comparison to the takes by legal longline fisheries.

### 7.2.2 Gillnet Fisheries in Coastal and Inshore Waters

A variety of gillnet fisheries is carried out in coastal and inshore waters along the margins of the range of the Black-footed Albatross. In the western North Pacific such fisheries include the drift gillnet fishery of Japan operating within the Japanese 200-mile EEZ and perhaps other gillnet fisheries along the coasts of other Asian countries. The Japanese driftnet fleet targets swordfish, primarily offshore of the Tohoku and Hokkaido regions of Japan (Takehashi and Yokawa 1999). Information on the magnitude and composition of seabird takes in Asian coastal and inshore gillnet fisheries, as in the inshore longline fisheries, is apparently unavailable or not collected on a systematic basis. However, the level of Black-footed Albatross takes in these Japanese fisheries is thought to be insignificant (H. Hasegawa; this workshop). In the eastern Pacific, several gillnet fisheries operate within the U.S. 200-mile zones of the U.S. and Canada. In California, a drift gillnet fishery targets swordfish and sharks (common thresher and mako) and a set-gillnet fishery harvests California halibut and Pacific angel shark. NMFS has routinely deployed observers on a sample of fishing trips in these fisheries since 1990. The observer data indicate that neither California gillnet fisheries take Black-footed Albatrosses (Julian and Beeson 1998). Various inshore salmon gillnet fisheries also operate in the U.S. and Canada, but do not appear to take Black-footed Albatrosses (Jones and DeGange 1988).

### 7.3 Other Fisheries

Other fisheries operating in the range the Black-footed Albatross may occasionally hook or entangle the species. Among these are the Russian demersal longline fishery off Kamchatka for Pacific cod, the U.S. troll fishery for albacore and the Canadian West Coast groundfish hook-and-line fishery and the demersal longline fisheries for halibut and sablefish (Table 10). Albacore trollers typically fish along frontal features of the NPTZ. Effort is widely distributed over the NPTZ between the dateline and coastal transition zone waters off California, Oregon, Washington and British Columbia, where the Black-footed Albatross is the most common albatross (McDermond and Morgan 1993). Seabird interactions in the troll fishery have not been monitored. Incidental takes of albatrosses (species unidentified) are known to occur but appear to be infrequent (N. Bartoo unpubl. data). Similarly, the incidental takes of albatrosses in the Canadian demersal longline fisheries and groundfish hook and line fishery are known to occur, but monitoring of these fisheries for seabird interactions is limited to non-existent (Morgan *et al.* 1999; Brothers *et al.* 1999a). Beginning sometime during 1999, observers will monitor two fisheries: the groundfish hook-and-line fishery that targets rockfish, dogfish and lingcod; and the halibut longline fishery. Projected observer coverage level for both of these fisheries is about

10%. Observers will be primarily tasked to monitor target catch and bycatch (including seabirds, by species or taxa) in these fisheries (H. McElderry, pers. comm.).

## 8 Designing a Monitoring Scheme to Determine the Effectiveness of Seabird Avoidance Measures

Incidental mortality during longline fishing has been determined to be a major factor contributing to decreases in some albatross populations (Weimerskirch and Jouventin 1987, Croxall *et al.* 1990, Brothers 1991, Gales 1998, Croxall 1998, Croxall *et al.* 1998). Mitigation measures for reducing the incidental catch of seabirds in longline fisheries developed during the past 5-10 years are now mandatory in the U.S. North Pacific, the Economic Exclusion Zones (EEZs) of Australia and New Zealand, and much of the Southern Ocean. These measures have demonstrated varying levels of effectiveness (Brothers *et al.* 1999a). To evaluate the effectiveness of such measures, two separate but parallel monitoring schemes are necessary: 1) monitoring of seabird bycatch in the fisheries, and 2) monitoring of affected seabird populations. Given the long-term requirements associated with the monitoring of long-lived species, it is not realistic to expect completion of such population monitoring assessments prior to decisions to implement mitigation measures.

### 8.1 Estimating Seabird Bycatch

Monitoring seabird/fishery interactions is a crucial component of any program to address the reduction of seabird mortality (FAO 1999a,b). Monitoring the interactions is critical for 1) estimating the total number of seabirds caught incidentally in fisheries and 2) addressing the efficacy of mitigation measures used to reduce seabird bycatch. Although monitoring programs have included the use of fishermen logbooks and other self-reporting mechanisms, evidence exists that self-reporting by itself is an inadequate method for monitoring protected species encounters in a fishery (NMFS 1996). In Alaska longline fisheries, the U.S. Fish and Wildlife Service (FWS) strongly discourages the use of self-reporting as the sole method for monitoring a longline fishery and encourages the use of observers to collect seabird/fishery interaction data.

### 8.2 Seabird Bycatch Data as Collected by Observers Onboard the Fishing Vessel

Numerous observer programs for fisheries around the world collect seabird bycatch data (Alexander *et al.* 1997). For most programs, the seabird interaction data collection has been added to the existing duties of observers collecting fisheries data (e.g. stock assessment, species composition, fish biological data, etc.). Alternatively, programs could be designed for the sole purpose of collecting seabird interaction data. In response to its "Threat Abatement Plan for the incidental catch of seabirds during oceanic longline fishing operations," Australia recently developed a design for a pilot seabird bycatch observer program to operate on domestic longline vessels. The resulting report includes the framework, guidelines, options and recommendations for the statistical and logistic design of the pilot seabird bycatch observer program (CSIRO 1999). Economies of scale may occur if an observer program is already in place and additional seabird duties can be added to existing data collection protocols. See point 6 below for potential concerns with these combined observer program objectives.

Collecting reliable data using onboard observer programs requires careful consideration of many factors. A description and brief discussion of such factors follow:

1. Identification of Specific Objectives of Seabird Bycatch Data Collection. This will be important for subsequent determination of necessary levels of observer coverage, observer training and qualifications, and what data are collected.

2. Determination of adequate observer coverage levels that will result in statistically valid data that can be analyzed according to the program objectives or research questions. A statistical design and corresponding operations logistic design will ensue.

3. Observer Training. Providing adequate training (sampling procedures, accurate seabird identification, etc.), detailed list of duties, standardization of sampling protocols, and means and methods to minimize potential observer bias and to estimate observer bias.

4. Observer Data Collection could include but is not limited to:

   a) During the set:
      i. Time, date, area, latitude and longitude of set position (if not available, it could be estimated from haul data), and speed and direction of the set
      ii. Number of hooks deployed; type and state of bait used
      iii. Weather and sea data; other vessel characteristics data
      iv. Data on placement, deployment and construction of seabird avoidance methods, gear and devices
      v. Bird interaction with the fishing gear and the avoidance gear—bird abundance in gear deployment vicinity, number of bird attempts at baited hooks, number of birds seen hooked

   b) During the haul:
      i. Number of seabird takes by species (some or all of the seabirds may be retained, or head, leg or band retained); were the birds taken at time of set or haul
      ii. Assess number of seabird discards, those hooked but not hauled onboard; "flicked" or cut off line, that probably would not be included in seabird take data
      iii. Life status of each bird (dead and damaged, dead in rigor, dead and flexible, just alive, alive and sluggish, alive and vigorous)
      iv. Data on placement, deployment, construction of seabird avoidance methods, gear, devices at haul location
      v. Bird interaction with the fishing gear and the avoidance gear – bird abundance in gear hauling vicinity, number of bird attempts at hauled gear.

5. Effectiveness of Seabird Avoidance Measures. Several studies have analyzed seabird bycatch observer data to determine the effectiveness of avoidance measures (Duckworth 1995, Klaer and Polacheck 1995, 1998, Brothers and Foster 1997, Brothers *et al.* 1999b). For an onboard observer program, observers could collect qualitative and/or quantitative data regarding perceived effectiveness of avoidance measures (i.e., bird behavior observations); analysis of effectiveness will need to include relating the use of measures to the observed seabird bycatch rates and/or bait attempts. In those cases where actual hooking rates are very low, it may be productive (and necessary) to identify some proxy for hooking (bird attempt at bait).

Although it seems inherently obvious, little work has been done to equate, scientifically, bird attempts with actual hookings.

6. Potential Bias in Bycatch Estimates may occur due to:

   a) Multiple demands on and priorities of observers. This bias can be large because it gives fishers the opportunity to discard bycatch while the observer is otherwise occupied; solving this problem requires dedicated seabird bycatch observers or the use of video technology.

   b) Seabird experience of observers. This will be a problem especially in those programs where fisheries observers are used and asked to collect seabird bycatch data in addition to their regular duties; this bias can be estimated and minimized by using specialized observers.

   c) Variation in take numbers between the set and the haul. There are multiple causes for this problem; scavenging by sharks and other fish, birds falling off the hook or getting off the hook themselves; the bias can be estimated by carefully estimating the number hooked during the set and comparing this to the number recovered. Experimental "fishing" with dead albatrosses from previous hauls on the hooks would also allow estimation of loss rates.

Such biases have been documented in the tuna longline fishery within the Australian Fishing Zone (Gales *et al.* 1998, Brothers *et al.* 1998). The potential for such biases warrants careful consideration prior to the design and implementation of a seabird bycatch observer program.

### 8.3 Estimation of total Incidental Catch

In those programs with 100% observer coverage the total seabird bycatch is measured directly by the observers, and has no associated sampling variance, although it is expected to be biased because of limitations of the observation methods currently in use. When only a portion of the total fishing effort is observed, the total bycatch must be estimated from the portion of effort observed, and that estimate will have an associated sampling variance. This situation requires well-designed statistical sampling and estimation models to ensure that the estimates have minimum variance and are unbiased, and that the level of precision of the estimates can be determined. In fact, the level of precision can be controlled by carefully designing the sampling methodology, devising an efficient sampling stratification across time, space and factors such as vessels and gear types, and optimally allocating observer effort among the sampling strata.

Obtaining an accurate measurement of the bycatch in the observed portion requires careful attention to those factors that can introduce bias or measurement error (see discussion earlier). In addition to recording bycatch, observers must collect data on the fishing effort that produced that bycatch, from which a bycatch rate, or bycatch per unit effort (BPUE), can be calculated. In the case of longline fishing activities, the basic unit of fishing effort is the number of hooks fished, as bird bycatch rates are always expressed as birds per thousand hooks. In addition, depending on the sampling and estimation model used, other measures of effort will have to be collected. For example, the estimator used in Australia (Klaer and Polacheck 1995, 1997) is based on a two–stage sampling model, and requires recording the number of cruises and sets, as well as the number of hooks. Other models may require the collection of data on many associated factors such as the type of vessel, gear, bait, setting methods, and environmental conditions. In addition, when sampling is stratified in time and space, data and geographic location must be recorded. The bycatch rate measured on the observed vessels must be extrapolated to the total fishing effort, which means that the same effort measures recorded in the observed portion must be recorded in all of the unobserved proportion of the fishery. Because these data are usually collected through the use of vessel logbooks, their accuracy and completeness must be determined.

## 9 Designing A Field-Based Monitoring Program

Albatrosses are species characterized by very low reproductive rates, delayed maturation and long reproductive lives, so when a mortality-producing factor increases significantly, population level effects may be masked by intrinsic demographic factors for almost a decade. Typically, trends in population growth, recruitment and breeding performance cannot be discerned with clarity in less than about 1.5 generation times (defined here as the time to become reproductively competent or seven to eight years) which is about 10 to 12 years for Black-footed Albatrosses. Competition with other species and environmental factors ranging from vagaries of the weather, ENSO (*El Nino*) events, to changes in ocean productivity can influence albatross productivity and, in turn, drive population replacement and growth over time. A monitoring program must discriminate among the effects of these factors and provide data relevant to the impacts of fishing bycatch, distinguishable from the other influencing factors. A monitoring task of this complexity requires a carefully designed program, and a long-term commitment from funding sources.

### 9.1 Decisions on What to Monitor and Basic Program Design

From the characteristics of its population biology and preliminary population models, priorities for monitoring Black-footed Albatross populations must include population size and the key demographic variables in order to have the potential to assess impacts of long-line fishing. The goals of such a long-term monitoring program should include:

- Determining the demographic factors responsible for observed changes in population size;
- Relating changes in population variables to changes in fishing effort and/or albatross bycatch rates.

It should be noted that many other factors could confound or complicate the assessment of causal affects within albatross population processes. In particular, Black-footed Albatross populations are likely to be affected by:

- Pesticides (organochlorines) and pollutants (e.g. ingested plastics)
- Parasite burdens
- Climatic variation, both episodic and systematic

- Oceanographic variation, especially ENSOs

Whenever possible attention should be devoted to simultaneous acquisition of, and/or appropriate access to, relevant data. Whereas climatic and oceanographic data are likely to be obtainable from various remote-recording schemes and programs, data on pesticides, pollutants and parasites could only be obtained by parallel programs of field-data collection.

A program to monitor population variables will need to run for at least one decade because this is the mean time for a fledgling to become a recruit and a realistic time to be able to begin to detect significant change in population variables. To have appropriate sensitivity for detection of change in the most important variables (e.g. adult survival), large samples will be needed. Formal analysis of the sample size required to detect say one to two percent changes in variables over 5 to 10 years should be undertaken. However, samples of at least 1000 individuals are likely to be needed.

To assure data quality, standard operating procedures (SOPs) could be developed with special attention to the needs of population monitoring. The draft SOPs should receive appropriate peer review; after adoption all relevant personnel should be trained in proper implementation.

If possible this work should be replicated at three sites in the NWHI. Either or both of Midway Atoll and Laysan Island is representative of the main centers of the Black-footed Albatross population. However, these very large colonies may impose some logistic constraints. A third candidate site is Tern Island, French Frigate Shoals. This is a small colony (in comparison with the others) and annual capture-mark-recapture of all breeding birds on the island is feasible and has been completed in the last few years. Both Midway Atoll and Tern Island sites have been known sources of contaminants like lead and PCBs. It is unknown to what extent these contaminants may affect Black-footed Albatross.

#### 9.1.1 Population Size

At the main study sites population size should be recorded annually, either as the cumulative total number of eggs laid or by a census at the end of egg laying, corrected for failure rate to this date based on sub-sample data. Estimation of breeding population size throughout the species' range should be made on a regular basis (say every two years) perhaps by a rolling program covering several islands each year.

#### 9.1.2 Adult Survival

Capture-mark-recapture of banded birds will generate reliable estimates for year-to-year survival. Where possible pairings (partnerships) should be recorded as these can provide data on re-mating rate (a variable of potential interest in relation to its contribution to fertility rate). This parameter could also provide information on mate loss.

#### 9.1.3 Age at First Breeding

Annual recapture (as part of capture-mark-recapture for adult breeders) of known-age birds will provide the age of the birds at first breeding. This requires banding of large samples (*c.* 1000 a year) of fledglings. Realistic estimation of this variable will take about 10 years.

### 9.1.4 Breeding Frequency

Breeding frequency could be obtained from a capture-mark-recapture program on breeding adults.

### 9.1.5 Breeding Success

As chicks fledged per egg laid this requires direct counts of eggs laid (see Population Size above), and of chicks fledged (usually most conveniently done when these are banded; a correction for post-banding, pre-fledging mortality may be required).

### 9.1.6 Juvenile Survival

Obtained from the survival of fledglings to age of recruitment (first, mean, modal) to the breeding population. The necessary data will be available from the capture-mark-recapture program on adult birds. It may also be feasible to obtain an index of juvenile survival to an earlier age through systematic recapture of juveniles attending breeding colonies (either cumulative recapture throughout the season or, most cost effectively, at a particular time of year).

Absolute estimates of juvenile survival require correction for rates of emigration. These may be estimated from immigration rate into the study area of birds banded elsewhere or from recapture operations (controlled for effort) at other sites to estimate the proportion of birds banded.

### 9.1.7 Genetic Studies

To determine if development of colony-specific genetic markers is possible would require a coordinated program of collection of blood or tissue samples, linked to appropriate molecular genetic research. The latter might be best conducted by, or in collaboration with, existing groups conducting genetic research on other albatross populations.

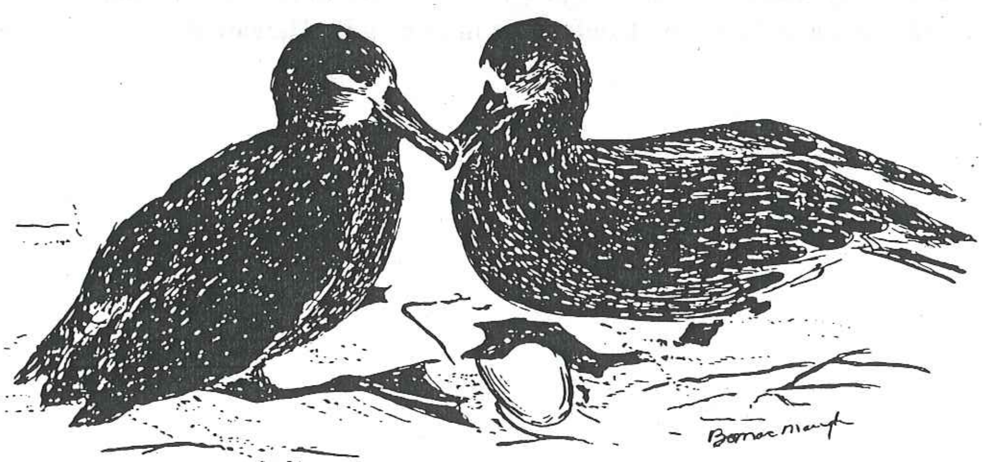
## 10 Recommendations

The following recommendations were agreed upon by the participants of the Black-footed Albatross Population Biology Workshop held at the Western Pacific Regional Fishery Management Council on 8 – 10 October 1998. The participants agreed that more stringent and uniform monitoring should be conducted at albatross breeding colonies, as well as that attempts be made to assess albatross mortality in fisheries other than the Hawaii longline fishery.

- Complete, develop and manage a relational database for banding records.
- Encourage further analyses of the existing data sets and conduct further modeling at a population dynamics modeling laboratory.
- Design and implement a population-monitoring program at breeding sites to address the effects of longlining mortality.
- Obtain information and make best estimates of fishing effort and mortality of birds from the Pacific halibut and non-US longline fisheries in the Northern Pacific Ocean.
- Design, implement and develop a longline fishery-monitoring scheme to test mitigation measures and to gather mortality data.
- Undertake comparative studies with Laysan and Japanese Black-footed Albatrosses.
- Hold a follow-up meeting to discuss progress with the above recommendations at the Second International Albatross Conference in Honolulu, Hawaii, 8 - 12 May 2000.

## 11 Acknowledgements

We thank the Western Pacific Regional Fishery Management Council staff and J. Cook, the Council Chair, and especially K. Simonds, the Executive Director, for funding, support and assistance during the workshop. We also thank the National Marine Fisheries Service, Pacific Islands Area Office and Honolulu Laboratory, and the U.S. Fish and Wildlife Service, Refuges Office, for their support and guidance. We also thank H. Dewar, M. Hamilton, A. Kaahanui, G. Layi and T. Menard for their technical assistance and guidance. We thank R. Clapp and B. Kirby, Smithsonian Institution, for assisting us with the Pacific Ocean Survey Program records and the two interns, J. Better-Rice and J. Haslerig, for photocopying. We thank D. Shearwater, B. McKee, G. Gillson, T. Wahl and R. Pyle for their sightings records and D. Anderson (Wake Forest University) for his satellite-tracking data. We thank D. Anderson and K. Burnham (Colorado State University) for their comments on the bird-banding database. We also thank D. Duffy, W. Stehn and P. Thomas (USGS-BRD) for their support with the bird-banding database. We thank the observers who took the time to attend the workshop and I. Kinan for her poster on seabird plastic ingestion. We especially thank K. Klimkiewicz and the USGS staff for their assistance with the bird-banding records. We thank N. Seto for her comments and D. Hopper and S. Conant for their technical assistance. In closing, we thank G.C. Whittow for a critical review of the draft report.



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**Appendix I**

**Participants of the Black-footed Albatross Population Biology Workshop, Honolulu, Hawaii, 8-10 October 1998.**

| Workshop Participants | Areas of Specialty |
|---|---|
| Chris Boggs<br>National Marine Fisheries Service<br>Southwest Fisheries Science Center<br>Honolulu Laboratory<br>2570 Dole Street<br>Honolulu, Hawaii<br>USA 96822<br>cboggs@honlab.nmfs.hawaii.edu | Fish Biology and Ecology |
| Jean F. Cochrane<br>University of Minnesota<br>Conservation Biology Program<br>1987 Upper Buford Circle<br>St. Paul, Minnesota<br>USA 55108<br>cochrane@boreal.org | Population Modeling |
| Evan Cooch<br>Department of Natural Resources<br>Fernow Hall<br>Cornell University<br>Ithaca, New York<br>USA 14853<br>evan.cooch@cornell.edu | Wildlife Ecology |
| John Cooper (Workshop Chair)<br>Birdlife International Seabird Conservation Programme<br>Avian Demography Unit<br>University of Cape Town<br>Rondebosch 7701, South Africa<br>jcooper@botzoo.uct.ac.za | Seabird Ecology and Conservation |
| Katherine L. Cousins (Workshop Coordinator)<br>Pacific Islands Area Office<br>National Marine Fisheries Service<br>Suite 1110, 1601 Kapiolani Blvd.<br>Honolulu, Hawaii<br>USA 96814<br>Kathy.Cousins@noaa.gov | Marine Biology and Animal Physiology |

| Workshop Participants | Areas of Specialty |
|---|---|
| John P. Croxall<br>British Antarctic Survey<br>Natural Environment Research Council<br>High Cross, Madingley Road<br>Cambridge CB3 OET<br>United Kingdom<br>j.croxall@bas.ac.uk | Seabird Ecology |
| Elizabeth Flint<br>U.S. Fish and Wildlife Service<br>Hawaii Pacific Islands Northwestern Region<br>300 Ala Moana Boulevard<br>Room 5-231, Box 50167<br>Honolulu, Hawaii<br>USA 96850<br>Beth_Flint@fws.gov | Seabird Ecology |
| Hiroshi Hasegawa<br>Toho University<br>Faculty of Science<br>Miyani 2-2-1, Funabashi, Chiba 274<br>Japan | Seabird Biology |
| Dennis Heinemann<br>CSIRO Division of Marine Research<br>Castray Esplanade<br>P.O. Box 1538<br>Hobart, Tasmania 7001<br>dennis.heinemann@hba.marine.csiro.au | Seabird Ecology and Modeling |
| Pierre Kleiber<br>National Marine Fisheries Service<br>Southwest Fisheries Science Center<br>Honolulu Laboratory<br>2570 Dole Street<br>Honolulu, Hawaii<br>USA 96822<br>pkleiber@honlab.nmfs.hawaii.edu | Fisheries Biology |
| Jean-Dominique Lebreton<br>C.N.R.S., C.E.F.E.<br>1919 Route de Mende<br>34 293 Montpellier Cedex 5<br>France<br>lebreton@srvlinux.cefe.cnrs-mop.fr | Population Ecology and Modeling |

| Workshop Participants | Areas of Specialty |
|---|---|
| James P. Ludwig<br>The SERE Group, Ltd.<br>138 Road 2 West<br>Kingsville, Ontario<br>Canada N9Y 2Z6 | Population Ecology and Toxicology |
| Miguel A. Pascual<br>Centro Nacional Patagónia, CONICET<br>(9120) Puerto Madryn<br>Chubut, Argentina<br>pascual@cenpat.edu.ar | Population Ecology and Modeling |
| Samuel Pooley<br>National Marine Fisheries Service<br>Southwest Fisheries Science Center<br>2570 Dole Street<br>Honolulu, Hawaii<br>USA 98622<br>spooley@honlab.nmfs.hawaii.edu | Fishery Management and Performance Investigation |
| Robert L. Pyle<br>Bishop Museum<br>1525 Bernice Street<br>P.O. Box 19000A<br>Honolulu, Hawaii<br>USA 96817<br>RLPyle@Bishop.bishopmuseum.org | Seabird Ecology |
| Kim S. Rivera<br>National Marine Fisheries Service<br>Protected Resources Division<br>P.O. 21668<br>Juneau, Alaska<br>USA 99802<br>Kim.Rivera@noaa.gov | Fisheries Management and Protected Resources |
| Chandler S. Robbins<br>Patuxent Wildlife Research Center<br>11410 American Holly Drive<br>Laurel, Maryland<br>USA 20708-4015<br>Chan_Robbins@usgs.gov | Seabird Population Ecology |

| Workshop Participants | Areas of Specialty |
|---|---|
| Monica Silva<br>Department of Zoology<br>University of Washington<br>Box 351800<br>Seattle, Washington<br>USA 98195 | Population Genetics |
| Anthony M. Starfield<br>University of Minnesota<br>Conservation Biology Program<br>1987 Upper Buford Circle<br>St. Paul, Minnesota<br>USA 55108<br>starf001@maroon.tc.umn.edu | Population Modeling |
| Catherine Swift<br>U.S. Fish and Wildlife Service<br>Hawaii Pacific Islands Northwestern Region<br>300 Ala Moana Boulevard<br>Room 5-231, Box 50167<br>Honolulu, Hawaii<br>USA 96850<br>Katie_Swift@fws.gov | Seabird Biology |
| Jerry Wetherall<br>National Marine Fisheries Service<br>Southwest Fisheries Science Center<br>Honolulu Laboratory<br>2570 Dole Street<br>Honolulu, Hawaii<br>USA 96822<br>jwetheral@honlab.nmfs.hawaii.edu | Fisheries and Population Modeling |


Figure 43. Some of the workshop participants and observers in the lobby of the Western Pacific Regional Fishery Management Council. Front row kneeling from left to right: P. Kleiber, J. Cochrane, K. Rivera, K. Cousins (Workshop Coordinator), H. Hasegawa, J. Ludwig. Kneeling second row (l-r): R. Pyle, L. Paul and M. Silva. Standing (l-r) J.-D. Lebreton, J. Croxall, D. Heinemann, J. Nelson, T. Starfield, E. Flint, C. Safina, C. Robbins, M. Pascual, A. Viggiano, C. Swift, E. Cooch and J. Cooper (Workshop Chair).

## Appendix II

Number of eggs, chicks, fledglings and calculated hatching, fledging and breeding success for Sand Island, Midway Atoll, Laysan Island and Tern Island, French Frigate Shoals. Hatching success is calculated as the number of eggs hatched divided by the total number of eggs laid x 100. Fledging Success is calculated as the total number of checks fledged by the total number of eggs hatched x 100. Breeding success is calculated as the total number of chicks fledged divided by the total number of eggs laid x 100.

| Location (Area) | Year | No. of eggs | No. of chicks hatched | No. of chicks fledged | Hatching success (%) | Fledgling success (%) | Breeding success (%) |
|---|---|---|---|---|---|---|---|
| Sand Island, Midway Atoll (General Plots) | 1987 | 51 | NA | 44 | -- | -- | 86.3 |
| Sand Island, Midway Atoll (Plots) | | | | | | | |
| (Frigate Point) | 1992 | 25 | 15 | 13 | 60.0 | 86.7 | 52.0 |
| (Fuel Farm) | 1992 | 25 | 19 | 14 | 76.0 | 73.7 | 56.0 |
| (NAVFAC*) | 1992 | 25 | 22 | 20 | 88.0 | 90.9 | 80.0 |
| (East Antenna Field) | 1992 | 23 | 18 | 16 | 78.3 | 88.9 | 69.6 |
| Total | 1992 | 98 | 74 | 63 | | | |
| Mean | 1992 | | | | 75.6 | 85.0 | 64.4 |
| *Old Navigational facilities | | | | | | | |
| Sand Island, Midway Atoll (Plots) | | | | | | | |
| (Frigate Point) | 1993 | 25 | 18 | 17 | 72.0 | 94.4 | 68.0 |
| (Water Tower) | 1993 | 25 | 22 | 20 | 88.0 | 90.9 | 80.0 |
| (NAVFAC*) | 1993 | 25 | 21 | 21 | 84.0 | 100.0 | 84.0 |
| (East Antenna Field) | 1993 | 25 | 23 | 21 | 92.0 | 91.3 | 84.0 |
| Total | 1993 | 100 | 84 | 79 | | | |
| Mean | 1993 | | | | 84.0 | 94.2 | 79.0 |

| Location (Area) | Year | No. of eggs | No. of chicks hatched | No. of chicks fledged | Hatching success (%) | Fledgling success (%) | Breeding success (%) |
|---|---|---|---|---|---|---|---|
| Laysan Island (Plots) | | | | | | | |
| Sand 1( 1-20) | 1992 | 20 | 10 | 9 | 50.0 | 90.0 | 45.0 |
| Era 1 (21-40) | 1992 | 20 | 7 | 5 | 35.0 | 71.4 | 25.0 |
| Era 2 (B141-150) | 1992 | 10 | 4 | 0 | 40.0 | 0.0 | 0.0 |
| Era 3 (B161-170) | 1992 | 10 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| Sand 2 (41-50) | 1992 | 10 | 7 | 6 | 70.0 | 85.7 | 60.0 |
| Sand 3 (51-60) | 1992 | 10 | 7 | 5 | 70.0 | 71.4 | 50.0 |
| Sand 4 (61-80) | 1992 | 20 | 7 | 7 | 35.0 | 100.0 | 35.0 |
| Sand 5 (81-100) | 1992 | 20 | 14 | 13 | 70.0 | 92.9 | 65.0 |
| Sand 6 (101-110) | 1992 | 10 | 8 | 8 | 80.0 | 100.0 | 80.0 |
| Sand 7 (111-120) | 1992 | 10 | 5 | 4 | 50.0 | 80.0 | 40.0 |
| Sand 8 (121-130) | 1992 | 11 | 4 | 4 | 36.4 | 100.0 | 36.4 |
| Sand 9 (131-140) | 1992 | 10 | 4 | 4 | 40.0 | 100.0 | 40.0 |
| Sand 10 (B151-160) | 1992 | 10 | 5 | 5 | 50.0 | 100.0 | 50.0 |
| Sand 11 (B171-185) | 1992 | 15 | 6 | 5 | 40.0 | 83.3 | 33.3 |
| Sand 12 (B186-200) | 1992 | 15 | 7 | 6 | 46.7 | 85.7 | 40.0 |
| Total/ Mean | 1992 | 201 | 95 | 81 | 47.5 | 77.4 | 40.0 |
| Laysan Island (Plots) | | | | | | | |
| (B1) – sandy beach | 1993 | 12 | 10 | 8 | 83.3 | 80.0 | 66.7 |
| (B2) – sandy beach | 1993 | 9 | 6 | 5 | 66.7 | 83.3 | 55.6 |
| (B3) – sandy beach | 1993 | 12 | 9 | 5 | 75.0 | 55.6 | 41.7 |
| (B4) – sandy beach | 1993 | 12 | 7 | 6 | 58.3 | 85.7 | 50.0 |
| (B5) – sandy beach | 1993 | 12 | 9 | 7 | 75.0 | 77.8 | 58.3 |
| (B6) – hardpan with vegetation | 1993 | 12 | 12 | 1 | 100.0 | 8.3 | 8.3 |
| (B7) – sandy beach | 1993 | 12 | 11 | 7 | 91.7 | 63.6 | 58.3 |
| (B8) – sandy beach | 1993 | 12 | 11 | 6 | 91.7 | 54.5 | 50.0 |
| (B9) – sandy beach | 1993 | 12 | 10 | 7 | 83.3 | 70.0 | 58.3 |
| (B10) – sandy beach | 1993 | 12 | 9 | 8 | 75.0 | 88.9 | 66.7 |
| (B11) – sandy beach | 1993 | 12 | 9 | 7 | 75.0 | 77.8 | 58.3 |
| (B12) – sandy beach | 1993 | 12 | 9 | 0 | 75.0 | 0.0 | 0.0 |
| (B13) – sandy beach | 1993 | 12 | 7 | 2 | 58.3 | 28.6 | 16.7 |
| (B14) – sandy beach | 1993 | 9 | 8 | 1 | 88.9 | 12.5 | 11.1 |
| (B15) – sandy beach | 1993 | 12 | 7 | 1 | 58.3 | 14.3 | 8.3 |
| (B16) – hardpan with vegetation | 1993 | 12 | 12 | 0 | 100.0 | 0.0 | 0.0 |
| (B17) – sandy beach | 1993 | 7 | 7 | 2 | 100.0 | 28.6 | 28.6 |
| (B18) – hardpan with vegetation | 1993 | 12 | 10 | 5 | 83.3 | 50.0 | 41.7 |
| Total/Mean | 1993 | 205 | 163 | 78 | 79.9 | 48.9 | 37.7 |

| Location (Area) | Year | No. of eggs | No. of chicks hatched | No. of chicks fledged | Hatching success (%) | Fledgling success (%) | Breeding success (%) |
|---|---|---|---|---|---|---|---|
| Laysan Island (Plots) | | | | | | | |
| (B1) – sandy beach | 1994 | 10 | 9 | 6 | 90.0 | 66.7 | 60.0 |
| (B2) – sandy beach | 1994 | 10 | 9 | 5 | 90.0 | 55.6 | 50.0 |
| (B3) – sandy beach | 1994 | 10 | 6 | 2 | 60.0 | 33.3 | 20.0 |
| (B4) – sandy beach | 1994 | 10 | 10 | 8 | 100.0 | 80.0 | 80.0 |
| (B5) – sandy beach | 1994 | 10 | 5 | 3 | 50.0 | 60.0 | 30.0 |
| (B6) – hardpan with vegetation | 1994 | 10 | 7 | 3 | 70.0 | 42.9 | 30.0 |
| (B7) – sandy beach | 1994 | 10 | 9 | 5 | 90.0 | 55.6 | 50.0 |
| (B8) – sandy beach | 1994 | 10 | 6 | 3 | 60.0 | 50.0 | 30.0 |
| (B9) – sandy beach | 1994 | 10 | 9 | 8 | 90.0 | 88.9 | 80.0 |
| (B10) – sandy beach | 1994 | 10 | 10 | 7 | 100.0 | 70.0 | 70.0 |
| (B11) – sandy beach | 1994 | 10 | 10 | 6 | 100.0 | 60.0 | 60.0 |
| (B12) – sandy beach | 1994 | 10 | 9 | 6 | 90.0 | 66.7 | 60.0 |
| (B13) – sandy beach | 1994 | 10 | 9 | 4 | 90.0 | 44.4 | 40.0 |
| (B14) – sandy beach | 1994 | 10 | 6 | 4 | 60.0 | 66.7 | 40.0 |
| (B15) – sandy beach | 1994 | 10 | 4 | 3 | 40.0 | 75.0 | 30.0 |
| (B16) – hardpan with vegetation | 1994 | 10 | 9 | 2 | 90.0 | 22.2 | 20.0 |
| (B17) – sandy beach | 1994 | 10 | 4 | 3 | 40.0 | 75.0 | 30.0 |
| (B18) – hardpan with vegetation | 1994 | 10 | 7 | 5 | 70.0 | 71.4 | 50.0 |
| (B19) – sand | 1994 | 10 | 7 | 4 | 70.0 | 57.1 | 40.0 |
| (B20) – vegetation | 1994 | 10 | 6 | 2 | 60.0 | 33.3 | 20.0 |
| (B21) – vegetation | 1994 | 10 | 7 | 1 | 70.0 | 14.3 | 10.0 |
| (B22) – vegetation | 1994 | 10 | 8 | 3 | 80.0 | 37.5 | 30.0 |
| Total | 1994 | 220 | 166 | 93 | | | |
| Mean | 1994 | | | | 75.5 | 55.8 | 42.3 |

| Location (Area). | Year | No. of eggs | No. of chicks hatched | No. of chicks fledged | Hatching success (%) | Fledgling success (%) | Breeding success (%) |
|---|---|---|---|---|---|---|---|
| Laysan Island (Plots) | | | | | | | |
| (B1) – sandy beach | 1995 | 10 | 7 | 4 | 70.0 | 57.1 | 40.0 |
| (B2) – sandy beach | 1995 | 10 | 6 | 1 | 60.0 | 16.7 | 10.0 |
| (B3) – sandy beach | 1995 | 10 | 4 | 0 | 40.0 | 0.0 | 0.0 |
| (B4) – sandy beach | 1995 | 10 | 5 | 4 | 50.0 | 80.0 | 40.0 |
| (B5) – sandy beach | 1995 | 10 | 5 | 4 | 50.0 | 80.0 | 40.0 |
| (B6) – hardpan with vegetation | 1995 | 10 | 9 | 2 | 90.0 | 22.2 | 20.0 |
| (B7) – sandy beach | 1995 | 10 | 6 | 3 | 60.0 | 50.0 | 30.0 |
| (B8) – sandy beach | 1995 | 10 | 7 | 3 | 70.0 | 42.9 | 30.0 |
| (B9) – sandy beach | 1995 | 10 | 7 | 5 | 70.0 | 71.4 | 50.0 |
| (B10) – sandy beach | 1995 | 9 | 6 | 4 | 66.7 | 66.7 | 44.4 |
| (B11) – sandy beach | 1995 | 9 | 4 | 3 | 44.4 | 75.0 | 33.3 |
| (B12) – sandy beach | 1995 | 10 | 5 | 2 | 50.0 | 40.0 | 20.0 |
| (B13) – sandy beach | 1995 | 10 | 9 | 6 | 90.0 | 66.7 | 60.0 |
| (B14) – sandy beach | 1995 | 10 | 7 | 7 | 70.0 | 100.0 | 70.0 |
| (B15) – sandy beach | 1995 | 10 | 8 | 4 | 80.0 | 50.0 | 40.0 |
| (B16) – hardpan with vegetation | 1995 | 10 | 7 | 3 | 70.0 | 42.9 | 30.0 |
| (B17) – sandy beach | 1995 | 9 | 7 | 7 | 77.8 | 100.0 | 77.8 |
| (B18) – hardpan with vegetation | 1995 | 10 | 7 | 3 | 70.0 | 42.9 | 30.0 |
| (B19) – sand | 1995 | 9 | 8 | 6 | 88.9 | 75.0 | 66.7 |
| (B20) – vegetation | 1995 | 9 | 9 | 2 | 100.0 | 22.2 | 22.2 |
| (B21) – vegetation | 1995 | 7 | 6 | 3 | 85.7 | 50.0 | 42.9 |
| (B22) – vegetation | 1995 | 10 | 9 | 7 | 90.0 | 77.8 | 70.0 |
| Total | 1995 | 212 | 148 | 83 | | | |
| Mean | 1995 | | | | 70.2 | 55.9 | 39.4 |

| Location (Area) | Year | No. of eggs | No. of chicks hatched | No. of chicks fledged | Hatching success (%) | Fledgling success (%) | Breeding success (%) |
|---|---|---|---|---|---|---|---|
| Tern Island, | 1981 | 96 | -- | 56 | -- | -- | 58.3 |
| French Frigate Shoals | 1982 | 149 | -- | 97 | -- | -- | 65.1 |
| (Direct Counts) | 1983 | 193 | -- | 104 | -- | -- | 53.9 |
| | 1984 | 221 | -- | 100 | -- | -- | 45.2 |
| | 1985 | 292 | -- | 225 | -- | -- | 77.1 |
| | 1986 | 304 | -- | 212 | -- | -- | 69.7 |
| | 1987 | 448 | -- | 336 | -- | -- | 75.0 |
| | 1988 | 451 | -- | 337 | -- | -- | 74.7 |
| | 1989 | 516 | -- | 350 | -- | -- | 67.8 |
| | 1990 | 618 | -- | 436 | -- | -- | 70.6 |
| | 1991 | 691 | -- | 538 | -- | -- | 77.9 |
| | 1992 | 767 | -- | 555 | -- | -- | 72.4 |
| | 1993 | 895 | -- | 633 | -- | -- | 70.7 |
| | 1994 | 918 | -- | 720 | -- | -- | 78.4 |
| | 1995 | 1034 | -- | 807 | -- | -- | 78.0 |
| | 1996 | 1048 | -- | 733 | -- | -- | 69.9 |
| | 1997 | 1304 | -- | 956 | -- | -- | 73.3 |
| | 1998 | 1519 | -- | 1038 | -- | -- | 68.3 |

## Appendix III: Chronology for the Northwestern Hawaiian Islands

### 1. Kure Atoll

1825 - 13 July – The schooner *Tartar* made the first known discovery of Kure Atoll (Woodward 1972).

1837 - 9 June – The British whaler H.M.S. *Gledstanes* wrecked on the reef; 10 men and a dog stranded on island. On 15 October 1838, the men sail to Honolulu, leaving the dog on the island (Woodward 1972).

1842 - 24 Sept. to May 1843 – The whaler U.S.S. *Parker* wrecked on reef and the crew lives on Green Island until rescued (Woodward 1972). The men killed 7,000 seafowl and ate the dog from the *Gledstanes*.

1859 - June to July – Remains of a wreck from China or Manila found on atoll (Brooks 1860, as cited in Woodward 1972).

1870 - 29 Oct. to 4 Jan. 1871 – Almost 1,000 'brown' albatrosses killed for food by crew of the U.S.S. *Saginaw* while shipwrecked on Green Island (Read 1912, as cited in Woodward 1972).

1881- 30 Dec. to 1 Jan. – British schooner *Ada* collected "plenty of bird eggs" (Hornell 1934, as cited in Woodward 1972).

1886 - 15 July – The vessel *Dunnottar Castle* wrecked on the reef leaving 29 men stranded on atoll. On 24 Jul, 7 men sail for Honolulu and the remaining 22 men ate turtles and seafowl until rescued; on 20 September the *Waialeale* takes possession of Green (Ocean) Island for King Kalakaua of Hawaii (Woodward 1972).

1898 - 7 July – Kure Atoll acquired by the U.S. as part of the Territory of Hawaii (Woodward 1972).

1915 - 28 Mar. – 1,500 birds (Munter 1915, as cited in Woodward 1972).

1923 - 17 to 22 Apr. – 300 breeding pairs (Wetmore, ms., as cited in Woodward 1972).

1957 - 9 Mar. – Tsunami hits atoll (Rice 1959, as cited in Woodward 1972).

1957 - 5 Jun. – 70-100 pairs estimated or 160 birds total; count of 42 nestlings and 10 unemployed birds, (Rice and Kenyon 1962a, Kenyon *et al.* 1958).

1958 - 9 May – 70 pairs estimated; about 50 chicks counted (Rice and Kenyon 1962a).

1960 - Construction of a Coast Guard radio (LORAN) station was begun June 1960 and continued until April 1961; 24 men were stationed on Green Island (Woodward 1972). 28 Mar. – 95 nesting pairs: 280 adults on island at one time; all nests seen counted and the number of adult birds present estimated; allowance was made for the estimated destruction or desertion of 10% of the nests prior to the date of the count. Kenyon and Rice (1962a) added 10% to their estimate, the same percentage of unemployed birds as had been found on Midway. Counts of nestlings and adults made in 1960 indicated that the percentage of adults present was considerably in excess of the numbers computed on the basis of an estimated 17% unemployed birds. The difference is believed due, at least in part, to an influx of non-nesting birds that are establishing territories for use in subsequent years. The 1960 estimates of total adult albatrosses were obtained by doubling the number of chicks, adding 10% for nest mortality, taking 10% of the resulting total as the number of nesting adults present on the island at any one time. The remaining 90% was added to the number of birds actually counted on the island on 28 March 1960; from this total was subtracted two-thirds of the number of adults whose nests were estimated to have been destroyed before the day of the count (Robbins 1966).

1961 - LORAN station consists of one third of the island covered by an airstrip, buildings and an aerial tower 625 feet high (Berger 1988); 19 to 21 January – 320+ birds 160 nesting pairs; 200 adults on island at one time (Robbins 1966). Robbins writes, "At the west tip of the island, where the biggest colony of Black-footed Albatrosses was located last year, we found only 23 nests and a total of 48 birds. Dredging away of the west point of the island to get sand for the west end of the runway apparently has disturbed this colony" (Robbins 1961).

1962 - 2 to 4 Feb. – 130+ birds; 65 nesting pairs; 100 adults on island at one time (Robbins 1966).

1963 - 3 to7 Feb. – 400+ birds; 200 nesting pairs estimated; 235 adults on island at one time (Robbins 1966); 178 nests actually counted; two dozen or so nests were destroyed in the December storm (Robbins 1963); 16 to 31 Dec. – 650 adults; POBSP highest semi-monthly estimate for 1963-1964 season (Woodward 1972).

1963 to 1964 – 42.6% breeding success (approximately 100 fledglings of 235 eggs) (POBSP, as cited in Woodward 1972).

1964 to 1965 – 43.2% breeding success (117 fledglings of 271 eggs) (POBSP, as cited in Woodward 1972).

1965 to 1966 – 45.5% breeding success (91 fledglings of 200 estimated eggs) (POBSP, as cited in Woodward 1972).

1966 to 1967 – 218 nestlings counted (Robbins, as cited in Woodward 1972).

1968 to 1969 – 43.8% breeding success (145 fledglings of 331 eggs) (POBSP, as cited in Woodward 1972).

1977 - 21 to 22 Dec. – 843 adults, including those on nests, attending mates, and walkers; accurate counts where possible, estimates for large colonies (Walker 1978).

1984 - 13 Mar. – low 100s of chicks (Fefer and Naughton unpubl. data).

1993 - Aug. to Sept. – Polynesian rats *Rattus exulans* eradicated from Green Island (Murphy, 1994).

1995 – 1,200 breeding pairs (E. Flint, USFWS unpubl. data/State of Hawaii unpubl. data, as cited in Gales 1998).

1997 – 1,653 breeding pairs; extrapolation to total eggs from chicks counted later in the season (assumes 75% reproductive success, E. Flint, USFWS unpubl. data); 13-17 Mar. – 1,240 chicks counted (Shallenberger 1997).

**2. Midway Atoll**

1859 - 8 Jul. – Captain N.C. Brooks of the Hawaiian bark *Gambia* discovers Midway (Berger 1988).

1867 - 28 Aug. – Captain William Reynolds of the U.S.S. *Lackawanna* takes possession of Midway under orders from the Secretary of the Navy (Berger 1988).

1870 - 24 Mar. to 28 Oct. – U.S.S. *Saginaw* attempts to blast and dredge a 600-foot wide shipping channel through the reef into the lagoon, but makes little progress (Bryan 1978).

1886 - 16 Nov. to 16 Mar. 1889 – the fishing schooner *General Siegel* wrecked, leaving seven men stranded (Adolph Jorgensen among them); the schooner *Wandering Minstrel* wrecked while trying to rescue them. The castaways were not rescued until fourteen months later (Bryan 1978).

1891 - Jul. – No birds seen on Sand Island (Munro 1942, 1943 as cited in McDermond and Morgan 1993); scarcity of vegetation and resultant continuous shifting of the sand probably prevented albatross from nesting (Bryan 1906, Hadden 1941 as cited in McDermond and Morgan 1993); Henry Palmer and George C. Munro are the first naturalists to visit Midway (Bryan 1978).

1902 - Feather poachers killed thousands of birds, with Black-footed Albatross carcasses outnumbering Laysan Albatrosses by roughly three to one on Eastern Island (Bryan 1906 as cited in McDermond and Morgan 1993).

1903 - 20 Jan. – Midway placed under the jurisdiction of the United States Navy Department (Bryan 1978); 29 Apr. – the Commercial Pacific Cable Company takes possession of Sand Island (Berger 1988).

1903 - Jan. to Spring 1908 – a detachment of U.S. Marines occupied Midway to protect the Cable Company from bird hunters (Bailey 1956, as cited in Berger 1988).

1906 - 1916? – For more than a decade, ship-loads of soil were transported from Honolulu (an estimated 9,000 tons total), and grass, shrubs, and hundreds of ironwood trees were planted (Bryan 1978, Berger 1988).

1923 - 23 to 24 Apr. – 2,000 pairs estimated; 1,000 pairs on Sand Island and 1,000 on Eastern Island (Wetmore, ms., as cited in Rice and Kenyon 1962a).

1935 - Sand Island becomes a stopover for Pan American Airways; an airport, hotel, warehouses, power plant, water tanks and other facilities were built (Bryan 1978).

Late 1930s - 30,000 birds estimated; presumably Sand Island only (Hadden 1941, as cited in Rice and Kenyon 1962a).

1940 - 29 Sep. – U.S. military Midway Detachment of 170 men begin installing defenses (Berger 1988).

1941 - 14 Feb. – Midway declared a national defense area by Executive Order (Berger 1988); Nov.- Dec. – Approximately 80,000 albatross of both species killed on Eastern Island by U.S. Marines (Kenyon *et al.* 1958).

1943 - Black rats *Rattus rattus* (also called ship or roof rats) accidentally introduced to Midway (Fisher and Baldwin 1946).

1945 - May – 35,000 birds on Sand Island, and 18,000 birds on Eastern Island, 53,000 total; estimates: "Nestlings were counted and the total number estimated by the density-times-area method. Two adults were allowed for each chick. A slight additional allowance was made for non-breeding adults, but this adjustment probably falls within the limits of error. Night counts were made on resting adults" (Fisher and Baldwin 1946).

1954 - Dec. – 7,700 nesting pairs on Sand Island, and 2,000 nesting pairs on Eastern Island, 9,700 total; estimates (DuMont and Neff 1955, as cited in Robbins 1966).

1956 - Nov. to May 1957 – about 800 chicks, at least 20% of the 3659 nestlings on Sand Island, and 25 adult Black-footed Albatrosses killed by construction (Kenyon *et al.* 1958).

1957 - Jan. to Feb. – 3,659 nests counted on Sand Island (a correction factor of 17% nest mortality from one small colony was applied to estimate 4,281 nests in early December 1956) and 1,669 nests were counted on Eastern Island on 27 Feb. and corrected to an estimated total of 2,286 nests early in the season (Rice and Kenyon 1962a).

1957 - 9 Mar. – Tsunami raises sea level by about 3 feet "and large waves flooded portions of the islands. In certain areas many young albatrosses were washed away or drowned, but the tide waters had little effect on the total number of young albatrosses" (Rice 1959).

1957 - 22 Apr. to 22 May – *c.* 100 adults and 1,371 chicks killed by U.S. Navy in Triangle area between runways on Sand Island (Kenyon *et al.* 1958); Triangle area cleared and flattened (Robbins 1966).

1957 - early Dec. – 6,188 nests counted on Sand Island Dec. 2-5 and 2,333 nests counted on Eastern Island on 9. Dec., total 8,521 (Rice and Kenyon 1962a).

1958 - 11 to 13 Jan. – An estimated 35% mortality of Black-footed Albatross nests occur on Sand Island due to flooding. "Twelve-foot breakers from Typhoon Ophelia pounded the beaches, breaching the dunes and flooding large areas inland" (Rice 1959).

1958 - 15 Jan. to 7 Mar. – 277 adults killed and all eggs removed from the Triangle area between runways on Sand Island (Robbins 1966).

1959 - 26 Nov. to 17 Mar. 1960 – albatross nesting areas adjacent to runways cleared and paved (Robbins 1966). Dec. – 1,435 nesting pairs on Sand Island and 1,400 nesting pairs on Eastern Island, 2,835 total; based on sample counts and estimates (Robbins 1966).

1960 - Dec. – 4,100 nesting pairs on Sand Island, and 2,750 nesting pairs on Eastern Island, 6,850 total; based on sample counts and estimates (Robbins 1966).

1961 - Dec. – 4,050 nesting pairs on Sand Island and 2,900 nesting pairs on Eastern Island, 6,900 total; based on sample counts and estimates (Robbins 1966).

1962 - summer – Triangle area between runways on Sand Island paved (Robbins 1966).

1963 - 21 Jan. – "There seems to have been more clubbing of birds this winter than any previous winter of which we have any record. I estimate that so far this winter close to 1000 birds have been maliciously clubbed and a high proportion of these are Black-footed Albatrosses in the two big Sand Island colonies that we have been studying" (Robbins 1963).

1963 - 19 Feb. – 31 adult birds (13 males and 18 females) killed by unknown vandal(s) on Sand Island (Robbins 1963).

1963 - Dec. – 2,700 nesting pairs on Sand Island, and 2,000 nesting pairs on Eastern Island, 4,700 total; based on sample counts and estimates (Robbins 1966).

1964 - 1 Feb. – "The Eastern Island dump has been moved to the NE point and probably has had some effect on the nesting population of Black-footed Albatrosses in that area as there seems to be a good sized area with no nesting Black-foots in the immediate vicinity of the dump" (Robbins 1964).

1979 - Feb. – 2,800-3,000 pairs estimated on Sand Island (Ludwig *et al.* 1979).

1981 - 82 – 7,500 pairs (Fefer *et al.* 1984).

1988 - Midway becomes an overlay refuge in cooperation with the U.S. Navy.
Apr. - Jul. – 7,000 - 10,000 breeding pairs estimated (Tyler 1988).

1991 - 10 Dec. to 30 Jan. – 19,757 breeding pairs; complete census of atoll (FWS unpubl. data).

1992 - 19,994 breeding pairs; estimated from 28 index plots (FWS unpubl. data).

1993 - Navy operations cease at Midway.

1994 - 1997 – Massive cleanup of atoll by U.S. Navy: fuel storage tanks, abandoned buildings, rubble, and contaminants removed; Black-footed Albatross colony displaced from Fuel Farm.

1994 - Rats eradicated from Eastern and Spit Islands (Murphy 1997a); Dec. -- 18,731 breeding pairs; complete census of atoll (Seto 1996).

1995 - Dec. – 19,255 breeding pairs; complete census of atoll (Seto 1996).

1996 - 22 May – The FWS, Department of the Interior, receives the federal transfer of Midway in its entirety for use as a National Wildlife Refuge. In June, rat eradication begins on Sand Island (Murphy 1997b); Dec. to 2 Jan. 1997 – 21,645 breeding pairs; complete census of atoll (Seto 1997).

1997 - Jun. – U.S. Navy leaves; Midway entirely under the jurisdiction of the U.S. Fish and Wildlife Service. In October the last rat found on Midway is caught on Sand Island (K. Niethammer, pers. comm.); Dec. – 20,490 breeding pairs; complete census of atoll (Seto 1998).

1998 - Dec. – 20,510 breeding pairs; complete census of atoll (E. Flint, FWS unpubl. data).

**3. Pearl and Hermes Reef**

1822 - 25 Apr. to Jun. – The English whaling ships, *Pearl* and *Hermes,* wreck and the crews survive for two months before being rescued by another ship (Bryan 1942 as cited in Amerson *et al.* 1974).

1882 – 19 to 21 Jan. – Americans from the chartered Japanese schooner *Ada* harvest 43 pounds of albatross down (Hornell 1934, as cited in Amerson *et al.* 1974).

1908 - Jul. to Jan. 1909 – Three Japanese were left on the atoll by a Japanese schooner and rescued the following January by the schooner *Florence Ward* (Thrum 1909, as cited in Amerson *et al.* 1974).

1913 - 15 Mar. – North Island: *c.* 300-350 chicks (Willett, ms., as cited in Amerson *et al.* 1974).

1916 - Feb. – Rabbits and signs of human habitation within the last year and a half, probably by Japanese fishermen, discovered on Southeast Island (Munter ms., as cited in Amerson *et al.* 1974).

1923 - 26 to 27 Apr. – Grass Island (27 Apr.): *c.* 800 pairs; Seal Island (27 Apr.): about 1,200 pairs; Southeast Island (26 Apr.): 1,000 pairs (Wetmore, ms., as cited in Rice and Kenyon 1962a); total (3 islands): 3,000 pairs.

1923 - May – *Tanager* Expedition kills all but one rabbit on Southeast Island (Wetmore, ms., as cited in Amerson *et al.* 1974).

1926 to 1931 Oct. – Fishing and mother-of-pearl harvesting operations conducted at the Reef; three buildings constructed on Southeast Island in 1929 or 1930 (Amerson *et al.* 1974).

1936 - Aug. to Oct. 1937 – U.S. Navy conducts exercises in Reef with base camps on Southeast Island (Amerson *et al.* 1974).

1942 - 19 Apr. – The old fishing buildings on Southeast Island bombed and burned to the ground as part of U.S. military training exercises (Amerson *et al.* 1974).

1942 – May to Jun. – The oiler U.S.S. *Kaloli,* the civilian yacht *Crystal*, and the minesweeper U.S.S. *Vireo* were deployed to Pearl and Hermes as part of Midway defenses (Morison 1949, as cited in Amerson *et al.* 1974).

1956 - 10 Dec. – Grass Island: 1,900 pairs; Kittery Island: 450 pairs; north sandspits (Little North Island?): 120 pairs; North Island: 1,900 pairs; Seal Island: 370; Southeast Island: 2,300 pairs; south sandspits (Bird and Sand Islets?): 63 pairs; aerial photographic surveys (Rice and Kenyon 1962a); total (7 islands?): 7,103 pairs.

1957 - 18 Dec. – "no significant change between 1956-1957 and 1957-1958" (Rice and Kenyon 1962a).

1958 - 11 to 13 Jan. – Typhoon Ophelia generates high storm tides; visual estimates from an aerial survey on 24 Jan. yield an estimated 43% mortality of Black-footed Albatross nests for all islands, with complete destruction of nests on Kittery and the North and South sand spits (Rice 1959).

1960 - An amphibious military operation from Midway lands on Southeast Island without permission, leaving a 15-foot steel observation tower, several 55-gallon drums full of fuel, and hollow tile blocks (Hawaii Division of Fish and Game 1961, as cited in Amerson *et al.* 1974).

1961 - Military personnel "engaged in plotting the exact location of Southeast Island landed by helicopter and camped for a few days" (Hawaii Division of Fish and Game 1961, as cited in Amerson *et al.* 1974).

1963 - Bird Island (5 Mar.): 40-50 birds roosting, none nesting; Grass Island (26-27 Jun.): 263 chicks counted; Kittery Island (26 Jun.): 124 chicks counted; Little North Island (23, 25 Jun.): 64+ chicks counted; North Island (23-25 Jun.): 751 chicks counted; Seal Island (26 Jun.): 97 chicks counted; Southeast Island (26 Feb.-8 Mar.): 5,000 adults, all with young (estimate may include chicks?), (18-23, 25 Jun.): 1,200 chicks counted (POBSP 1963, 1964, as cited Amerson *et al.* 1974); total (7 islands): 2,499+ pairs.

1964 - 14 Mar. – Bird Island: 14 chicks and 30 adults counted; Grass Island: 1,275 chicks, 3,000 adults; Kittery Island: 126 chicks and 300 adults counted; Seal Island: 275 chicks counted (including 10 dead); Southeast Island (13-14 Mar.): 2,500 chicks, many dead chicks, 5,000 breeders, 1,000 non-breeders (BSFW/ POBSP 1964, as cited in Amerson *et al.* 1974); total (5 islands): 4,190+ pairs.

1965 - 15 to 22 Mar. – Bird Island (22 Mar.): 5 birds roosting, none nesting; Grass Island (22 Mar.): 480 chicks, 800 adults; Kittery Island: (18 Mar.) 200-225 chicks, 400-500 adults; (22 Mar.) 180 chicks, 205 adults; Little North Island (18 Mar.): 16 chicks counted, 40-50 adults; North Island (17 Mar.): 500-600 chicks; Seal Island (22 Mar.): 41 chicks, 144 adults counted; Southeast Island (15-19 Mar.): 2,000 chicks, 4,000-5,000 adults; (21-22 Mar.): 1,250 chicks and 2,000 adults (BSFW/ POBSP 1965, as cited in Amerson *et al.* 1974); total (7 islands): 3,237+ pairs.

1967 - Bird Island (31 May): 19 chicks counted; Grass Island (22 Mar.): 1,503 chicks counted (including 37 dead); Kittery Island (31 May): 353 chicks counted; North Island (16-17 Mar.): 1150 $\pm$ 50 chicks counted; Seal Island (22 Mar.): 329 chicks counted (including 4 dead); Southeast Island (28, 30 May-1 Jun.): 1,971 chicks (BSFW/ POBSP 1967, as cited in Amerson *et al.* 1974, DeLong 1967); total (6 islands): 5,325+ pairs.

1968 - 22 to 24 Mar. – Grass Island (24 Mar.): 1,190 chicks counted (complete count); Kittery Island (24 Mar.): 228 chicks counted (complete count); Seal Island (24 Mar.): 219 chicks counted (complete count); Southeast Island (22-24 Mar.): 2,002 chicks counted (may have been some slight overlap between two survey parties covering the island) (Clapp 1968a); total (4 islands): 3,639 pairs.

1969 - Southeast Island: 1,478 chicks (31 Mar. to 2 Apr.); 1,964 chicks counted (26 to 31 May) (BSFW 1969, as cited in Amerson *et al.* 1974).

1974 - 14 Nov. – North Island: about 150 birds; Southeast Island: about 3,500 birds (Sekora 1974a).

1982 - 29 Apr. to 11 May – Bird Islands (30 Apr.): 1 chick, 1 adult; Grass Island (30 Apr., 4 May): 1,330 chicks; Little North Island (5 May): 0; North Island (5-7 May): 1,633 chicks; Sand Islet (30 Apr.): 0; Seal-Kittery Island (3-10 May): 1,063 chicks; Southeast Island (29 Apr. - 11 May): 2,184 chicks; direct counts; total (7 islands): 6,211 chicks (E. Flint, FWS unpubl. data).

1986 - 4 to 9 Jun. – Bird Islands (8 Jun.): 1 chick; Grass Islet (8 Jun.): 685 chicks (direct count); North Island (4 Jun.): 1,168 chicks (direct count); Seal-Kittery (8-9 Jun.): 327 chicks (direct count); Southeast Island (6 Jun.): 2,294 chicks (direct count) (FWS unpubl. data); total (5 islands): 4,475 chicks.

1987 - 5 to7 Jun. – Bird Islands (7 Jun.): 15 chicks; Grass Island (7 Jun.): 1,844 chicks (direct count); Little North Island (6 Jun.): 0; North Island (6 Jun.): "similar numbers to 1986" (D. McDermond unpubl. data); Sand Islet (7 Jun.): 0; Southeast Island (5-6 Jun.): 2,538 chicks (direct count) (FWS unpubl. data); total (6 islands): 5,565 chicks.

1988 - 1 to 3 Jul. – 3,366 chicks: all islands (direct count); "should be considered minimum count" (FWS unpubl. data).

1990 - 8 to 9 Jun. – Big Bird Island (8 Jun.): 18 chicks (direct count); Small Bird Island (8 Jun.): 0; Grass Island (9 Jun.): not counted; Little North Island (8 Jun.): 0; North Island (8 Jun.): 500 chicks ("crude estimate" by M. Morin); Sand Islet (8 Jun.): 0; Seal-Kittery Island (9 Jun.): not counted; Southeast Island (8 Jun.): not counted (FWS unpubl. data).

1996 - 17 May to 16 Jun. – Bird Island (16 Jun.): 14 chicks; Grass Island (16 Jun.): 349 chicks (includes 3 dead chicks); North Island (23 May): 1,438 chicks (includes 22 dead chicks); Seal-Kittery Island (25 May): 785 chicks (0 dead chicks); Southeast Island (17 May): 1,343 chicks (includes 9 dead chicks); all direct counts; total (5 islands): 3,929 chicks (including 34 dead chicks) (FWS unpubl. data); 5,220 pairs (E. Flint, FWS, as cited in Gales 1998).

1997 - 2 to15 Jun. – Bird Island (8 Jun.): 24 chicks (includes 1 dead chick); Grass Island (11 Jun.): 1,482 chicks (dead chicks not counted, but estimated at <25); Little North Island (14 Jun.): 5 chicks; North Island (14-15 Jun.): 1675 chicks (includes 13 dead chicks); Seal-Kittery Island (25 May): 2,387 chicks (dead chicks not counted, but estimated at <25); Southeast Island (17 May): 1,343 chicks (dead chicks not counted, but estimated at <25); all direct counts; total: 8,846 chicks (including 14 dead chicks) (FWS unpubl. data).

1998 - 6,949 breeding pairs; extrapolation to total eggs from chicks counted later in the season (assumes 75% reproductive success) (E. Flint, FWS unpubl. data).

**4. Lisianski Island**

1805 - 15 Oct. – the Russian exploring vessel *Neva*, captained by Urey Lisiansky, runs aground on the reef (Clapp and Wirtz 1975).

1844 - 12 Apr. to 14 Dec. – the wreck of the whaler *Holder Borden* leaves men stranded on the island for five months, until 14 September, when some of the crew sail to Honolulu in a rebuilt ship; they returned for the remaining eleven men on the first of November, finally departing on 14 December (Ward 1967, as cited in Clapp and Wirtz 1975).

1846 - 24 May – the whaler *Konohasset* wrecked; the captain and six crew members sail for Honolulu in mid-June in a sloop built from the wreckage; the rest of the crew were subsequently rescued (Ward 1967, as cited in Clapp and Wirtz 1975).

1872 - May – Sometime after 9 May, the German brig *Wanderer* goes aground on the reef; on 24 July, the *Kamehameha V* discovers evidence that the crew had lived on Lisianski for a time, but they were never found (Clapp and Wirtz 1975).

1891 - 29 Jun. to 7 Jul. – Henry Palmer and George C. Munro are the first naturalists to visit Lisianski (Clapp and Wirtz 1975).

1903 - 1 Jul. – At some time before this date, the U.S.S. *Iroquois* ordered a group of Japanese bird poachers to leave Lisianski (Clapp and Wirtz 1975).

1904 - 8 Jan. to 16 Jun. – Thirty-eight Japanese feather poachers were put ashore and eventually stranded; another Japanese ship dropped off an additional thirty-nine men in late February; the U.S. revenue cutter *Thetis* removed them in June, finding Black-footed Albatrosses among the birds killed (Hamlet, ms., as cited in Clapp and Wirtz 1975).

1904 - 1909 – Rabbits introduced sometime during this period (Clapp and Wirtz 1975).

1909 - Apr. to 19 Jan. 1910 – Ten Japanese harvest birds, mostly Bonin Petrels and Sooty Terns; on 21 August, they depart with their cargo and are replaced by another eight poachers; the U.S. revenue cutter *Thetis* removed them in January; their harvest included about one and a quarter tons of bird feathers and about 140,400 bird wings (Jacob, ms., as cited in Clapp and Wirtz 1975).

1913 - 12 Mar. – 600 breeding birds (Willett, ms., as cited in Clapp and Wirtz 1975).

1915 - 24 Mar. – 8,000 birds (Munter, 1915, as cited in Clapp and Wirtz 1975).

1915 - Mar. to Feb. 1916 – The extinction of the rabbits occurred sometime within this period (Clapp and Wirtz 1975).

1923 - 15 to 20 May – 2,000 breeding birds (Wetmore, ms., as cited in Clapp and Wirtz 1975).

1954 - 26 Mar. – 4,000 breeding birds; approximately 2,000 chicks (Richardson, pers. comm., as cited in Clapp and Wirtz 1975).

1957 - 7 Jan. – 3,665 birds total counted by aerial photographic survey; 2,749 breeding pairs estimated based on the assumption that 25% of the birds counted were unemployed birds (i.e., non-breeding), as was the case on Midway during ground surveys (Rice and Kenyon 1962a).

1957 - 28 Dec. – 3,490 birds total counted by aerial photographic survey; 2,618 breeding pairs estimated based on the assumption that 25% of the birds counted were unemployed birds (i.e., non-breeding), as was the case on Midway during ground surveys (Rice and Kenyon 1962a).

1964 – 11 to 12 Mar. – 3,000-4,000 breeding birds; 1,500-2,000 chicks (BSFW/ POBSP, as cited in Clapp and Wirtz 1975).

1965 – 12 to 14 Mar. – 2,000-3,600 breeding birds; 1,000-1,800 chicks (POBSP, as cited in Clapp and Wirtz 1975).

1966 – 16 to 19 Jun. – 993 chicks counted; an estimated 1,000 present (POBSP, as cited in Clapp and Wirtz 1975).

1967 - 2 to 6 Jun. – 1,161 chicks counted; an estimated 1,200 present (POBSP, as cited in Clapp and Wirtz 1975).

1968 - 20 to 21 Mar. – 1,500-2,000 breeding birds (BSFW, POBSP, as cited in Clapp and Wirtz 1975).

1974 - 4 Nov. – Roughly 5,000 birds (Sekora 1974b).

1977 – The Liberian tanker *Irenes Challenge* sinks and spills 10.4 million gallons of crude oil 50 miles north of the island; effect on wildlife unknown, although many birds were oiled (Steiner and Townsend 1997).

1979 - 12 to 13 May – 1,891 chicks counted (USFWS unpubl. data).

1980 - 6 May – 19,836 breeding birds estimated; 59,508 total. All chicks were counted in thirty 5m x 100m quadrats. The quadrats were located by systematically sampling every other quadrat along randomly selected transect lines. The average density obtained from the sample counts (9.6) was multiplied by the total number of quadrats inhabited by the species (740) and a correction factor of the egg and chick mortality (Woodward 1972) was incorporated to calculate a breeding bird estimate. The total bird estimate was determined by correcting the breeding bird estimate for the percent of the population not breeding each year (Rice and Kenyon 1962a).

1982 - 17 to 18 Apr. – 2,109 chicks, direct count (E. Flint, FWS unpubl. data); 2,800 pairs (E. Flint, FWS unpubl. data, as cited in Gales 1998).

1986 - 30 May to 2 Jun. – 1,316 breeding pairs; direct beach perimeter count (Hu 1986).

1997 – 3,577 breeding pairs; extrapolation to total eggs from chicks counted later in the season (assumes 75% reproductive success) (E. Flint, FWS unpubl. data).

1998 - 5 May – 6,949 breeding pairs; extrapolation to total eggs from 5,212 chicks counted (assumes 75% reproductive success) (A. Pairis, NMFS unpubl. data).

1999 - 5 May – 2,901 breeding pairs; extrapolation to total eggs from 2,176 chicks counted (assumes 75% reproductive success) (A. Pairis, NMFS unpubl. data).

**5. Laysan Island**

1828 - Mar. 24 – First recorded discovery, by the Russian ship *Moller*, although actual discovery occurred in the early 1820s by a New England whaling ship, the *Wilmington and Liverpool Packet* (Ely and Clapp 1973).

1890 - Feb. to 16 Jul. – George D. Freeth leaves two men on Laysan to hold possession and then secures rights from the Hawaiian Kingdom to mine phosphate deposits before returning to Laysan (Ely and Clapp 1973).

1890 - Nov. to May 1904 – The North Pacific Phosphate and Fertilizer Company mines guano; the operation used about forty Japanese laborers and mule-drawn carts on a narrow-gauge railway; 1,017 tons were removed in the first year of operation (Thomas, ms., Bryan 1942, as cited in Ely and Clapp 1973).

1903 - 1923 – European rabbits *Oryctolagus cuniculus* introduced by Max Schlemmer virtually devegetate the island, leading to the extinction of the Laysan Rail (*Porzana palmeri*), Millerbird (*Acrocephalus familiaris*) and the Laysan Honeycreeper (*Himatione sanguinea*) (Berger 1988); from Dec. 21, 1912, until Mar. 11, 1913, a four-man U.S. Bureau of Biological Survey party kills 5,024 rabbits, an estimated two-thirds of the population (Salisbury, ms., as cited in Ely and Clapp 1973); the 1923 Tanager Expedition finally exterminates the rabbits (Ely and Clapp 1973).

1904 - to May 1910 – The Pacific Guano and Fertilizer Company sells everything on Laysan, except the buildings, to Max Schlemmer, who continued mining until 1910 (Ely and Clapp 1973).

1908 - 1910 – Max Schlemmer illegally sponsors Japanese feather-harvesting; from 13 April 1909 to 16 January 1910, approximately two and one-quarter tons of feathers and 310,600 wings were harvested before the 15 Japanese were arrested by the U.S. Revenue Cutter *Thetis*; Schlemmer and the Japanese were tried in Honolulu, but were found not guilty (Jacobs, ms., as cited in Ely and Clapp 1973).

1911 - 24 Apr. to 5 Jun. – 85,000 breeding adults; based on nest density and colony area computations (Dill and Bryan 1912, as cited in Ely and Clapp 1973).

1913 - Feb. – 15,444 breeding adults; 7,506 occupied and 216 abandoned nests counted (Bailey 1952, as cited in Ely and Clapp 1973).

1915 - Jan. – Feather poachers kill 150,000 to 200,000 birds, chief among them Laysan Albatross, followed by Black-footed Albatross (Munter 1915, as cited in Ely and Clapp 1973).

1915 - 3 Apr. – 20,000 breeding pairs (Munter 1915, as cited in Ely and Clapp 1973).

1915 - 12 Jul. to 2 Dec. – Max Schlemmer and two other men live on Laysan, pickling 350 albatross eggs (Ely and Clapp 1973).

1923 - 9 to 13 Apr., and 2-14 May – 18,800 breeding adults; breeding population prior to estimated mortality from windstorm at end of April; 4,700 chicks, based on count (Wetmore, ms., as cited in Ely and Clapp 1973).

1951 - late Jun. to early Jul. – 36,480 breeding adults; estimate from transect censuses of *c.* 18,240 (Brock 1951, as cited in Ely and Clapp 1973).

1957 - 7 Jan. – 42,837 birds total counted by aerial photographic survey; 32,128 breeding pairs estimated based on the assumption that 25% of the birds counted were unemployed birds (i.e., non-breeding), as was the case on Midway during ground surveys (Rice and Kenyon 1962a).

1957 - 28 Dec. – 44,697 birds total counted by aerial photographic survey; 33,523 breeding pairs estimated based on the assumption that 25% of the birds counted were unemployed birds (i.e., non-breeding), as was the case on Midway during ground surveys (Rice and Kenyon 1962a).

1958 - 27 May to 4 Jun. – 8,700 chicks estimated (Warner, ms., as cited in Ely and Clapp 1973).

1963 - 3 to10 Dec. – 38,666 birds; extrapolation from several 50x100 ft. census plots in each habitat type: the figures for each block were averaged for each type of habitat and multiplied times the total acreage of each habitat (Walker 1964).

1964 - 10 to 11 Mar. – 37,000- 42,000 birds estimated; *c.* 10,700 chicks on outer beach, less than 1,000 elsewhere (BSFW/ POBSP, as cited in Ely and Clapp 1973).

1965 - 6 to 11 Mar. -- 30,000- 45,000 breeding birds estimated; *c.* 10,000 to 15,000 chicks (POBSP, as cited in Ely and Clapp 1973).

1966 - 26 to 31 Mar. – 10,000 chicks estimated (Crossin 1966).

1967 - 18 to 19 Mar. – 10,000- 20,000 breeding pairs estimated (BSFW/ POBSP, as cited in Ely and Clapp 1973).

1968 - 17 to 19 Mar. – 5,000-10,000 chicks (estimate by E. Kridler) (Clapp 1968b).

1969 - 26 to 29 Mar. – Estimate of 14,694 chicks based on 159 transect censuses (BSFW, as cited in Ely and Clapp 1973).

1979 to 1980 – 21,000 pairs (Fefer *et al.* 1984).

1980 - 1 to 2 April – 12,569 chicks estimated. Chicks counted in 300x16 ft. quadrats regularly spaced along randomly selected transect lines. The counts were stratified according to vegetation: bare sand and vegetated. The density calculated in the census areas was multiplied by the total area of vegetation or bare sand on Laysan Island (FWS unpubl. data).

1988 - May – Hawaiian Monk Seal researchers notice an area approximately 10 square meters with dead crabs, flies and albatross chicks and dubbed the area the "Dead Zone."

1991 - 24,352 breeding pairs estimated (Bauer and Gauger 1994); 25,109 ± 7,766 eggs (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data); samples collected from the "Dead Zone" are analyzed and found to contain an insecticide called carbofuran.

1992 - 15 to 17 Dec. – 29,559 breeding pairs estimated from 263 nests counted in 121 5x100 m quadrats sampled along transects (Rogers and Schauffler 1993); 29,558 ± 16,566 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data).

1993 - 11 to 12 Dec. – 29,617 breeding pairs estimated from 482 nests counted in 106.23 5x100 m quadrats sampled along 19 transect lines, 330 m apart (Bauer and Gauger 1994); 32,414 ± 12,143 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data).

1995 – 15 to 16 Jan. – 24,163 breeding pairs estimated from 5x100 m quadrats sampled along 19 transect lines (Boswell and Keitt 1995); 22,805 ± 5,166 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data).

1995 -12 to 19 Dec. – 24,346 breeding pairs estimated from 413 nests counted in 5x100 m quadrats sampled along 19 transect lines (Leroux *et al.* 1996); 24,813 pairs (E. Flint, FWS unpubl. data, as cited in Gales 1998); 24,813 ± 10,201 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data).

1996 - 16 to 17 Dec. – 26,723 breeding pairs estimated from 811 nests counted in 220 5x100 m quadrats sampled along 39 transect lines (Bernard *et al.* 1997); 26,723 ± 6,520 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (FWS unpubl. data).

1997 - 10 to 16 Dec. – 22,314 nests by direct count; 24,519 ± 6,200 (mean ± 95% C.I.) eggs estimated by quadrat sampling method (E. Flint, FWS unpubl. data); (8-9 Dec.) 24,520 ± 6,201 pairs estimated from 747 nests counted in 212 5x100 m quadrats sampled along 38 transect lines (Depkin *et al.* 1998).

1998 - 12 Dec. to 14 Jan. 1999 – 23,297 nests by direct count; (15-18, 21 Dec. 1998) 27,472 ± 7,375 (mean ± 95% C.I.) estimated from 820 nests counted in 229 measured 5x100m quadrats sampled along 38 transect; a storm washed out many nests around the lake between these two surveys; (2-3 Jan. 1999) 29,140 ± 7,415 nests estimated from 836 nests counted in 223 paced 5x100m quadrats sampled along 38 transect lines (Bradley *et al.* 1999).

## 6. French Frigate Shoals

1786 - 6 Nov. – French Frigate Shoals discovered by French explorer Jean Francois de Galaup, Comte de la Perouse (Amerson 1971).

1859 - 4 Jan. – The Unitied States took formal possession of French Frigate Shoals under the U.S. Guano Act of August 1856.

1859 - 13 Mar. – the whaling ship *South Seaman* wrecked; 30 or so crewman were left for an unspecified time on one of the islands until they were rescued (Amerson 1971).

1867 - 14 Apr. – the bark *Daniel Wood* wrecked; 27 crewman were left for an unspecified time on one of the islands until they were rescued (Amerson 1971).

1882 - 3 Feb. to 1 May – the Japanese-owned, American-chartered schooner *Ada* collects cargo of bird down, among other items (Amerson 1971).

1891 - 30 May to 5 Jun. – Henry Palmer and George C. Munro make the first biological survey of French Frigate Shoals (Walker 1909, as cited in Amerson 1971).

1915 - Mar. – East Island: 400 birds, nesting (Munter 1915, as cited in Amerson 1971).

1923 - 22 to 26 Jun. – East Island (22-23 Jun.): 75 chicks; Little Gin Island (24 Jun.): 150 chicks, a number of dead young; Round Island (22 Jun.): 90 chicks; Skate Island (26 Jun.): 30 chicks; Trig Island (26 Jun.): 50 chicks; Whale Island (26 Jun.): 90 chicks (Wetmore, ms., as cited in Amerson 1971).

1923 - 24 to 28 Jun. – Tern Island: 8 chicks (Wetmore, ms., as cited in Amerson 1971).

1935 - Sept., Nov. to Oct.-Nov. 1936 – a wooden cook shed and a "tent city", covering most of East Island, supported Naval training exercises (Amerson 1971).

1942 to 1943 – The Navy constructed an airfield on Tern Island to act as a refueling station between Pearl Harbor and Midway Atoll. The Navy operated the airfield until 1946 when it was abandoned in place.

1946 - 1 Apr. – Tidal wave completely inundates the islands in the atoll; effect on nesting wildlife unknown (Amerson 1971).

1949 - Spring – East Island; 60+ birds, few adults, many chicks (U.S. Coast Guard Headquarters Photo 30154912, as cited in Amerson 1971); 80+ birds, few adults, many chicks (Photo by Henry 1949, as cited in Amerson 1971).

1949 - Fall – 100+ nests (Wilder 1949, as cited in Amerson 1971).

1952 - 31 Jan. – The U.S. Coast Guard renovated a portion of Tern Island to serve as a Long Range Aid to Navigation (LORAN) station. Subsequent renovations of Tern Island and bird hazing procedures were done by the U.S. Coast Guard to continue the mission of the LORAN station. The LORAN station was decommissioned in 1979.

1953 - 31 Oct. – Round Island: 20 adults present (Richardson pers. corr., as cited in Amerson 1971).

1953 - 18 to 19 Dec. – Tern Island: 6 nests (Richardson, 1954, as cited in Rice and Kenyon 1962a).

1953 - 19 Dec. – East Island: 200 nests; Gin Island: 300-400 nests; Little Gin Island: 14 nests (according to Amerson, it is possible that Richardson reversed the numbers for Gin and Little Gin); Trig Island: 200 nests; Skate Island: 400 nests; Whale Island: 400 nests (Richardson 1954, 1957, as cited in Amerson 1971).

1954 - Jan. – Tern Island: nests destroyed by very high waves (Richardson 1954, as cited in Amerson 1971).

1956 - 11 to 21 Feb. – Tern Island: few present, but not nesting (Svilha 1957, as cited in Amerson 1971).

1957 - 28 Dec. – Aerial survey – Disappearing Island: 2 pairs; East Island: 170 pairs; Gin Island: 3 pairs; Little Gin Island: 340 pairs; Round Island: 12 pairs; Trig Island: 130 pairs; Whale Island: 840 nests; Tern Island: 2 nests, Amerson (1971) suggests that they "could have over-counted..., since one can see and distinguish flying Great Frigatebirds in their photographs, but one cannot distinguish those on the ground from Black-footed Albatross"; counts from aerial photographs reduced by 25% to allow for unemployed birds, and rounded to two significant digits (Rice and Kenyon 1962a).

1960 - 13 Apr. – East Island: 150 birds; no count of chicks possible; count taken from plane; Tern Island: 0 with one pair reported nesting earlier that winter (HDFG 1960, as cited in Amerson 1971).

1963 - 7 to 15 Jun. – East Island (7-11 Jun.): 420 chicks; Little Gin Island (9 Jun.): 17 chicks; Trig Island (14, 15 Jun.): 39 chicks; Whale-Skate Island (12-15 Jun.): 390 chicks (POBSP 1963, as cited in Amerson 1971).

1965 - 25 Aug. – Little Gin Island: two dead chicks (POBSP 1965, as cited in Amerson 1971).

1965 - 19 Nov. – Tern Island: 6 adults, no nests (Park pers. corr., as cited in Amerson 1971).

1966 - 22 to 23 Mar. – East Island (23 Mar.): 547 chicks, 661 adults; Little Gin Island (23 Mar.): 252 chicks, 78 adults; Trig Island (22 Mar.): 11 chicks; Whale-Skate Island (22 Mar.): 528 chicks, 219 adults; Tern Island (21 Mar.): 10 (chicks?) (BSFW, 1966, as cited in Amerson 1971).

1966 - 10 Jun. to 4 Jul. – East Island (10-14, 16-21 Jun.): 550 chicks, 25+ adults; Trig Island (10, 23 Jun., 1, 3-4 Jul.): 20 chicks, 2 adults; Whale-Skate Island (10, 23-29 Jun., 1-3 Jul.): 300 chicks, 25 adults (POBSP 1966, as cited in Amerson 1971).

1967 - 11 to 14 Mar. – East Island (11-12 Mar.): 772 chicks; Trig Island (13 Mar.): 51 chicks, 38 adults; Whale-Skate Island (14 Mar.): 431 chicks (BSFW, 1967, POBSP 1967, as cited in Amerson 1971).

1967 - 26 May to 20 Jun. – East Island (26-31 May, 9-13 Jun.): 500 chicks, 50 adults; Little Gin Island (9 Jun.): 75 chicks, 25 adults; Trig Island (2, 8-9, 19-20 Jun.): 34 chicks, 10 adults; Whale-Skate Island (2-7, 15-19 Jun.): 300 chicks, 30 adults (POBSP 1967, as cited in Amerson 1971).

1967 - 7 Dec. – Tern Island: 7 nests (BSFW 1967, as cited in Amerson 1971).

1967 - 9 Dec. – East Island and Little Gin Island: several hundred adults; Trig Island: large number; Whale-Skate Island: 800-1,000 adults; all islands surveyed from helicopter (BSFW 1967, as cited in Amerson 1971); Kridler (pers. corr., as cited in Amerson 1971) suggests that the "1967 population figure might be just a little high because these birds were mixed up with the the frigatebirds."

1968 - 29-30 May to 27 Jun. – Tern Island: 6 adults, 4 chicks (POBSP 1968, as cited in Amerson 1971).

1968 - 6 to 25 Jun. – East Island (6-11, 14-16, 25 Jun.): 600+ chicks, 1200+ adults; Little Gin Island (7 Jun.): 23 chicks, 86 adults; Trig Island (6, 11, 24-25 Jun.): 30 chicks, 60 adults; Whale-Skate Island (6, 16, 17-25 Jun.): 300+ chicks, 600+ adults (POBSP 1968, as cited in Amerson 1971).

1969 – 22 to 24 Feb. – Trig Island (22 Feb.): 56 chicks, 112 adults; Whale-Skate Island (23 Feb.): 494 chicks, 700-800 adults; Tern Island: 4 adults, 2 chicks (BSFW 1969, as cited in Amerson 1971).

1969 - 3 to 24 Jun. – East Island (5-10, 21 Jun.): 800 chicks, 1600+ adults; Little Gin Island (7, 21 Jun.): 125+ chicks, 25 adults; Trig Island (3, 14, 23-24 Jun.): 80 chicks, 160 adults; Whale-Skate Island (3, 16-20, 22 Jun.): 550+ chicks, 1,100+ adults (POBSP 1969, as cited in Amerson 1971).

1969 - 1 Dec. – Large swells caused by a distant storm completely inundated and severely damaged Tern Island, and presumably the other islands in the atoll; effect on nesting wildlife unknown (Amerson 1971).

1977 - East Island (19 Feb.): 450 chicks counted; Gin and Little Gin Islands: no count taken; Trig Island (19 Feb.): 17 chicks counted; Whale-Skate Island (19 Feb.): 300 chicks counted; Tern Island (19 Mar.): 17 chicks counted; 784 pairs, minimum total for atoll (FWS unpubl. data).

1979 - 8 to 20 May – East Island: 500 chicks estimated; Gin Island: 246 chicks counted; Little Gin Island: 0 chicks counted; Trig Island: 92 chicks counted; Whale-Skate Island: 880 chicks counted; Tern Island: 14 chicks counted; 1732 pairs, minimum total for atoll (FWS unpubl. data).

1979 - Dec. – Tern Island: 82 eggs counted (Schulmeister 1980). LORAN station is decommissioned.

1980 - East Island (29 Dec. 1979): 2,500 nests estimated (approaching storm prevented direct count); Gin Island: no data; Little Gin Island (10 Mar. 1980): 103 chicks counted; Trig Island (11 Dec. 1979): 111 eggs counted; Whale-Skate Island (22 Dec. 1979): 1,130 eggs counted; Tern Island (16 Dec.1979): 82 (Schulmeister 1980); 3,926 pairs, minimum total for atoll (FWS unpubl. data).

1981 - East, Gin Islands: no data; Little Gin Island (2 Feb.): 12 nests counted (most nests destroyed around 19 Jan. by large waves); Trig Island (11 Jan.): 66 nests counted; Whale-Skate Island (11 Jan.): 1,076 nests counted; Tern Island (Dec. 1980): 96 nests counted; 1,250 pairs, minimum total for atoll (FWS unpubl. data).

1982 - East Island (23 Jan.): 1,970 nests counted; Gin, Little Gin Islands: no data; Trig Island (31 Jan.): 75 chicks counted; Whale-Skate Island (31 Jan.): 1,172 nests counted; Tern Island (12 Dec.1981): 149 nests counted; 3,366 pairs, minimum total for atoll (FWS unpubl. data).

1983 - East Island (14 Dec. 1982): 2,167 nests counted; Gin Island (13 May 1983): 0 chicks counted; Little Gin Island (7 May 1983): 199 chicks counted; Trig Island (14 Dec. 1982): 77 nests counted; Whale-Skate Island (14 Dec. 1982): 1,408 nests counted; Tern Island (16 Dec. 1982): 193 nests counted; 4,214 pairs, minimum total for atoll (FWS unpubl. data).

1984 - 28 Dec.1983: East Island: 2,007 nests counted; Little Gin Island: 206 nests counted; Trig Island: 81 nests counted; Whale-Skate Island: 2,046 nests counted; Tern Island: 221 nests counted; 4,561 pairs, total for atoll (FWS unpubl. data).

1985 - East Island (29 May to 5 Jun. 1985): 1,536 chicks counted; Gin Island (23 Mar.): 0 chicks counted; Little Gin Island (23 Mar.): 183 chicks counted; Trig Island (5 Jun.): 63 chicks counted; Whale-Skate Island (9 Feb.): 797 nests counted; Tern Island (31 Dec. 1984): 292 nests counted; 3,637 pairs, minimum total for atoll (FWS unpubl. data).

1986 - Large swells washed away approximately 480 albatross nests (species not specified) from all islands on 9-10 Dec. 1985; more large swells on 20 Dec. destroyed virtually all nests on the north side of Tern Island. East Island (28 Dec. 1985): 1,823 nests counted; Gin Island (13 Feb.): 0 chicks counted; Little Gin Island (28 Dec. 1985): 120 nests estimated; Trig Island (28 Dec. 1985): 0 nests counted; Whale-Skate Island (28 Dec. 1985): 576 nests counted; Tern Island (30 Nov. 1985): 304 nests counted; 2,823 pairs, minimum total for atoll (FWS unpubl. data).

1987 - East Island (14 Dec. 1986): 2,541 nests counted; Gin Island (8 Jun.): 0 chicks counted; Little Gin Island (7 Jun.): 82 chicks counted; Trig Island (14 Dec. 1986): 125 nests counted; Whale-Skate Island (14 Dec. 1986): 1,844 nests counted; Tern Island (18 Dec. 1986 - 20 Jan. 1987): 448 nests counted; 5,067 pairs, minimum total for atoll (FWS unpubl. data).

1988 - East Island (10 Mar. 10): 1,660 chicks counted; Gin Island (22 April) 0 chicks counted; Little Gin Island (22 April): 190 chicks counted; Trig Island (April 10): 31 chicks counted; Whale-Skate Island (4 Mar.): 1,190 chicks counted; Tern Island (24 Dec. 1987 to 16 Jan. 1988): 451 nests counted; 4,535 pairs, minimum total for atoll (FWS unpubl. data).

1989 - East Island (9 Dec. 1988): 2009 nests counted; Gin Island (11 April) 0 chicks counted; Little Gin Island (11 April): 146 chicks counted; Trig Island (9 Dec. 1988): 15 – 25 eggs scattered on beach after storm of 5-7 Dec. 1988; Whale-Skate Island (9 Dec. 1988): 1,735 nests counted; Tern Island (20 Dec. 1988): 516 nests counted; 4,501 pairs, minimum total for atoll (FWS unpubl. data).

1990 - East Island (3 Jan.): 2,118 nests counted; Gin Island (8 May) 0 chicks counted; Little Gin Island (8 May): 206 chicks counted; Trig Island (4 Jan.): 87 nests counted; Whale-Skate Island (4 Jan.): 1,473 nests counted; Tern Island (20 Dec. 1989): 618 nests counted; 4,588 pairs, minimum total for atoll (FWS unpubl. data).

1991 - East Island (14 Jan.): 1,853 nests counted; Gin Island (9 April): 0 chicks counted; Little Gin Island (9 April): 179 chicks counted; Trig Island (17 Jan.): 38 nests counted; Whale-Skate Island (17 Jan.): 1,148 nests counted; Tern Island (20 Dec. 1990): 691nests counted; 3,960 pairs, minimum total for atoll (FWS unpubl. data).

1992 - East Island (4 Jan.): 2,052 nests counted; Little Gin Island (14 Mar.): 160 chicks counted; Trig Island (10 Jan.): 12 nests counted; Whale-Skate Island (10 Jan.): 556 nests counted; Tern Island (22 Dec. 1991): 767 nests counted; 3,608 pairs, minimum total for atoll (FWS unpubl. data).

1993 - East Island (12 Jan.): 1,974 nests counted; Gin Island (18 Jan.): 1 nest counted; Little Gin Island (14 Dec. 1992): 238 nests counted; Trig Island (10 Dec. 1992): 66 nests counted; Whale-Skate Island (11 Jan.): 643 nests counted; Tern Island (24 Dec. 1992): 895 nests counted; 3,817 pairs, minimum total for atoll (FWS unpubl. data).

1994 - East Island (10 Jan.): 1,838 nests counted; Gin Island (14 Feb.): 2 chicks counted; Little Gin Island (10 Jan.): 204 nests counted; Trig Island (9 Jan.): 36 nests counted; Whale-Skate Island (9 Jan.): 818 nests counted; Tern Island (23 Dec. 1993): 918 nests counted; 3,816 pairs, minimum total for atoll (FWS unpubl. data).

1995 - 27 Dec. to 12 Jan. 1996 – 2,742 breeding pairs (E. Flint, FWS, unpubl. data, as cited in Gales 1998); East Island (27 Dec. 1994): 1,881 nests counted; Gin Island (16 Jan.): 2 nests counted; Little Gin Island (16 Jan.): 195 nests counted; Trig Island (27 Dec. 1994): 10 nests counted; Whale-Skate Island (21 Dec. 1994): 158 nests counted (Whale-Skate Island is noted to be eroding rapidly); Tern Island (11-23 Dec. 1994): 1,034 nests counted; 3,280 pairs, minimum total for atoll (FWS unpubl. data).

1996 - High surf washed over Little Gin Island, causing many nests to fail (i.e., 43 scattered abandoned eggs) (Staff 1996). East Island (5 Jan.): 1,587 nests counted; Gin Island (12 Jan.): no nests noted; Little Gin Island (12 Jan.): 18 nests counted; Trig Island (5 Jan.): 10 nests counted; Whale-Skate Island (5 Jan.): 97 nests counted; Tern Island: 1,048 nests counted; 2,760 pairs, minimum total for atoll (FWS unpubl. data).

1997 - East Island (9 Jan.): 1,750 nests counted; Gin Island (11 Jan.): 2 nests counted; Little Gin Island (11 Jan.): 241 nests counted; Whale-Skate virtually gone (~1 acre) (E. Flint, unpubl. data); Trig Island (11 Jan.): 24 nests counted; Tern Island (23 Dec. 1997): 1,304 nests counted; 3,321 pairs, minimum total for atoll (FWS unpubl. data).

1998 - East Island (27 Dec. 1997): 2,007; Trig Island (3 Jan.): 438; Little Gin Island (27 Dec. 1997): 220; Gin Island (27 Dec. 1997): 2; Tern Island (26 Dec. 1997): 1,519 nests counted; 4,186 active nests counted for atoll (Dec. 1997) (E. Flint FWS unpubl. data).

1999 - East Island: 2,028 eggs (23 Dec. 1998), 1,290 chicks (3 June 1999); Trig Island: 461 eggs (23 Dec. 1998), 50 chicks (4 June 1999); Little Gin Island: 181 eggs (23 Dec. 1998), 128 chicks (3 June 1999); Gin Island: 1 egg (23 Dec. 1998), 1 chick (3 June 1999); Tern Island: 1,493 nests counted (23 Dec. 1998), 581 chicks fledged; 4,164 active nests counted for atoll (Dec. 1998) (E. Flint FWS unpubl. data).

**8. Necker Island**

?? - Evidence of prehistoric Polynesian inhabitation, possibly dating to before the thirteenth century (Emory 1928, as cited in Clapp and Kridler 1977).

1802 - Dec. – First documented historical landing (Bryan, Jr. 1942, as cited in Berger 1988).

1894 - 27 May – Necker annexed by Hawaii (Berger 1988).

1916 - 11 Feb. – several hundred individuals; island estimate, with eggs or very young chicks (Munter, ms., as cited in Clapp and Kridler 1977).

1923 - 17-20 Jun. – 200 breeding adults; based upon an island count of approximately 100 chicks (Clapp and Kridler 1977).

1953 - 20 Dec. – 200-300 nesting birds (only about half of the island seen during the survey) (Richardson, pers. comm., as cited in Clapp and Kridler 1977).

1957 - 28 Dec. – 491 birds total counted by aerial photographic survey; 368 breeding pairs estimated based on the assumption that 25% of the birds counted were unemployed birds (i.e., non-breeding) birds, as was the case on Midway during ground surveys (Rice and Kenyon 1962a).

1965 - 15 Mar. – 375-400 birds; 94 young counted; 100 estimated present (POBSP, as cited in Clapp and Kridler 1977).

1967 - 10 Mar. – 75 birds; approximately 25-30 young seen (POBSP, as cited in Clapp and Kridler 1977).

1969 - 22 Mar. – 350; estimated number of breeding birds; 175 young counted, no more than 10 or 15 missed (BSFW, as cited in Clapp and Kridler 1977).

1979 - May – 164 chicks direct count (S. Conant, FWS unpubl. data).

1984 - 28 Jun. to 2 Jul. – 35+ breeding pairs; number of near fledging chicks and carcasses recorded (Fefer 1984).

1986 - 21 May – 288+ breeding pairs (Hu 1986).

1987 - 19 May – 259+ breeding pairs; direct count of chicks (Hu 1987).

1988 - 13 Jun. – 166+ breeding pairs; direct count (McDermond 1988).

1995 - 26 Jun. – 112 breeding pairs; extrapolation to total eggs from chicks counted later in the season (assumes 75% reproductive success), based on count of 84 chicks (Marks 1995).

**9. Nihoa Island**

?? - Evidence of prehistoric Polynesian inhabitation, possibly dating to before the thirteenth century; permanent population may have been about 100 people (Emory 1928, as cited in Clapp *et al.* 1977).

1822 - First modern landing, annexed for the Kingdom of Hawaii (Bryan 1978).

1857 - 23 Apr. – King Kamehameha IV landed and took possession of Nihoa for Hawaii (Bryan 1978).

1885 - 2 Jul. – Over 200 people, including Princess Liliuokalani and Sanford Dole, land; a fire breaks out, consuming much of the island's vegetation (Bishop 1885, as cited in Clapp *et al.* 1977).

1915 - 18 Mar. – 500 birds (Munter 1915, as cited in Clapp *et al.* 1977).

1923 - 11 to 16 Jun. – 120 breeding birds; 60 chicks counted, 3 adults (Wetmore, ms., as cited in Clapp *et al.* 1977).

1957 - 28 Dec. – ca. 100 breeding birds; a rough estimate of 50 nests was made with 7 x 50 binoculars from the open hatch of an airplane (Rice and Kenyon 1962a).

1961 - 9 to 16 Dec. – 50 breeding birds (Kramer, ms., as cited in Clapp *et al.* 1977).

1964 - 6 to 7 Mar. – 120-130 breeding birds; 50 chicks banded, possibly 5 or 10 more present (Clapp *et al.* 1977).

1965 - 13 to 14 Mar – 80-90 breeding birds; 35 chicks banded, about 10 or 15 more present (Clapp *et al.* 1977).

1968 - 7 to 9 Mar. – 120-124 breeding birds; 60 chicks counted (BSFW/POBSP as cited in Clapp *et al.* 1977).

1980 - June – 30 chicks direct count (S. Conant FWS unpubl. data).

1981 - Feb. – 26 nests direct count (FWS unpubl. data).

1984 - 21 to 27 Jun. – 53+ breeding pairs; number of near-fledging chicks and carcasses recorded (Fefer 1984).

1986 - 17 to 20 May – 0; (Hu 1986).

1987 - 13 to 17 May – 28+ breeding pairs; direct count of chicks (Hu 1987).

1988 - 7 to 9 Jun. – 35+ breeding pairs; direct count (McDermond 1988).

1990 - 20 to 28 Jun. – 23+ breeding pairs; direct count (Rowland 1990).

1994 - 31 breeding pairs; extrapolation to total eggs from chicks counted later in the season (assumes 75% reproductive success) (E. Flint, FWS unpubl. data, as cited in Gales 1998).

**10. Kaula Island**

1932 - 17 to 19 Aug. – First landing by scientists (Berger 1988).

1957 - 28 Dec. – 50 birds; aerial survey (Rice and Kenyon 1962a).

1976 - 20 to 21 Jan. – 85 birds recorded during complete survey of island; 100 estimated (not specified whether adults or chicks) (Walker 1976).

1978 - 7 Mar. – 50 birds estimated from partial survey (not specified whether adults or chicks) (Burr 1978).

1979 - 7 Mar. – 75 birds estimated (not specified whether adults or chicks) (Walker 1979).

1980 - 19 to 20 Jun. – 2 fledglings counted; complete survey (Walker 1983); 1 to 2 Dec. –39 birds counted during complete census; 100 estimated (US Fish and Wildlife Service 1981).

1984 - 16 to 18 Apr. – 2 chicks (Walker 1984).

1993 - 2 Jun. – 4 chicks, direct count (Walker 1993); 5 breeding pairs (E. Flint, FWS unpubl. data).