University of Alaska Sea Grant • AK-SG-01-01, 2001

The Black-footed Albatross Population Biology Workshop: A Step to Understanding the Impacts of Longline Fishing on Seabird Populations

Katherine L. Cousins
National Marine Fisheries Service
Honolulu, Hawaii

Abstract

Experts in seabird ecology, fisheries management, and population modeling participated in a three-day workshop (October 8-10, 1998) at the Western Pacific Regional Fishery Management Council (WPRFMC) offices in Honolulu to investigate the population dynamics of the Black-footed Albatross *(Phoebastria nigripes).* The workshop's primary goal was to characterize the population biology of the Black-footed Albatross and evaluate its resilience to the effects of mortality due to longline fishery interactions. Worldwide there are 61,866 and 558,415 breeding pairs of Black-footed and Laysan *(P. immutabilis)* Albatrosses, respectively, and both species are caught in approximately equal numbers during longline fishing. This suggests that the Black-footed Albatross population may be more seriously affected. The Black-footed Albatross population suffers different combinations of both anthropogenic and natural mortalities, in common with many seabird populations. Thus, a series of simulations were conducted to investigate how population removals added onto baseline mortality would affect the sustainable population growth rates. Also, analyses generated from the bird-banding data sets found that juvenile Black-footed Albatrosses were caught on longline more frequently than adults. Simulated experiments also investigated how differences in juvenile and adult removals would affect the Black-footed Albatross population dynamics. The findings showed that over the long term, a chronic mortality such as longline fishing resulted in slow decline of species population size irrespective of uncertainties associated with the estimated parameters.

Workshop participants generated seven recommendations for consideration by the WPRFMC, including the improvement and standardization of data collection and the completion of analyses as studies progress.

Introduction

Hawaii-based longline vessels targeting broadbill swordfish *(Xiphias gladius)* and tuna *(Thunnus* spp.) inadvertently hook and kill both Black-footed Albatrosses and Laysan Albatrosses *(P. immutabilis)* that nest in the Northwestern Hawaiian Islands (NWHI). Records of fishing activity extend only from 1991, after logbook catch records were required of longline vessels under Amendment 2 to the Fishery Management Plan of the Pelagic Fisheries in the Western Pacific Region (FMP). In 1994, the National Marine Fisheries Service (NMFS) initiated an observer program to monitor the incidental catch of sea turtles in the Hawaii-based longline fleet. NMFS observers also reported the incidental catches of Black-footed and Laysan Albatrosses; however, the observer program was not initiated or designed to monitor seabird and fishery interactions. Consequently, methods to extrapolate seabird catch estimates from the logbook and observer data generated values with wide ranges of uncertainty. For instance, log transformed point estimates for Black-footed Albatross catch averaged about 1,704 per year with confidence intervals ranging between 616 and 3,329 (Table 1).

Few papers on the Black-footed Albatross are published, although a wealth of information exists in unpublished reports and raw data sets. In addition, thousands of albatrosses have been marked with bird-bands in the NWHI. Lack of understanding for NWHI Black-footed Albatross population dynamics and inconclusive albatross mortality figures for the Hawaii-based longline fishery prompted the Western Pacific Regional Fishery Management Council (WPRFMC) to convene a three-day workshop October 8-10, 1998 in Honolulu, Hawaii (Table 2).

The findings and recommendations from the workshop were timely because the WPRFMC was in the midst of developing a regulatory amendment for the Hawaii-based pelagic longline fishery mitigating impacts on seabirds. WPRFMC also hired a private contractor, Garcia and Associates, to conduct a seabird mortality mitigation study on board Hawaii-based longline vessels. In theory, if the effects of seabird mortality rates and population parameters could be measured and modeled, this could lead to better estimates of the effectiveness of proposed seabird bycatch mitigation methods for use on longline fishing vessels. This paper summarizes some of the findings from the Black-footed Albatross workshop and lists seven recommendations generated by the 21 workshop participants (Table 3).

Table 1. Incidental catches of Laysan and Black-footed Albatrosses in the Hawaii-based longline fishery estimated by two methods (log transformed versus non-log transformed) from NMFS observer and logbook data, 1994 to 1997.

Year	Method	Laysan Albatross catch			Black-footed Albatross catch		
		Lethal	Non-lethal	Total	Lethal	Non-lethal	Total
1991	Log	513	253	766	887	222	1,108
		(165, 853)	(81, 420)	(246, 1,273)	(488, 1,376)	(122, 345)	(610, 1,724)
	Non-log	554	273	828	4346	1,087	5,433
		(273, 1,032)	(134, 508)	(407, 1,540)	(1,019, 5,633)	(255, 1,408)	(1,273, 7,042)
1992	Log	554	273	826	1,270	318	1,588
		(290, 777)	(143, 383)	(433, 1,160)	(885, 1,646)	(221, 411)	(1,107, 2,056)
	Non-log	580	286	865	3,635	909	4,544
		(381, 902)	(188, 444)	(569, 1,346)	(1,834, 4,572)	(458, 1,143)	(2,292, 5,716)
1993	Log	1,175	579	1,754	1,981	495	2,477
		(567, 1,826)	(279, 900)	(846, 2,726)	(1151, 2,707)	(288, 677)	(1,439, 3,384)
	Non-log	1,159	571	1,729	5,762	1,441	7,203
		(706, 1962)	(348, 966)	(1,053, 2,928)	(1,757, 7,866)	(439, 1,967)	(2,196, 9,833)
1994	Log	666	328	994	1,685	421	2,106
		(412, 1,149)	(203, 566)	(615, 1,715)	(984, 2,008)	(246, 502)	(1,230, 2,511)
	Non-log	950	468	1,418	4,252	1,063	5,315
		(569, 1,322)	(280, 651)	(850, 1,972)	(1,273, 5,149)	(318, 1,287)	(1,592, 6,437)
1995	Log	536	264	800	1,287	322	1,609
		(305, 774)	(150, 381)	(456, 1,155)	(659, 1,602)	(165, 400)	(823, 2,002)
	Non-log	744	367	1,111	3,391	848	4,239
		(392, 977)	(193, 481)	(585, 1,458)	(777, 4,375)	(194, 1,094)	(972, 5,469)
1996	Log	397	196	592	1,069	267	1,336
		(281, 680)	(138, 335)	(419, 1,015)	(674, 1,272)	(168, 318)	(842, 1,590)
	Non-log	614	302	917	4,222	1,055	5,277
		(360, 848)	(177, 418)	(537,1,265)	(943, 5,088)	(236, 1,272)	(1,179, 6,360)
1997	Log	429	211	640	1,019	255	1,274
		(280, 625)	(138, 308)	(417, 934)	(666, 1,330)	(166, 332)	(832, 1,662)
	Non-log	597	294	891	5,263	1,316	6,579
		(336, 812)	(165, 400)	(501, 1,211)	(784, 6,140)	(196, 1,535)	(981, 7,674)

The 1991 to 1993 values are conditional on statistical models developed from 1994-1997 observer data. Values in parentheses are the confidence intervals. Estimates of non-lethal catches include albatrosses observed alive or injured. Lethal catch estimates include albatrosses that were known to be dead or their condition was listed as unknown. There were no sightings or incidental catches of Short-tailed Albatross reported in the fishery.

Source: P. Kleiber, NMFS, Southwest Fisheries Science Center, Honolulu Laboratory.

Table 2. Agenda for the Black-footed Albatross Population Biology Workshop, held at the Western Pacific Regional Fishery Management Council, October 8-10, 1998.

Time	Day 1	Day 2	Day 3
0830	Plenary • Welcome from K. Simonds • Introductions and overview of agenda	Plenary • Summary of findings from working groups submitted	Data analysis and discussion within working groups
0900	Plenary • Presentations by: K. Cousins H. Hasegawa S. Pooley P. Kleiber K. Rivera	Data analysis and discussion within working groups	
1100			• Summary of findings from working groups
1400	Plenary • Establishing working groups	Plenary • Review and discussion	
1500	Data analysis and discussion within working groups	Data analysis and discussion within working groups	
1600			Plenary • Review and discussion • Development of the workshop recommendations
1700	Plenary • Review and discussion		
1800 Evening	Data analysis and discussion within working groups		

Table 3. List of participants, affiliations, and areas of specialty for the Black-footed Albatross Population Biology Workshop held in Honolulu, HI, October 8-10, 1998.

Participant	Affiliation	Areas of Specialty
C. Boggs	NMFS, Hawaii, USA	Fish biology and ecology
J.F. Cochrane	University of Minnesota, USA	Population modeling
E. Cooch	Cornell University, USA	Wildlife ecology and population modeling
J. Cooper (Workshop Chair)	University of Cape Town, South Africa	Seabird ecology and conservation
K. Cousins (Workshop coordinator)	NMFS, Hawaii, USA	Marine biology and animal physiology
J.P. Croxall	British Antarctic Survey, UK	Seabird ecology
E. Flint	USFWS, Hawaii, USA	Seabird ecology
H. Hasegawa	Toho University, Japan	Seabird biology
D. Heinemann	CSIRO Division of Marine Research, Tasmania	Seabird ecology and modeling
P. Kleiber	NMFS, Hawaii, USA	Fisheries biology
J.D. Lebreton	C.N.R.S., C.E.F.E., France	Population ecology and modeling
J.P. Ludwig	The SERE Group, Ltd., Ontario, Canada	Population ecology and toxicology
M.A. Pascual	Centro Nacional Patagónia, Argentina	Population ecology and modeling
S. Pooley	NMFS, Hawaii, USA	Fishery management and performance investigation
R.L. Pyle	Bishop Museum, Hawaii, USA	Seabird ecology
K.S. Rivera	NMFS, Juneau, Alaska, USA	Fisheries management and protected resources
C. Robbins	Patuxent Wildlife Research Center, Maryland, USA	Seabird population ecology
M. Silva	University of Washington, USA	Population genetics
A. Starfield	University of Minnesota, USA	Population modeling
C. Swift	USFWS, Hawaii, USA	Seabird biology
J. Wetherall	NMFS, Hawaii, USA	Fisheries and population modeling

Data Sources

Sixty years of bird-banding data were obtained from the Bishop Museum, Honolulu; workshop participants J. Ludwig and C. Robbins, the National Bird-banding Laboratory, Maryland; and the Smithsonian Institution, Washington, D.C. The U.S. Fish and Wildlife Service (USFWS), Pacific Refuges Office, Honolulu, also provided bird-banding data, as well as census and reproductive success data. Seabird counts and sighting records were obtained from the Bishop Museum, Honolulu, and from private tour guides operating seabird cruises in Oregon (G. Gillson) and California (D. Shearwater). At-sea sightings and satellite tagging data sets were supplied by T. Wahl and D. Anderson (Anderson and Fernandez 1998), respectively. NMFS provided information regarding seabird mortality on Hawaii-based longline vessels and from annual pelagic fishery reports.

Notwithstanding problems of multiple banding and lost banding records presumed to be dead chicks, over a period of four months prior to the workshop, 116,752 Black-footed Albatross records were recovered (representing 100,862 individual birds). Band-numbers belonging to a single bird were manually linked together in a relational database.

Census and Reproductive Success Data

Prior to the 1960s, many of the historical counts of albatross breeding pairs in the NWHI appeared to be best guesses, especially those from the 1910s to the 1930s. None of these counts was supported by scientific surveys or represented a complete direct count (a direct count is a count of every bird on the island). In the 1960s, aerial photographs were used to count Black-footed Albatross colonies; however, these were later criticized for overestimating the population because Great Frigatebirds *(Fregata minor)* may have been mistaken for Black-footed Albatross (Amerson 1971). Since 1996, direct counts have been conducted for smaller colonies at Pearl and Hermes Reef and, since 1979, for Tern Island, French Frigate Shoals. In recent years direct counts of Black-footed Albatross breeding pairs were completed on the larger colonies at Midway Atoll and Laysan Island. The USFWS also extrapolated based on counts of all nests within randomly selected small plots or quadrats of large populations to estimate the number of breeding pairs on Laysan Island (Fig. 1). These counts were multiplied by the proportion of nesting area occupied by breeding birds. Direct counts of chicks corrected for an estimated loss of eggs and chicks were also used to estimate of the total number of breeding pairs.

Overall, in 1998 the USFWS reported approximately 59,622 Black-footed Albatross breeding pairs in 12 colonies in the NWHI, with about 74% of the population breeding on Midway Atoll and Laysan Island (E. Flint, unpubl. data). In addition to the colonies on NWHI, three colonies exist in the western Pacific near Japan. About 25 Black-footed Albatross breeding pairs were reported at Senkaku Island (Kita-Kojima), 1,000 breeding pairs at

Bonin Island (Chichijima), and 1,219 breeding pairs at Izu Island (Torishima) (H. Hasegawa, Toho University, Japan, unpubl. data).

Reproductive Success Data

Reproductive data, specifically the number of eggs, chicks and fledglings on Sand (Midway Atoll), Laysan, and Tern (French Frigate Shoals) islands, were supplied by the USFWS (Table 4). Sand and Laysan islands were plot estimates, whereas the numbers collected from Tern were direct counts.

Hawaii Longline Fishery Information and Data

The Hawaii longline fishery began as early as 1917, with immigrants from Japan (Boggs and Ito 1993). This fishery consisted of wooden sampans using poles and rope lines to target tuna within 2-20 nautical miles of the coast. The fishery peaked in the mid-1950s with landings exceeding 2,000 tons. With the establishment of the 200-nautical mile U.S. Exclusive Economic Zone (EEZ) in 1976, foreign fleets were removed, allowing further development of the domestic Hawaiian fisheries. The Hawaiian longline fishery grew from 37 vessels in 1987, to 80 in 1989, and then increased again to 144 vessels in 1991. The new entrants in the longline fishery were mostly steel-hulled vessels up to 33 meters in length. Their operators were former participants in the U.S. East Coast tuna and swordfish fisheries. Newer vessels used sophisticated electronic gear for navigation, marking deployed longline gear and finding fish. The revitalized fleet also adopted continuous nylon monofilament main lines with snap-on monofilament branch lines. Over the same period, the range of the longline fishery expanded, with some vessels fishing up to 1,000 nautical miles from Hawaii and over half of the longline sets made at distances greater than 50 nautical miles from the Main Hawaiian Islands (MHI).

Following the rapid expansion of the longline fishery between 1987 and 1991, entry to the fishery was halted through a moratorium on permit issuance in 1991, under Amendment 4 to the FMP. In early 1991, longline fishing was prohibited within 50 nautical miles of the NWHI to prevent interactions between the fishery and endangered populations of Hawaiian monk seals *(Monachus schauinslandi).* A further longline exclusion zone of 50-75 nautical miles was established in mid-1991 around the Main Hawaiian Islands through further amendment of the FMP to address a gear conflict issue. In 1994, the FMP established a cap of 164 permits for the Hawaii longline fishery, and limited fishing capacity by restricting maximum vessel size to 101 feet. At present, vessels in the Hawaii-based longline fishery are categorized in three size classes: small (< 56 ft), medium (56-74 ft), and large (> 74 ft) vessels. The majority of vessels operating in the longline fishery are medium- and large-sized vessels.

The longline fleet comprises vessels with different gear configurations to target either swordfish or tuna. Some longline sets target both swordfish and bigeye tuna *(Thunnus obesus)* and are called “mixed” sets. These sets are typically made with a modified swordfish gear configuration and without the use of a hydraulic line-setting machine (line-shooter or line-setter). Both daytime and nighttime fishing are practiced and vessels set a single monofilament longline (i.e., mainline) up to 155.4 km (60 miles) in length. Generally, the mainline holds between 600 and 3,000 branch lines, each about 15-20 meters (49.2-65.6 feet) holding a single hook. The branch lines are usually weighted with 40-80 grams of lead, but the proximity of the weight to the hook varies by vessel and target species.

Hawaii-based longline vessels targeting tuna tend to operate in the relatively warm southern waters and set their lines relatively deep (15-180 m). To facilitate the deployment of tuna fishing gear, these vessels use a line-shooter and branch lines with 40-80 gram weights attached close (20-90 cm) to the hooks to increase the longline sink rate.

In contrast, for swordfish the longline is set at a shallow depth (5-60 m), and the line and baited hooks sink slowly. Swordfishing longline vessels operate in the colder and more northern waters between 25°N and 40°N latitude. Gear generally consists of fewer hooks between floats (3-5), branch line (gangion) weights attached farther from the hooks (4-5 m), and buoyant chemical light sticks attached about one meter from the hook. Consequently, albatrosses following a swordfishing vessel have a greater opportunity to dive on hooks and become caught. The vessels often set

Figure 1. (Facing page.) Number of Black-footed Albatross breeding pairs for three NWHI colonies and fishing effort for the Hawaii-based longline fishery (by millions of hooks) for the period between 1991 and 1998. Black dots (●) represent point estimates (with associated confidence intervals) of Black-footed Albatross breeding pairs extrapolated from quadrats on Laysan Island. Other symbols represent direct counts for Black-footed Albatross breeding pairs for Laysan Island (O), Midway Atoll (∇), and French Frigate Shoals (□). Linear regressions were performed on the number of breeding pairs for each colony. These analyses showed trends with the number of Black-footed Albatross breeding pairs declining by approximately 450 breeding pairs per year for Laysan Island ($r^2 = 0.06$), and increasing by about 165 and 24 breeding pairs for Midway Atoll ($r^2 = 0.20$) and French Frigate Shoals ($r^2 = 0.03$), respectively. Note that a direct count was not performed on Midway Atoll in 1993. Interestingly, all three colonies show a decline in the number of breeding pairs for 1994, although fishing effort had not changed appreciably. Also note that there are increases in the direct counts of breeding pairs for all three colonies in 1998 even though the fishing effort had increased by 5.6 million hooks. Sources: (USFWS Refuges, unpubl. data; Ito and Machado 1999).

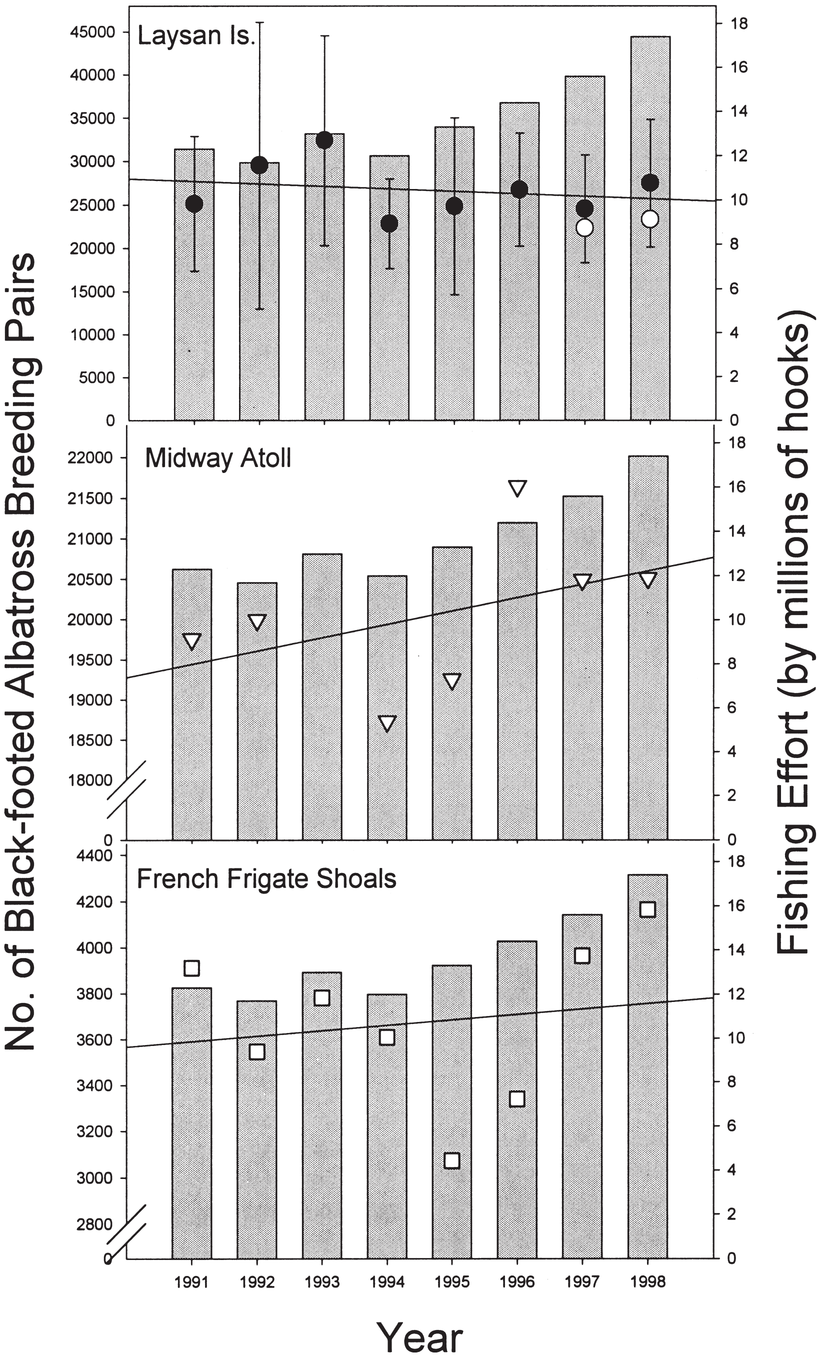
Laysan Is.
Midway Atoll
French Frigate Shoals
No. of Black-footed Albatross Breeding Pairs
Fishing Effort (by millions of hooks)
Year
1991
1992
1993
1994
1995
1996
1997
1998

Table 4. Reproductive information for breeding Black-footed Albatrosses at three locations: Sand Island, Midway Atoll; Laysan Island; and Tern Island, French Frigate Shoals.

Location (area)	Year	Total no. of eggs	Total no. of chicks hatched	Total no. of chicks fledged	Mean hatching success (%)	Mean fledgling success (%)	Mean breeding success (%)
Sand Island, Midway Atoll	1987	51	na	44	—	—	86.3
	1992	98	74	63	75.6	85.0	64.4
	1993	100	84	79	84.0	94.2	79.0
Laysan Island	1992	201	95	81	47.5	77.4	40.0
	1993	205	163	78	79.9	48.9	37.7
	1994	220	166	93	75.5	55.8	42.3
	1995	212	148	83	70.2	55.9	39.4
Tern Island, French Frigate Shoals	1981	96	—	56	—	—	58.3
	1982	149	—	97	—	—	65.1
	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	1,034	—	807	—	—	78.0
	1996	1,048	—	733	—	—	69.9
	1997	1,304	—	956	—	—	73.3
	1998	1,519	—	1,038	—	—	68.3

Reproductive data collected from Sand and Laysan islands were obtained from general plots and are presented as averages. Data collected from Tern Island were obtained by direct counts of all eggs and chicks fledged. Hatching success was calculated as the number of eggs hatched divided by the total number of eggs laid × 100. Fledging success was calculated as the total number of chicks fledged by the total number of eggs hatched × 100. Breeding success was calculated as the total number of chicks fledged divided by the total number of eggs laid × 100.

Source: USFWS Refuges, Honolulu, HI, unpubl. data.

their lines in the late afternoon or at dusk when the foraging activity of seabirds may be especially high.

The two major sources of information on albatross interactions with Hawaii-based longline vessels are the mandatory logbook and observer data collection programs administered by NMFS. Since 1991, the longline logbook program requires vessel operators to submit detailed catch and effort data on each set (50 CFR 660.14). Although extensive, the information was not as complete as data collected by NMFS observers. The NMFS Observer Program was implemented in February 1994 to collect data on protected species interactions, with marine turtles having the highest priority. Although data collection on protected species was the program's primary purpose, the observers also collected catch data on the fishery and in total recorded five different sets of data: (1) incidental sea turtle take events; (2) fishing effort; (3) interactions with other protected species; (4) fishes kept and discarded, by species; and (5) life history information, including biological specimens in some instances. The NMFS Observer Program achieved 3.5% to 5.5% coverage in the first four years. The selection of trips to observe was based on a sampling design by DiNardo (1993) to monitor sea turtle interactions.

The NMFS Southwest Fisheries Science Center, Honolulu Laboratory, used data from NMFS observer reports and the NMFS Western Pacific Daily Longline Fishing Log to estimate the annual incidental catch of seabirds in the Hawaii longline fishery between 1991 and 1997 (Table 1). Fleetwide incidental catch estimates were computed using a regression tree technique and bootstrap procedure (Skillman and Kleiber 1998). The regression tree technique was used on observer data sets (1994-1997), starting with an array of independent variables (e.g., month, latitude, longitude, target species, gear type, sea surface temperature, and distance to seabird nesting colonies). The model was "pruned" by cross validation, meaning that only the statistically significant predictors of seabird catches were kept in the analysis. Catches of Black-footed Albatrosses were significantly related only in proximity to nesting colonies and longitude, whereas catches of Laysan Albatrosses were significantly related only in proximity to nesting colonies and year. The model was then applied to daily logbook records (1991-1997) to generate estimates of fleetwide seabird bycatch estimates. Uncertainty, expressed as 95% confidence bounds, was assessed with a non-parametric bootstrap technique (Efron 1982, Efron and Tibshirani 1993).

Longline fishing effort was not uniform throughout the year, with a seasonal decline in the number of trips and hooks set in the third quarter (June, July, and August). Hooks set in this quarter represent 17.5% of the annual total number set, while the numbers set in the first, second, and fourth quarters are about equal at 27.5% (Ito and Machado 1999). The distribution of fishing effort was not homogenous. On average, 57% of longline fishing occurred within the U.S. Exclusive Economic Zone (EEZ) surrounding the Hawaiian Islands, with a further 40% on the high seas and

3% in the 200 nautical mile U.S. EEZs of islands such as Palmyra and Kingman Reef, Jarvis, Howland, and Baker (Ito and Machado 1999). The distribution of fishing effort in 1998 was notable for the high volume of fishing within the U.S. EEZs of these mainly uninhabited islands (11.4%), particularly around Palmyra and Kingman Reef. This was in response to the high abundance of bigeye tuna which occurs periodically in the lower latitudes to the south of Hawaii.

Records of fishing activity extend only from 1991, after logbook catch records were required under federal regulations. Although the number of vessels active in the fishery has decreased, the overall fishing effort in number of hooks deployed has risen from 12.3 million in 1991 to 17.4 million hooks in 1998 (Ito and Machado 1999; Fig. 1).

Workshop Highlights

The workshop opened with morning presentations followed by a plenary session and workshop participants dividing into smaller working groups. Participants engaged in detailed discussions about the data sets and the potential for modeling exercises. C. Robbins presented new information on a cohort of 1,000 Black-footed Albatross chicks that were banded by D. Rice in June 1957 on Eastern Island, Midway Atoll. Robbins reported that 313 of the 1,000 chick cohort were re-encountered and their bands read and then released alive (262 Eastern Island; 12 Sand Island, Midway Atoll; 11 Kure Atoll; one at Pearl and Hermes Reef) with only 273 surviving to breeding age. J. Ludwig reported that five birds from this cohort were seen in 1994; therefore, these birds were 37 years old when last seen. Robbins noted that 37 of the birds were taken at sea during the Pacific Ocean Biological Survey Program.

H. Hasegawa reported on the Black-footed Albatross colonies located on Torishima where a total of 914 Black-footed Albatross chicks were observed in two colonies on opposite slopes of this volcanic island. The colony on the volcano's rocky southeast slope had grown from six chicks in 1957 to 636 chicks in 1998. A second colony on the northwestern slopes was established in 1989, with the rearing of a single chick. This new colony produced 278 chicks in 1998. Hasegawa started the new colony by luring the birds to the site with decoy albatrosses.

M. Silva reported that findings from her genetic studies of Black-footed Albatross indicate the Japanese birds originated from NWHI populations. Japanese Black-footed Albatross tend to be smaller than the Hawaii Black-footed Albatross. It is unknown whether the Japanese population is growing or if the increases in breeding pairs reported by Hasegawa were solely due to immigration.

S. Pooley and P. Kleiber presented information on the Hawaii longline fishery. Prior to 1989, when vessels started to target swordfish, NMFS had little evidence that there were many interactions with seabirds. Pooley discussed the NMFS Observer and logbook data sets, and Kleiber described

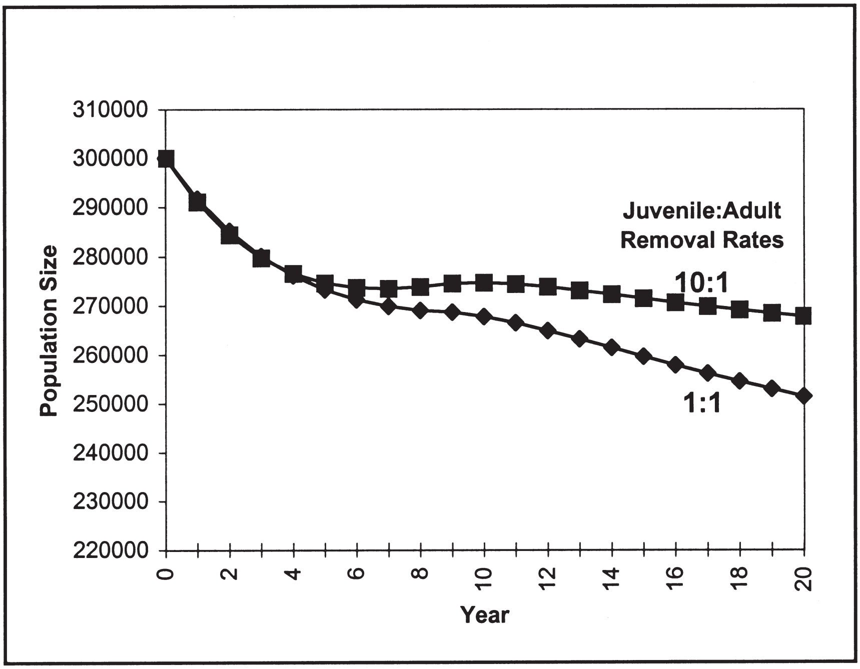

Figure 2. *A model showing the comparison of removals taken at an equal rate among adults and juveniles with removals at a rate 10 times higher for juveniles than for adults. The model was based on a population size of 300,000 birds, and each year 3,000 birds were removed from the population. If juvenile birds were removed at a greater rate than adult birds, then the population size decreased more slowly than if removal rates were equal. The difference was not apparent initially, but accumulated over time due to resulting changes in the population age structure. Also note that the population size declined more noticeably in the first five years of removals. After this initial period, further removals resulted in smaller changes in population size, such that the population would require at least a decade of monitoring to detect noticeable changes in the population size.*

the methods used to determine the seabird catch estimates (Table 1) and problems associated with them. Huge confidence levels were associated with the seabird catch estimates, and gross differences existed between the non-log and log transformed point estimates. Kleiber was unable to resolve the difficulties associated with the analyses in time for the workshop. However, the data supported his findings that (1) vessels targeting swordfish tended to incidentally catch more seabirds than vessels targeting tuna, and (2) the incidental catch of seabirds increased the closer a vessel fished to a seabird breeding colony.

K. Rivera reported on federal measures to reduce the incidental catch of seabirds employed in the demersal and hook-and-line fisheries in the Gulf of Alaska, the Bering Sea, and around the Aleutian Islands. Observer data were collected in the groundfish longline fisheries and any incidental take reported to the USFWS in Alaska, responsible for estimating takes in these fisheries. On average more Black-footed Albatross were caught in the Gulf of Alaska than in the Bering Sea. Rivera briefly discussed the March 1997 Food and Agriculture Organization of the United Nations Committee on Fisheries meeting in which the committee proposed a plan of action that would implement mitigation guidelines to reduce seabird takes. In Alaska, the primary concern was reducing the incidental takes of Short-tailed Albatross *(P. albatrus)* in longline fisheries and regulations were in place. NMFS observers on Alaska longline vessels started collecting information in April 1998 on measures being used and found that buoy bag, the bird-scaring line, and line weighting measures predominated. While Alaska had seabird bycatch regulations in place in the northern longline fisheries, these measures had not been tested on Alaska vessels. Rivera said agencies should consider the unique characteristics in their own fisheries before implementing measures, and this was the next step in Alaska.

Additional discussions varied from problems estimating population parameters and monitoring colonies to understanding the requirements and methods for population modeling exercises. E. Cooch said there were at least four fundamental parameter estimates critical to describing the basic dynamics of the albatross population: first year survival rate, adult survival rate, age of sexual maturity, and an estimate of fertility. J.D. Lebreton said maximum population growth was severely limited in albatross populations and rarely exceeded 3% (Lebreton 1981). He also provided an estimate for the total population based on the Leslie matrix model (Leslie 1945, 1948; Cull and Vogt 1973), indicating that the total population is five to six times the number of breeding pairs, or in the case of the Black-footed Albatross, about 300,000 birds. Lebreton proposed that workshop participants could estimate the four fundamental parameters while asking questions. For instance, were the estimates themselves influenced by longline fishing? Also, was longline fishing something that could be controlled (i.e., with regulation) and if so, could the pattern and extent of the fishing be measured?

C. Boggs said the pattern and extent of the Hawaii-based longline fishery was measurable, but this fishery only represented a fraction of the total longline effort in the North Pacific and comprised gear types different from foreign fisheries. D. Heinemann noted extra mortality factors that required consideration when comparing fishing and non-fishing mortality in a population, especially factors that had large impacts on the demographic behavior of the population, such as changes in overall productivity in the ocean. These factors needed to be built into a model and the model linked to a system that gathered information about the fishery and the mortality sources so that (1) changes in the fishery behavior or fishery regulations are measured, and (2) the length of monitoring intervals determined. A. Starfield explained that another approach to modeling exercises was to ask broad questions and not start with a preconceived four-parameter, end-parameter model. Starfield was interested in finding evidence for spikes of high recruitment, which could confound interpretation of the data.

J.P. Ludwig completed an analysis of the 255 known-age, at-sea Black-footed Albatross bird-banding records, which spanned 1941 through 1998, and showed 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. The data suggested that younger birds are more vulnerable to being caught by longline vessels. This finding was similar to reports from longline fisheries operating in the Southern Hemisphere, where about four times as many juveniles as adult albatrosses were taken (Brothers 1991).

The modeling exercises developed at the workshop were designed to generate robust conclusions; i.e., broad conclusions that are valid irrespective of the uncertainties associated with the parameters. For simplicity it was assumed that survival and fecundity rates remained constant with time. The model demonstrated that no matter what the exact values of the parameters were, a loss of about 1% of the adult population will reduce the growth rate of the population by an amount greater than 1%.

J.F. Cochrane developed an age-structured model and experimented with it on a spreadsheet while M.A. Pascual investigated changes in population growth rates during periods of large-scale impacts, such as ENSO (El Niño-Southern Oscillation) events. Lebreton and Cooch worked on a model that compared different rates of juvenile and adult removal from a baseline population. This model later graphically demonstrated that in a population of 300,000 birds, removal of 1% of the population (3,000 birds) each year resulted in rapid population decline in the first five to six years regardless of bird age (Fig. 2). Subsequent removals with more juveniles taken than adults resulted in the population size leveling and then slowly declining after a period of 10 years. This model demonstrated that noticeable changes in the population size could be difficult to detect in the short term. Not surprisingly, removal of more adults than juveniles resulted in a more dramatic decline in population size.

Heinemann said if an objective of the modeling exercises was to develop models into a management tool, three elements were missing: (1) the spatial context, especially with respect to the mortality rates due to fishing, such that proximity of the breeding colonies to the fishing front varies; (2) other forms of anthropogenic (human caused) mortality; and (3) stochastic variation in the system. Heinemann concluded that models could be used to test the potential efficiency of mitigation measures in a fishery.

Workshop Recommendations

On the final day of the workshop, the participants developed the following seven recommendations:

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

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

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

4. Obtain information and make best estimates of fishing effort and Black-footed Albatross mortality from the Pacific halibut and non-U.S. longline fisheries in the North Pacific Ocean.

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

6. Undertake comparative studies with Laysan Albatrosses and Hawaii versus Torishima Black-footed Albatrosses (i.e., to research possible competition for resources between species and to determine if there is genetic exchange between NWHI and Torishima Black-footed Albatrosses).

7. Convene a followup workshop in Honolulu, Hawaii, at the Second International Albatross Conference, May 8-12, 2000.

Discussion

Historical information on factors that affect bird populations, especially mortality figures and data on disturbances to the breeding colonies, is vital to population models. In addition, changes in the oceanic productivity, climate, and weather patterns can affect breeding albatross populations (Polovina et al. 1994). Fisheries that directly compete with the albatross for food resources, such as the mid-Pacific squid fisheries, could also possibly affect the population. However, all of these variables—including mortality of albatrosses caught incidentally by foreign fleets operating north of the NWHI—affect the Black-footed Albatross to a certain degree, complicating the assessment of a particular mortality on the population.

At the time of the workshop, the Black-footed Albatross mortality estimates for the Hawaii-based longline fishery had high levels of uncertainty, especially since NMFS had only four years of observed incidental catches of seabirds (1994 to 1997). Several workshop participants reviewed Kleiber's extrapolation methods and concluded that another year of observer data would most likely reduce the uncertainly in estimates. Indeed, a few months after the workshop, the 1998 observer data were added and resolved the problems associated with Kleiber's analyses (Table 5). At the workshop, however, all participants agreed that increasing the NMFS Observer Program coverage from 5% to at least 10% and restructuring the sampling strategy to include seabirds would be a critical first step.

Aside from the difficulties associated with estimating seabird takes, looking for impacts of the Hawaii-based longline fishery on the Black-footed Albatross breeding colonies was not without its own set of problems. For instance, at Midway Atoll there was an increase in reported Black-footed Albatross breeding pairs from 10,000 in 1988 (Tyler 1988) to 19,757 in 1991 (USFW unpubl. data). During this period the fishery was increasing, with 80 longline vessels fishing out of Hawaii in 1989, and 144 in 1991 (Ito and Machado 1999). During this same period the Hawaii-based longline vessels were fishing within 50 nautical miles of the NWHI breeding colonies, as this area was not closed to longline fishing until 1991. According to Kleiber, these longline vessels must have had high seabird catch rates because they were fishing close to breeding colonies where seabird densities are higher. If longline fishing had affected the breeding population on Midway Atoll, the impact was not reflected in the number of breeding pairs. According to the at-sea bird-banding data, more juvenile Black-footed Albatrosses are incidentally caught on longline gear than adult albatrosses. If so, then a decline in the recruitment rate would be expected approximately three to five years later. Indeed, the number of breeding pairs on Midway Atoll appeared to be lower in 1994 (Fig. 1), but without knowing the recruitment rate or the age structure and composition of the population it is difficult to know how the population was affected.

Noticeable changes in the number of breeding pairs occurred at French Frigate Shoals where the number of Black-footed Albatross breeding pairs declined from 5,067 in 1987, to 3,960 in 1991. The breeding colonies there differ greatly from the colonies at Midway Atoll in location and size. French Frigate Shoals represents approximately 7% of the total NWHI Black-footed Albatross population with 4,164 breeding pairs (USFWS, Honolulu,

Table 5. Estimated annual total incidental catch of albatrosses in the Hawaii longline fishery based on catches recorded by NMFS observers on monitored fishing trips between 1994 and 1998.

Year	Black-footed Albatross		Laysan Albatross	
	Observed catch	Estimated total catch	Observed catch	Estimated total catch
1994	126	1,994 (1,508-2,578)	73	1,828 (933-2,984)
1995	105	1,979 (1,439-2,497)	107	1,457 (767-2,308)
1996	59	1,568 (1,158-1,976)	31	1,047 (569-1,610)
1997	107	1,653 (1,243-2,101)	66	1,150 (599-1,875)
1998	46	1,963 (1,479-2,470)	56	1,479 (822-2,336)

Values in parentheses are 95% confidence bounds.
Source: P. Kleiber, NMFS, Southwest Fisheries Science Center, Honolulu Laboratory.

HI, unpubl. data, 1998) and is the southernmost breeding colony for the species in the NWHI. Although other factors could have affected this population, it seems likely that longline fishing activities could have been responsible for the noted decline, especially since longline fishing was permitted within 50 nautical miles of the breeding colonies. Since 1991, the population size at French Frigate Shoals has not declined, although it is still below the 1987 count, suggesting that the management action restricting longline fishing near the breeding colonies may have provided some protection.

In addition, disruptions occurring at the breeding colony at the same time that the Hawaii pelagic longline fishery was in operation could obscure the effects of the Hawaii longline fishery on the population. For example, Midway Atoll became a National Wildlife Refuge in 1996, with closure of the U.S. Naval Station there. Massive restoration work was conducted on the atoll between 1994 and 1997. The U.S. Navy removed fuel storage tanks, abandoned buildings, rubble, and contaminants. During the cleanup of Sand Island, Midway Atoll, a Black-footed Albatross colony (approximately 590 nesting pairs) was displaced from the Fuel Farm area. Thus, the apparent increases and decreases in Black-footed Albatross breeding pairs cannot be attributed solely to changes in fishing effort and further analysis of the data must be completed before any conclusions can be made.

Certainly, this was where the findings generated from the population models at the workshop assisted the agencies. Population models can be developed to address broad or robust conclusions that are valid even if the parameters used to generate the models are full of uncertainties. Three conclusions were generated from the modeling exercises at the workshop: (1) in the absence of anthropogenic and catastrophic influences, the growth rate of the Black-footed Albatross population ranges between zero and 4%; (2) if the total number of birds killed in the longline fishery each year is 1% of the total population, then the population growth rate will be reduced by more than 1%; and (3) a total population of 300,000 birds can withstand, maximally, a loss of 10,000 birds per year to all mortality sources including natural and anthropogenic sources. Without a doubt, all of the modeling exercises indicated that a loss of, for example, 1% of the Black-footed Albatross population had a fairly dramatic long-term effect on the population growth rate.

Workshops such as the Black-footed Albatross Population Biology Workshop bring experts together in a common forum to exchange information, identify problems, and offer recommendations to resource management agencies. The predominant need identified at this workshop was for both the USFWS and NMFS to standardize and complete their data sets for Black-footed Albatross population parameters and at-sea fishery interactions. Gaps in the data sets and problems with seabird catch and population estimates complicate the population dynamic analyses. Because disturbances at the breeding colonies have occurred at the same time mortalities have been reported in the Hawaii-based longline fishery, it is difficult to separate the effects of the different sources of mortality.

Acknowledgments

First, I thank the workshop participants for their hard work and willingness to generate recommendations to our managing agencies. Much aloha and mahalo to the Western Pacific Regional Fishery Management Council staff, council chair Jim Cook, and executive director K. Simonds for their support and assistance during the workshop. This work was supported through NOAA NMFS grant NA77SC0541. I also thank the U.S. Fish and Wildlife Service, Refuges Office, for their support and assistance. I thank J. Cooper for chairing the workshop and for all the advice and encouragement during the completion of the workshop proceedings. I thank K. Klimkeiwicz and the USGS staff for their assistance with the bird-banding records. I also thank E. Melvin for organizing and inviting me to participate at the Pacific Seabird Group Seabird Bycatch Symposium. And in closing, I especially thank J. Parrish, M. Hamilton, S. Conant, and A. Katekaru for their careful review of the draft document and the comments from two anonymous reviewers.

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Seabird Bycatch

Trends, Roadblocks, and Solutions

Edited by
Edward F. Melvin
Washington Sea Grant Program
University of Washington
and
Julia K. Parrish
Zoology Department
University of Washington

Proceedings of the Symposium

Seabird Bycatch: Trends, Roadblocks, and Solutions,
February 26-27, 1999, Blaine, Washington,
Annual Meeting of the Pacific Seabird Group

University of Alaska Sea Grant
AK-SG-01-01
2001

Elmer E. Rasmuson Library Cataloging in Publication Data

Seabird bycatch : trends, roadblocks, and solutions / edited by Edward F. Melvin and Julia K. Parrish – Fairbanks: University of Alaska Sea Grant College Program, 2001.
204 p. : ill. ; cm. – (University of Alaska Sea Grant College Program ; AK-SG-01-01)

Includes bibliographical references and index.

Notes: Proceedings of the Symposium Seabird Bycatch: Trends, Roadblocks, and Solutions, February 26-27, 1999, Blaine, Washington, sponsored by the Pacific Seabird Group.

ISBN 1-56612-066-7

1. Sea birds—Effect of bycatches (Fisheries) on—Congresses. 2. Sea birds—Mortality—Congresses. 3. Bycatches (Fisheries) —Congresses. I. Title. II. Melvin, Edward F. III. Parrish, Julia K., 1961- IV. Series: Alaska Sea Grant College Program report ; AK-SG-01-01.

QL677.4.S43 2001

Citation for this volume is: 2001. Seabird Bycatch: Trends, Roadblocks, and Solutions. Edward F. Melvin and Julia K. Parrish, Eds. University of Alaska Sea Grant, AK-SG-01-01, Fairbanks.

Acknowledgments

This book is published by the University of Alaska Sea Grant College Program, which is cooperatively supported by the U.S. Department of Commerce, NOAA National Sea Grant Office, grant no. NA86RG-0050, project A/161-01; and by the University of Alaska Fairbanks with state funds. The University of Alaska is an affirmative action/equal opportunity institution.

Sea Grant is a unique partnership with public and private sectors combining research, education, and technology transfer for public service. This national network of universities meets changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

This book is a joint project of the University of Alaska Sea Grant College Program and the University of Washington Sea Grant College Program.

University of Alaska Sea Grant
P.O. Box 755040
203 O'Neill Bldg.
Fairbanks, Alaska 99775-5040
(907) 474-6707 Fax (907) 474-6285
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