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Status Report and Future Directions Towards the Development of a National Plan of Action for the Reduction of Incidental Catch of Seabirds in Domestic and Foreign Longline Fisheries in Canadian Waters

DFO-CWS National Working Group on Seabird Bycatch in Longline Fisheries

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Abstract

In response to an International Plan of Action endorsed by the United Nations Food and Agriculture Organization (UN FAO) Committee on Fisheries (COFI), Canada is working towards the development of a National Plan of Action for reducing the incidental mortality of seabirds in domestic and foreign longline fisheries in Canadian waters (inside the 200-mile limit). This Status Report provides information obtained, measures to improve reporting, and initiatives planned and undertaken to reduce bycatch of seabirds in longline fisheries. The Status Report documents the beginning of a work in progress and will be updated as more information becomes available. Based upon very limited data, it appears that the number of seabirds caught in Atlantic and Arctic coast longline fisheries is low, but an adequate assessment has yet to be done. On the Pacific coast, recent modeling of Black-footed Albatross (BFAL) catch suggests that bycatch mortality in Canada is not having a detectable impact on global populations of BFAL. Canada will continue to assess the situation and to work with longline fleets to minimize any seabird bycatch. Canada will also continue to work with industry groups to educate fishing industry participants about seabird bycatch problems and to promote changes to fishing practices where necessary.

Résumé

Dans la foulée du Plan d'action international adopté par le Comité des pêches (COFI) de l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO), le Canada est en train d'élaborer un plan d'action national visant à réduire la capture accidentelle d'oiseaux de mer attribuable à la pêche à la palangre canadienne et étrangère pratiquée dans les eaux canadiennes (à l'intérieur de la limite de 200 milles). Le présent rapport d'étape rend compte des informations recueillies, des mesures visant à améliorer les rapports et des initiatives prévues et en cours dont l'objectif est de réduire la capture accidentelle d'oiseaux de mer par les palangriers. Ce rapport d'étape fait état des débuts d'un travail en cours et sera mis à jour à mesure que de nouvelles informations se présentent. Selon des données très limitées, il semblerait que le nombre d'oiseaux de mer abattus pendant la pêche à la palangre côtière dans l'Atlantique et l'Arctique est faible, mais une évaluation en bonne et due forme n'a pas encore été réalisée. Sur la côte du Pacifique, des modèles récents des captures d'albatros à pieds noirs laissent croire que le taux de mortalité attribuable aux captures accidentelles au Canada n'a pas un impact sensible sur les populations mondiales d'albatros à pieds noirs. Le Canada continuera d'évaluer la situation et de travailler en collaboration avec les flottilles de palangriers pour réduire au minimum les captures accidentelles d'oiseaux de mer. Le Canada poursuivra également sa collaboration avec des intervenants de l'industrie en vue de sensibiliser les pêcheurs à la capture accidentelle d'oiseaux de mer et de les encourager à modifier leurs pratiques de pêche, le cas échéant.

1.0 Background

1.1 Purpose of the Status Report

This status report is and always will be a work in progress. It will be updated periodically when there is new information on mitigation measures, new data or new assessments that have been done to reduce seabird bycatch in longline fisheries and to report bi-annually at COFI meetings. The purpose of this status report is to:

- outline Canada's commitment and responsibilities under the Food and Agriculture Association's (FAO) International Plan of Action to reduce incidental mortality of seabirds in longline fisheries.
- report available data on an ongoing basis on seabird bycatch in domestic and foreign longline fisheries in Canadian fisheries
- assess the extent of the problem based on available information
- identify data gaps where more information, training or communication is required
- report existing measures to reduce incidental mortality of seabirds in Canada
- propose additional measures to reduce bycatch of seabirds
- propose methods of monitoring and reporting to regularly assess the effects of longline fisheries on incidental mortality of seabirds.

1.2 Canada's Commitment to Reduce Incidental Mortality of Seabirds in Longline Fisheries

Canada is working towards the development of a National Plan of Action (NPOA-S) for reducing the incidental mortality of seabirds in the domestic and foreign longline fisheries in Canadian waters (inside the 200-mile-limit). Canada has observed the longline fisheries of all countries fishing in Canadian waters (now largely Canadian fleet only). This status report has been prepared in response to the responsibilities described in the International Plan of Action for reducing the incidental mortality of seabirds in longline fishing (IPOA-S). The IPOA-S is a voluntary plan endorsed by the UN FAO (Food and Agriculture Organization) Committee on Fisheries (COFI) in February 1999, and adopted in November 1999 at the FAO Conference (FAO, 1999).

The FAO commitment made by all signatory countries states that: "States with longline fisheries should conduct an assessment of these fisheries to determine if a problem exists with respect to incidental catch of seabirds. If a problem exists States should adopt a National Plan of Action for reducing the incidental catch of seabirds in longline fisheries (NPOA-Seabirds). States, which determine that an NPOA-Seabirds is not necessary, should review that decision on a regular basis".

This status report was developed through collaboration between the Department of Fisheries and Oceans and the Department of the Environment, (the Canadian Wildlife Service, CWS). The strategy reflects the different roles of the two federal departments on seabird interactions in longline fisheries. DFO is charged with managing the fisheries under the *Fisheries Act*. The Department of the Environment (CWS) is responsible for the protection of migratory birds in Canada through the *Migratory Birds Convention Act* of 1917 (MBCA), replaced by the *Migratory Birds Convention Act* of 1994 (MBCA). The MBCA gives legal force in Canada to the *Migratory Birds Treaty* negotiated with the US in 1916 by Great Britain on behalf of Canada. Relevant to this report, the CWS also has the responsibility for the protection and conservation of all seabirds that are under federal jurisdiction.

1.3 General Description of Longline Fisheries in Canada

Longlines are fishing gear comprising a line that is deployed horizontally and to which lines with hooks of various sizes are attached. Longlines can be stationary, anchored or buoyed lines that are hauled and set manually, electrically or hydraulically (US National Plan of Action 1998). The gear may be set at the seabed (demersal longlining), float off the bottom at variable depth (semi pelagic longlining) or suspended from a line drifting freely at the surface (pelagic longlining). During longline setting, seabirds may feed on baits and become entangled in the gear and incidental catches occur. Variations in gear configurations and operation affect seabird bycatch (FAO, 1999).

1.3.1 Canadian Atlantic Longline Fishery

Based on information collected by observers and compared to landing data, it is estimated that since the 1980s about 75 million individual fishing hooks are deployed annually in the demersal and pelagic longlining fisheries of Atlantic Canada. This estimate does not include the Gulf of St. Lawrence where seabird bycatch had not previously been recorded by observers. The fisheries have changed greatly over the years most likely affecting the bycatch of seabirds over time. For example, prior to the mid-1980s, longlining for Atlantic cod *(Gadus morua)* offshore by non-Canadian fleets was common off Nova Scotia, Newfoundland and Labrador, and to a lesser extent in the Gulf of St. Lawrence until the 1992 groundfish moratorium (Bakken and Falk, 1998; Brothers et al., 1999). Limited longlining for cod commenced again in 1997 along the south coast of Newfoundland. There is no recorded scientific data on the effect of the historic cod longline fishery on seabirds. The tuna (*Thunnus spp.*)/swordfish *(Xiphius gladius)* and the Atlantic halibut *(Hippoglossus hippoglossus)* fisheries have been exploited over the entire time period whereas Greenland halibut (*Reinhardtius hippoglossoides*) fishing off northern Labrador has been reduced since the mid-1990s. All of these changes have undoubtedly affected the numbers of birds killed.

An average set of Atlantic pelagic gear may cover 40 nautical miles and contain 1500 individual hooks set at regular intervals on the longline. The pelagic fishery falls under the International Convention on the Conservation of Atlantic Tunas (ICCAT). Table 1 shows the directed species in longline fisheries in Atlantic Canada.

Table 1. Directed Longline Fishery Species in Atlantic Canada

Directed Fishery	**Species Name**	**Pelagic or Demersal**
Greenland halibut	*Reinhardtius hippoglossoides*	Demersal
Atlantic cod	*Gadus morhua*	Demersal
White hake	*Urophycis tenuis*	Demersal
Monkfish	*Lophius americanus*	Demersal
Atlantic halibut	*Hippoglossus hippoglossus*	Demersal
Skate	*Raja spp.*	Demersal
Yellowfin tuna	*Thunnus albacares*	Pelagic
Bigeye tuna	*Thunnus obesus*	Pelagic
Bluefin tuna	*Thunnus thynnus*	Pelagic
Swordfish	*Xiphias gladius*	Pelagic
Porbeagle shark	*Lamna nasus*	Pelagic

1.3.2 Canadian Pacific Longline Fishery

Demersal longlining is deployed on the Pacific coast of Canada with most effort directed at Pacific halibut *(Hippoglossus stenolepis*) (5-6 million individual hooks set annually), spiny dogfish *(Squalus acanthias*) and rockfish *(Sebastes spp.)* (400,000 hooks) and sablefish (*Anoplopoma fimbria*) (500,000 hooks) (McElderry, 1998; Morgan et al., 1999). In 1998, there were about 570 vessels licensed to use longline gear off the west coast of British Columbia (McElderry, 1998). Directed fishing for halibut is controlled by the International Pacific Halibut Commission (IPHC). The quotas for halibut are set by IPHC but DFO manages this fishery and is responsible for regulating it. An onboard observer program was initiated in 1999 in the halibut fisheries to supplement a dockside monitoring program already in place. Observer coverage ranged from a small number of trips in 1999 to 7% in 2001 (Smith, 2002).

The rockfish fishery occurs year-round although the highest effort occurs in summer. There are approximately 160 licensed vessels which average 4000 sets annually. The on board observer coverage is limited to about 15-20 charters per year (McElderry, 1998). The sablefish longline fishery occurs year round, with up to 20 vessels participating. In 1998, 12 vessels fished about 629 sets; in this fishery, longline gear is increasingly being replaced by traps. Fishing for sablefish occurs along the shelf break, with most effort since the early 1990's focused on the shallow seamounts. The distribution of the effort has been relatively stable over the last nine years. Table 2 shows the directed longline fishery species in the Pacific ocean. There is no pelagic longlining on the Pacific coast of Canada.

Table 2. Directed Longline Fishery Species in Pacific Canada

Directed Fishery	Species Name	Pelagic or Demersal	Approximate # hooks deployed annually
Pacific halibut	*Hippoglossus stenolepis*	Demersal	5-6 million
Spiny dogfish	*Squalus acanthias*	Demersal	400,000
Rockfish	*Sebastes sp.*		
Sablefish	*Anoplopoma fimbria*	Demersal	500,000

1.3.3 Canadian Arctic Longline Fishery

Although fishery effort with longlines in the Canadian part of the Arctic Ocean is very low compared to other areas, there is a limited Greenland halibut fishery; both longlines and gill nets are used.

2.0 Working Towards a National Plan of Action to Reduce Seabird Bycatch in Longline Fisheries

2.1 Assessing the Scope of the Problem of Seabird Bycatch

The following table summarizes the information that is required for a complete assessment of seabird bycatch in any fishery. The information that is currently available in Canada on seabird populations and for longline fisheries has been outlined as well as areas where information can be improved in order that a more detailed assessment can be made.

Table 3. Information required and available for a complete assessment of seabird bycatch in longline fisheries

Information Type	Ideal Information for an Assessment	Available Information	Potential for Improvement
Fishing effort	Fishing effort by gear and directed species *for the total fishery*, ideally presented by month/season, year and geographic area of fishing effort	Observed fishing effort, presented by gear and directed species, available by month, year and Northwest Atlantic Fisheries Organization (NAFO) area for a more detailed assessment if required	Increase percentage of observer coverage on Canadian vessels, with wider representations and proportional distribution
% Fishing Effort Observed	High percentage of fishing effort observed for all gear and all directed species	Percentage of fishing effort observed for a portion of each directed species. Foreign vessels have approximately 100% observer coverage	Increase percentage of observer coverage on Canadian vessels to meet statistical requirements for adequate sampling.
Number of birds caught in fishing gear	Actual number of birds caught and properly identified for each gear type and directed fishery including information on the time of year and geographic location that birds were caught	Seabird identification guides are used where available to identify species of birds caught. The estimated weight of birds caught is recorded *in observed fisheries only and t*he number of birds caught is then estimated using a mean/median bird weight. The estimated number of birds caught reflects the particular month/season, year and geographic location that fishing effort has been observed	Improve seabird identification manuals and skills and increase use of guides on observed vessels. Provide numbers instead of weights of birds caught on observed vessels.

Table 3 (cont.). Information required and available for a complete assessment of seabird bycatch in longline fisheries

Information Type	Ideal Information for an Assessment	Available Information	Potential for Improvement
Bird Distribution	Distribution and density by month/season for seabird species potentially caught in fishing gear or locations where longlining occurs	PIROP (Programme Integré de Reserche sur les Oiseaux Pelagiques) database available, but no new Atlantic data since 1992; Pacific species information is continuously being added. Includes locations, densities and variability by species.	Revitalize at-sea survey program in Atlantic. Observed effort on fishing boats (temporal and spatial) should be evened out and gaps filled.
Bird Population Size and Percentages of birds caught	Population estimates by season and geographic area for seabird species potentially caught in fishing gear; numbers of birds near boats at time of setting by gear type, location, time of day and season	Population size estimates and information varies among species, better for breeding colonial species, much worse for dispersed breeders and non-breeding populations; no data available on number of birds near boats during fishing activity.	Continue colony monitoring. Obtain seabird at-sea density estimates with improved at-sea monitoring program; observers of video cameras could provide counts of birds attending vessel during settings.

3.0 Seabird Bycatch in Atlantic Canada

3.1 Seabird Bycatch in the Gulf of St. Lawrence

For the 976 longline fishery sets observed on Canadian vessels in the Gulf of St. Lawrence in 2001, seabird bycatch consisted of 8kg of unidentified gull and 3 kg of herring gull (likely 1 bird/kg). Observed fishing effort for the longline fisheries in this region is approximately 5-10 %.

3.2 Seabird Bycatch in the Maritimes Region

The number of seabirds caught and the corresponding fishing effort (number of sets) on observed vessels in the Scotian Shelf and Bay of Fundy regions are reported in Table 4.

The total number of seabirds caught was not estimated due to the low percentage of observer coverage and the sporadic nature of the fishing effort. It should be noted that longline fishing effort varies greatly in terms of season, duration of trip, location, number of sets per trip and number of hooks per set. Due to total coverage on foreign vessels, it can be said that the total number of birds caught for the 5,839 sets that were observed on Japanese vessels in Canadian waters between 1986 and 2001 is 394. Most of these were unidentified birds and all of the fishing effort occurred between October and December. Out of 848 sets from Faroese vessels and 15 sets from Greenlandic vessels with 100% observer coverage, no seabirds were caught between 1986 and 2001.

Table 4. Observed Fishing Effort (number of sets) and estimated numbers of seabirds caught in the Scotian Shelf and Bay of Fundy waters during longline trips observed 1986-2001 on Canadian and foreign vessels.

Country fishing in Canadian waters	**Canada**	**Canada**	**Japan***	**Japan***	**Greenland & Faroes***	**Faroes***	**Total**
Directed longline fishery species	**Demersal**	**Pelagic**	**Demersal**	**Pelagic**	**Demersal**	**Pelagic**	
Observed fishing effort (number of sets)***	15762	1528	1595	4244	11	838	
Bird species							
Double-crested Cormorant**		1					1
Great Black-backed Gull**	6	16		3			25
Greater Shearwater**	6	37					43
Lesser Black-backed Gull**	1						1
Herring Gull**		15					15
Northern Fulmar**	53	1					53
Northern Gannet**				9			10
Sooty Shearwater**	4						4
Non-specified bird**	5			382			387
Total	75	70	0	394	0	0	539

* observer coverage is approximately 100% on foreign vessels and was found to be between 0.1 to 53% in the cod,/haddock/ pollock fishery for Canadian vessels in the Scotia Fundy region.

** number of birds has been calculated using estimated bird weights (kg) from Birds of the World (Northern Fulmar 0.6, Double- crested Cormorant 1.9, Great Black-backed Gull 1.6, Greater Shearwater 0.85, Sooty Shearwater 0.8, Herring Gull 1.1, Northern Gannet 3.0, non-specified bird 1.0 was used)

*** number of hooks released per longline set can vary greatly from one hook to 1500 hooks per set ; number of longline sets released per fishing trip may vary from one to 10.

3.3 Seabird Bycatch in the Newfoundland Region

The number of seabirds caught on observed vessels and the corresponding fishing effort (number of sets) in Newfoundland region are reported in Table 5. Between 1989 and 2001, between 5 and 10% of the Canadian vessels had observers on board. During that period, 120 birds were caught in the Newfoundland region. The majority of birds (115) were caught in the Canadian demersal longline fishery, of which 1,044 sets were observed. Out of 59 sets observed in the Canadian pelagic longline fishery, only 5 birds were caught between 1989 and 1990 (approximately 5-10% observer coverage on Canadian vessels in Newfoundland waters). With 100% observer coverage on foreign vessels in Canadian waters the picture is more complete. Of the 313 sets fished (mostly for Greenland halibut) from Norwegian vessels, 146 Northern Fulmars were killed. In contrast, Faroese vessels fished 848 longline sets between 1989 and 1992 and only 4 gulls were observed caught. As these represent 100% observer coverage, it is suggested from these catches that the relationship between the fishing effort and the number of birds caught is highly variable, difficult to predict and depends on many factors.

Table 5. Observed Fishing Effort (number of sets) and estimated numbers of seabirds caught in Newfoundland waters during longline trips observed 1989-2001 on Canadian and foreign vessels.

Directed longline fishery species	**Canada**	**Canada**	**Faroes & Japan & Norway***	**Faroes***	**Greenland ***	**Japan***	**Norway***	**Russia***
Directed longline fishery	**Demersal**	**Pelagic**	**Demersal**	**Pelagic**	**Demersal**	**Pelagic**	**Pelagic**	**Pelagic**
Observed fishing effort (number of sets)***	**1044**	**59**	**21**	**4455**	**67**	**53**	**312**	**88**
Bird species**								
Great Black-backed Gull				4		1		
Herring Gull	8							
Northern Fulmar	70						146	
Greater Shearwater	4	5						
Sooty Shearwater	19							
Non-specified bird	14					3		
Total	115	5	0	4	0	4	146	0

* observer coverage is approximately 100% on foreign vessels is estimated at 5-10% for Canadian vessels in the Newfoundland region.

** number of birds has been calculated using estimated bird weights (kg) from Birds of the World, 19 (Northern Fulmar 0.6, Great Black-backed gull 1.6, Sooty Shearwater 0.8, Herring Gull 1.1, non-specified bird 1.0 was used)

*** number of hooks released per longline set and number of sets per trip can vary greatly. Number of longline sets released per trip also varies.

3.4 General Conclusions for Atlantic Canada

Despite the large effort put into PIROP (Programme Integré de Reserche sur les Oiseaux Pelagiques), there is still relatively known about the seasonal variability in the numbers and distribution of seabirds off the Atlantic coast (Brown et al., 1975; Lock et al., 1994; Huettman and Lock, 1997; Huettman and Diamond, 2000; 2001ab). Northern Fulmars, Herring and Great Black-backed Gulls, shearwaters and Northern Gannets are the species most often caught in long-line fisheries. Breeding populations in Canadian Arctic and Europe have expanded and are now stabilizing (Hatch and Nettleship, 1998); within Newfoundland and Labrador, the small breeding populations have increased and are probably now stable (Stenhouse and Montevecchi, 1999; CWS unpublished data). Herring Gull populations are declining throughout their Atlantic range (Chapdelaine and Rail, 1997; Robertson et al., 2001; Boyne and Hudson, 2002), probably due to reductions of food made available through fishery activities and in landfills. Great Black-backed Gull populations have shown a mix of trends, declining in Labrador, stable in Newfoundland, and increasing or stable in parts of the Maritimes (Mawhinney et al., 1999; Boyne and Hudson, 2002; Robertson et al., 2002). Northern Gannet populations are increasing at all colonies in North America (Chardine, 2000). There is no information on population trends of shearwaters, but the small Manx Shearwater breeding population in southern Newfoundland has probably declined (Robertson, 2002).

Fisheries observers have been deployed on approximately 5 to10 % of the Atlantic pelagic and demersal longline fleets and have gathered information on seabird mortality in some fisheries since the mid-1980s. Bird species identification was enhanced in the Scotian Shelf and Bay of Fundy region observer program in 1998. Seabirds have been identified and recorded in the Newfoundland region since 1989 where instructors and manuals were enhanced in 2000. In addition, training courses have been given to observers by DFO and CWS in recent years to enhance seabird data collection.

Canadian observers are deployed in each fisheries region of Canada. Each region has its own independent observer company, operated by the private sector, and a cadre of observers. The minimum qualifications for an observer include high school graduation plus additional courses in biological sampling, fish identification and scientific record keeping. Observers receive five weeks of training in the specifics of observing (mainly by Fisheries and Oceans staff). Costs of observer coverage are shared by the fishing industry and the Department of Fisheries and Oceans. Levels of observer coverage are guided by what the industry is prepared to pay. Coverage is generally conducted in a random manner. Observer coverage can also be planned in advance to verify compliance in specific instances.

Demersal longline fisheries in Canadian Atlantic waters had an associated observed bycatch rate of 0.016 birds/1,000 hooks over the 14-year period between 1986 and 1999. For these years, it was estimated that about 500 birds have been killed annually by demersal longliners, although the numbers have varied greatly from year to year depending on fishing effort. For only the 27 demersal sets observed with seabird bycatch, on average, 1.3 birds were taken on 3,100 hooks (per set). A high majority of sets contained no seabirds. The longline fishery for Greenland halibut, taking place prior to the 1990's in an area along the shelf edge between Canada and Greenland, had been the primary source of mortality of seabirds by demersal longliners in Canadian Atlantic waters. Observers reported mortality of Northern Fulmars, *Fulmarus glacialis* and Great Black-backed Gulls, *Larus marinus* at a rate of about 0.02 birds/1,000 hooks in the turbot fishery.

Based on information presented by Dave Kulka at the April, 2000 Conservation of Arctic Flora and Fauna (CAFF) meeting on seabird bycatch (Chardine et al., 2000; Cooper et al., 2000), the catch rate for pelagic longline fisheries in the Canadian Atlantic between 1986 and 1999 was estimated as 0.032 birds/1,000 hooks, double that observed for demersal fisheries. Between these years, all of the fishing effort had taken place along the outer slope of the Scotian Shelf and the southwest slope of the Grand Banks. It is estimated that some 1400 birds have been killed annually by pelagic longliners. Bird mortality was recorded when fishing was directed at tuna and swordfish but not for porbeagle shark. On average, four birds were taken on 1,700 hooks (per set) from the 55 pelagic sets observed with seabirds between 1986 and 1999. The species recorded were Northern Gannet (Morus bassanus), Herring Gull (L. argentatus) and Great Black-backed Gull. Until the late nineties, most bird mortalities in this fishery were not identified to species and it is thought that some of the catch may have also comprised shearwaters, since Sooty (*Puffinus griseus)* and Greater *(P. gravis)* Shearwaters have been captured in gillnets in the same and adjacent areas. None of the affected species is considered to be at serious conservation risk (Chardine et al., 2000). One Double-crested Cormorant was caught in August, 1998 in area 5ZM (Georges bank) during a swordfish (pelagic) longline trip.

Four trips on pelagic longline vessels targeting tuna and swordfish were observed by Smith (2000) on the Scotian shelf between June and December, 2000. In addition, twelve interviews were held using a questionnaire with longline skippers and crew. The seabird bycatch during those trips was low, and only one bird, a Greater Shearwater was caught. The catch per 1000 hooks overall for 4 trips was 0.03. Typical of most bycatch events, the bird ingested the bait during setting of the gear. The number of seabirds taken by this fishery appears to be very low, possibly because the gear is most often set and hauled in low light conditions and baits are heavy enough to sink quickly. Results obtained from returned questionnaires suggested that there is not a substantial seabird bycatch problem in this fishery.

It should be stressed that the observations above are based on relatively low observation rates (3-10% of the sets observed), incomplete coverage (Gulf of St. Lawrence not covered) and inadequate identification to species in historical data. Although these data indicate low catch rates, better data on catch rates are required.

4.0 Seabird Bycatch in the Pacific Ocean

4.1 General Information on Seabird Bycatch in the Pacific Region

The International Pacific Halibut Commission (IPHC) stock assessment surveys reported 1 Black-footed Albatross from 80,000 hooks hauled in 1998. No birds were caught when 100,000 hooks were hauled in 1999 when all survey vessels used a seabird deterrent device (Gilroy et al., 2000). A summary of IPHC port interview data indicated that 24 birds were caught in 1998 (out of 4.6 million hooks hauled) and 23 birds were caught in 1999 out of 8.3 million hooks hauled (Gilroy et al., 2000). Albatrosses were the most commonly reported species although not all birds caught were identified.

As shown in Table 6b, the majority of the species caught in all Pacific longline fisheries between 1999 and 2001 were Black-footed or unidentified albatross species. The rockfish fishery observer coverage ranged from 0.1-0.5% between 1999 and 2001 while observer coverage in the Pacific halibut fishery ranged from 1.5% in 1999 to 6.9% in 2001 (Table 6a).

Table 6a. Observed fishing effort (by number of sets) in Pacific ocean for longline trips observed between 1999-2001 on Canadian vessels.**

	Year								
Directed longline fishery species	**1999**			**2000**			**2001**		
	Observed**	Total**	% coverage	Observed**	Total**	% coverage	Observed**	Total**	% coverage
Halibut	20	1313	1.5	22	1043	2.1	69	1004	6.9
Rockfish nearshore	5	1604	0.5	4	1383	0.3	19	1273	0.1
Rockfish seamount	5	23	21.7	6	7	85.7	0	0	
Dogfish lingcod	0	1047	0	0	1228	0	8	912	0.9
Total									

Table 6b. Estimated number of seabirds caught in the Pacific region for longline trips observed between 1999-2001 on Canadian vessels.

Directed longline fishery species		**Halibut**	**Rockfish nearshore**	**Rockfish seamount***	**Dogfish Lingcod**
Bird species	**Year**				
Black-footed Albatross	1999	1		3	
	2000		1		
	2001	2**			
Unidentified albatross	2000	1		3	
Glaucous-winged Gull	2001	1			
Pigeon Guillemot	2001	1			
Total		6			0

*No directed rockfish seamount fishery in 2001.
**Number estimated using an average weight of 3.3 kg.

Limited published information is available on bird mortality from Pacific fisheries prior to 1998, with only two Black-footed Albatrosses reported killed (Brothers *et al.,* 1999; Morgan *et al.,* 1999). See also Trumble et al.(1998) and Smith (2002).

Despite the efforts of Morgan *et al.* (1991) there are still large gaps in our knowledge of the seasonal variability in the numbers and distribution of seabirds off the Pacific coast of Canada. The following briefly summarizes the general patterns of distribution, period of occurrence, estimated numbers of birds present and areas of high overlap with longline fishing effort.

The seabirds considered in this report are restricted to species known (or suspected) to have been caught on longlines elsewhere in the North Pacific; they include Black-footed Albatross, Laysan Albatross (*Phoebastria immutabilis*), Short-tailed Albatross (*P. albatrus)*, Northern Fulmar, Sooty Shearwater, Short-tailed Shearwater (*Puffinus tenuirostris*), Pink-footed Shearwater (*P. creatopus)*, Buller's Shearwater (*P. bulleri)*, Glaucous-winged Gull (*Larus glaucescens*) and Black-legged Kittiwake (*Rissa tridactyla*). Table 7 presents the estimated numbers of birds present off the entire British Columbia coastline during summer and winter.

Relevant to this report, there are two species of seabirds that have occurred off the West coast of Canada, that are listed Near Threatened by the IUCN (The World Conservation Union). There are an additional seven listed as Vulnerable, and one as Endangered. The Near Threatened species are Mottled Petrel (*Pterodroma inexpectata*) and Murphy's Petrel (*P. Ultima*); and the Vulnerable species are Short-tailed Albatross, Black-footed Albatross, Solander's Petrel (*P. solanderi*), Hawaiian Petrel (*P. sandwichensis*), Buller's Shearwater, Pink-footed Shearwater and Black-vented Shearwater (*P. opisthomelas*). Although infrequently encountered, the Endangered Cook's Petrel (*Pterodroma cookii*) also occurs in Canadian west coast waters. While not all of these species have been documented killed by longline gear, they all forage in similar ways and as such, may be at risk of becoming entangled. Currently, the status of two of these species (Short-tailed Albatross and Pink-footed Shearwater) is being reviewed by COSEWIC, the Committee on the Status of Endangered Wildlife in Canada.

The global distribution of the above species of seabirds is relatively well known in the context of their breeding colonies; most field guides accurately present that information (del Hoyo 1992; 1996). However, the at-sea wanderings of seabirds in search in food, for even the most common species, is poorly understood for both the breeding and non-breeding seasons. Seven of the 10 species listed in Table 8 breed outside of Canada, but migrate into or through Canadian territorial waters during the breeding and nonbreeding seasons. This constant passage of birds in and out of Canadian waters makes it virtually impossible to come up with a precise estimate of the total or maximum number of birds present. Additionally, because the abundance and distribution of their preferred prey items are controlled by a complex interaction of physical, chemical and biological processes; the distribution of seabirds varies to a high degree in response to variations in prey availability (Hunt et al., 2000).

During summer, Black-footed and Laysan Albatross occur offshore as well as over the continental shelf The shelf is roughly the seaward boundary of where most rockfish longlining occurs.

Maps contained within Morgan et al.(1991) allows for the following generalizations. Based on averaged distribution, Northern Fulmar, Pink-footed Shearwater and Glaucous-winged Gull are at risk of interacting with longline gear especially along the outer shelf and along the shelfbreak west of Barkley Sound, west coast of Vancouver Island. Sooty and Short-tailed Shearwaters appear to be at greatest risk over the shelf to the west, southwest of Estevan Point, and over Cook Bank (west and north of Vancouver Island), as well as over shallow banks in Hecate Strait north of Cumshewa Head (Queen Charlotte Islands). Buller's Shearwater also concentrate to the southwest of Estevan Point, but tend to occur more seaward, out along the shelfbreak. Black-footed Kittiwake have occurred in high numbers west of Englefield Bay (QCI) and west of Kunghit Island (QCI); both of these areas are locations where black cod longlining occurs.

4.2 Detailed Modeling Assessment of Black-footed Albatross

In early 2003, a detailed modeling assessment of mortality estimates and population effects of Pacific longline fisheries on Black-footed Albatross (*Phoebastria nigripes*) was done by Wiese and Smith (2003) and results show that bycatch of this albatross species in Canadian waters is relatively low. The complete report is attached as Appendix 2 to this status report. The following is the abstract taken from this assessment.

Black-footed Albatross are the species most commonly reported caught in the demersal longline fisheries in British Columbia. Black-footed Albatross are listed as vulnerable by the World Conservation Union, with a projected 20 percent decline over 60 years. In this study, we estimate total annual mortality of Black-footed Albatross from the demersal halibut and rockfish longline fishery in British Columbia, based on fishing and observer effort during 2000-2002, and the occurrence of Black-footed Albatross in waters less than 500m deep between 1982-2001. To assess population effects, we developed a stochastic, density-independent matrix population projection model based on published demographic parameters from the three main colonies in the North Hawaiian Islands. Lastly, we compared the annual estimate of incidental capture of Black-footed Albatross off the coast of British Columbia with the estimated mortality from the United States and International demersal and pelagic longline fisheries in the North Pacific.

The combined halibut and rockfish annual fishing effort in British Columbia between 2000 and 2002 ranged from 9-11 million hooks. Albatross bycatch rates ranged from 0-0.0524 birds per 1,000 hooks observed. Bycatch was highest in those areas along the shelf break, in spring and summer, where albatross are known to occur. Based on the most spatially and temporally explicit model possible given the available data, we estimate conservatively, that between 67 and 162 Black-footed Albatross are killed yearly in the rockfish and halibut demersal longline fishery off British Columbia, although mortality may be as low as 22 or as high as 253. Currently, Back-footed Albatross populations on the Hawaiian Islands appear stable with a stochastic intrinsic growth rate of 1.005 (0.990-1.018). Current colony census and population projections do not predict population declines, yet potential population growth appears to have been severely reduced as a result of longline fisheries bycatch mortality. Projecting the estimated bycatch mortality inflicted on these birds in Canadian waters onto the population had no effect on survival rates and potential population growth rates. In comparison, modeling the effects of mortality estimates produced for the USA, Japan and Taiwan, increased juvenile and adult survival rates by 3.9% of its current rates, and predicts a potential population growth rate of 1.04 (1.03 - 1.06). Combined, the Canadian estimate added another 0.1% to the current survival rates. Effectively, this means that Black-footed Albatross populations in the Northern Hawaiian Islands have the potential to grow up to 4% per year in the absence of bycatch mortality from longline fisheries in Canada, USA, Japan and Taiwan. Mortality estimates and bycatch rates presented here for Canada should be considered conservative because of the lack of complete spatial and temporal fishing data, incomplete observer coverage, and limited knowledge of the spatial and temporal abundance of albatross off the coast of British Columbia. Given current population trends in Black-footed Albatross populations, we consider this species vulnerable to any increases in anthropogenic mortality and stress the need to reduce bycatch wherever possible (Wiese and Smith, 2003).

Table 7. Estimated numbers of seabirds present in Pacific Canada off the BC coast during summer and winter. Only species known to be taken on longlines are listed. Summer values taken from Hunt *et al.* 2000; winter population estimates are from K. Morgan (unpubl. data)

Species[1]	Population[2]	Summer	% of Population	Winter	% of Population	IUCN Ranking
Black-footed Albatross	170, 000***	20,000	11.76	200	0.12	Vulnerable
Laysan Albatross	800,00***	200	0.03	15,000	1.88	
Short-tailed Albatross	1,500*	<50	3.33	<50	3.33	Vulnerable
Northern Fulmar	4,600,000**	6,500	0.14	10,000	0.22	
Sooty Shearwater/ Short-tailed Shearwater	50,000,000*	140,000	0.28	500	0.00	
Buller's Shearwater	2,500,000*	7,500	0.30	0	0	Vulnerable
Pink-footed Shearwater	50,000*	20,000	40.00	0	0	Vulnerable
Glaucous-winged Gull	380,000***	78,000	20.53	125,000	32.89	
Black-legged Kittiwake	14,000,000*	< 100	0.00	100,000	0.71	

* = total global population

** = total North Pacific population

***= breeders

5.0 Current Measures

5.1 Pacific Longline Fisheries

A selective fishing policy was adopted for the Pacific coast in January, 2001 that includes fishing selectively to minimize mortality and maximize chances for survival of non-target species, including seabirds.

In the Pacific longline fisheries for halibut , sablefish, rockfish and longline fisheries under Schedule II (lingcod and dogfish), with the cooperation of the fishers, seabird avoidance measures are now being used. Such measures have been made mandatory as a condition of licence; for halibut they have been mandatory since 2001, for sablefish since 2002 and for rockfish and Schedule II longline fisheries since 2003. These measures include the use of weighted lines, thawed bait, additional weights on the ground line, and vessels must be equipped with streamers and a towed buoy. Bait and offal must be handled to avoid attracting seabirds to the hooks. Birds must be released in the least harmful manner, and a record is kept of seabird bycatch. If compliance with these measures is found to be an issue, enforcement will be strengthened.

Observer coverage in the rockfish fishery has increased from minimal in previous years, to about 15% in 2002, as part of the Rockfish Conservation Strategy.

5.2 Atlantic Longline Fisheries

No specific measures are in place in the Canadian Atlantic longline fisheries to mitigate seabird bycatch.

6.0 Conclusions and Recommendations

6.1 General Conclusions

- Although Canada has not developed a NPOA at this stage, actions have been taken to reduce seabird bycatch, to enhance the collection of bycatch data, and to educate the longline fishing industry. These actions will become part of Canada's NPOA.

- Canada has taken a number of actions to determine the nature and the extent of the problem of seabird bycatch in our longline fisheries. DFO and CWS have formed a working group to assess and report on the status of the impact of fisheries on seabirds. The working group will continue to collaborate on the assessment work.There has been an increase in fisheries observer activities to capture seabird bycatch data, and the development of training tools in seabird identification for at-sea observers. Specimens of dead seabirds could be frozen or iced and brought back to Canadian Wildlife Service for identification and biological processing.

- Based on available data (which are incomplete), the number of seabirds caught in Atlantic and Arctic coast longline fisheries appears to be low, but an adequate assessment has yet to be made. On the Pacific coast, recent modeling of Black-footed Albatross bycatch suggests that bycatch mortality in Canada is not having a detectable impact on global populations. Longline fisheries in the Arctic are little developed.

- New mitigation measures have been implemented for reducing incidental mortality of seabirds from all longline fishery activities on the Pacific coast. Pacific halibut vessels have a mandatory licence condition as of March, 2002 that involves the use of mitigation devices (tori lines to scare the birds) that have been shown to be effective in reducing seabird bycatch (Melvin 2000).

- Although the assessment is not complete, Canada will continue to work with longline fleets to minimize any seabird bycatch. If an assessment concludes that certain species are particularly at risk of bycatch, or there are particular locations where by catch is high, additional measures may be required in some fisheries or locations.

- DFO will work through the Canadian Responsible Fisheries Board and other industry bodies to educate fishing industry participants about seabird bycatch problems and to promote changes to fishing practices.

6.2 Action Plan Towards Reducing Seabird Bycatch in Longline Fisheries

- Continue the DFO-CWS Working Group activities and broaden membership as needed;
- Regularly report on the status of seabird bycatch in Canada at COFI
- In at-sea observer programs, continue to emphasize the importance of collecting good information, to improve the collection of data and to carry regular analysis of the data to identify possible areas of concerns;
- Raise the awareness of officials and fishery managers about the Seabirds NPA through distribution of relevant information
- Assess the possibility of holding a national workshop to review all available information on seabird bycatch and consider appropriate measures for reducing them;
- Bring to the attention of longline fleets, using a number of communication tools, the potential problem of seabird bycatch in their fishery and Canada's commitments in this area;
- Work with fleets through the Integrated Fisheries Management Plan process on voluntary measures to reduce seabird bycatch.
- Discuss the possible role of the *Canadian Responsible Fisheries Board* as an integral part of the National Plan of Action.
- A detailed modeling assessment of seabird bycatch similar to that done for Black-footed Albatross will be done for Pacific and Atlantic seabird species, as appropriate.

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8.0 Appendices

Appendix 1: Contact Information for those involved or have contributed information to the National Working Group on Seabird Bycatch in Longline Fisheries

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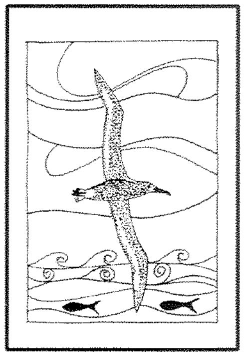
Appendix 2: Mortality estimates and population effects of Canada ín Pacific longline fisheries on Black-footed Albatross (*Phoebastria nigripes*): national and international implications. A paper by Dr. Francis K. Wiese and Joanna L. Smith



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SUMMARY

The incidental capture of seabirds in Canada's longline fisheries is a concern, yet the magnitude or effect of this mortality has remained unknown. To develop an Assessment Report and a possible National Plan of Action however, requires that the extent of seabird bycatch in Canada be understood. Black-footed Albatross are the species most commonly reported caught in the demersal longline fisheries in British Columbia. Black-footed Albatross are listed as vulnerable by the World Conservation Union, with a projected 20 percent decline over 60 years. In this study, we estimate total annual mortality of Black-footed Albatross from the demersal halibut and rockfish longline fishery in British Columbia, based on fishing and observer effort during 2000-2002, and the occurrence of Black-footed Albatross in waters less than 500m deep between 1982-2001. To assess population effects, we developed a stochastic, density-independent matrix population projection model based on published demographic parameters from the three main colonies in the North Hawaiian Islands. Lastly, we compared the annual estimate of incidental capture of

Black-footed Albatross off the coast of British Columbia with the estimated mortality from the United States and International demersal and pelagic longline fisheries in the North Pacific.

The combined halibut and rockfish annual fishing effort in British Columbia between 2000 and 2002 ranged from 9-11 million hooks. Albatross bycatch rates ranged from 0-0.0524 birds per 1,000 hooks observed. Bycatch was highest in those areas along the shelf break, in spring and summer, where albatross are known to occur. Based on the most spatially and temporally explicit model possible given the available data, we estimate conservatively, that between 67 and 162 Black-footed Albatross are killed yearly in the rockfish and halibut demersal longline fishery off British Columbia, although mortality may be as low as 22 or as high as 253. Currently, Back-footed Albatross populations on the Hawaiian Islands appear stable with a stochastic intrinsic growth rate of 1.005 (0.990-1.018). Current colony census and population projections do not predict population declines, yet potential population growth appears to have been severely reduced as a result of longline fisheries bycatch mortality. Projecting the estimated bycatch mortality inflicted on these birds in Canadian waters onto the population had no effect on survival rates and potential population growth rates. In comparison, modeling the effects of mortality estimates produced for the USA, Japan and Taiwan, increased juvenile and adult survival rates by 3.9% of its current rates, and predicts a potential population growth rate of 1.04 (1.03 ñ 1.06). Combined, the Canadian estimate added another 0.1% to the current survival rates. Effectively, this means that Black-footed Albatross populations in the Northern Hawaiian Islands have the potential to grow up to 4% per year in the absence of bycatch mortality from longline fisheries in Canada, USA, Japan and Taiwan. Mortality estimates and bycatch rates presented here for Canada should be considered conservative because of the lack of complete spatial and temporal fishing data, incomplete observer coverage, and limited knowledge of the spatial and temporal abundance of albatross off the coast of British Columbia. Given current population trends in Black-footed Albatross populations, we consider this species vulnerable to any increases in anthropogenic mortality and stress the need to reduce bycatch wherever possible.

INTRODUCTION

The incidental catch, or bycatch of non-target species such as fin-fish species, marine mammals, seabirds, and sea turtles in fisheries worldwide is a concern for fishery managers, regulatory agencies, environmentalists, and scientists alike. About 90% of todayís global fish catch comes from longline fishing (Brothers et al. 1999, Hall et al. 2000). During longlining, baited hooks are set behind the vessels either along the ocean floor (demersal) or suspended in the water column (pelagic). Baited hooks near the surface attract seabirds, and in the water column the bait is an attractive food source to many marine organisms other than just the target species. While attempting to feed on these baits, seabirds, marine mammals, sharks and sea turtles may get caught and drown. These marine organisms are generally characterized by their longevity and low reproductive success, making them particularly vulnerable to increased levels of adult mortality.

It is characteristic of several seabird species to follow fishing vessels. The incidental capture of seabirds during pelagic longline fishing has been implicated in the decline of several species of albatross in the southern and northern hemisphere (Brothers et al. 1999, IUCN 2000, Melvin et al. 2001). There have been no studies to quantify the number of seabirds accidentally killed each year in Canadaís demersal longline fisheries. However, Canada voluntarily endorsed the International Plan of Action (IPOA) proposed by United Nations Food and Agriculture Organization (FAO 1999), and is currently working towards the development of a National Plan of Action (NPOA) to reduce the incidental bycatch of seabirds in its longline fisheries. Developing such a plan involves an assessment of the level of bycatch in Canadaís longline fisheries.

This report focuses specifically on the incidence of Black-footed Albatross (*Phoebastria nigripes*) bycatch in the nearshore rockfish (*Sebastes* species) and Pacific halibut (*Hippoglossus stenolepi*s) demersal longline fisheries in British Columbia. One of three species of albatross that occur off the coast of British Columbia (including Short-tailed, *P. albatrus*, and Laysan Albatross, *P. immutabilis*), Black-footed Albatross are the most common species reported caught in British Columbia (Smith 2002) and are listed by the International Union for the Conservation of Nature (IUCN) as vulnerable (IUCN 2000). Fishing effort and seabird abundance are patchy in space and time, making total bycatch hard to predict. Six data requirements must be met to accurately quantify species-specific bycatch rates for any longline fishery in a given time period: 1) spatial and temporal information on total fishing effort, 2) spatial and temporal observer coverage that is representative of the fishery, 3) locations and numbers of birds caught in relation to the number of hooks observed, 4) spatial and temporal information of seabird distribution 5) demographic information on the species caught to assess population level effects and, 6) information on vulnerability of each age class of species to bycatch.

We present all available information for these critical points as they pertain to Black-footed Albatross mortality and the demersal rockfish and halibut longline fisheries in British Columbia. We draw inferences from these data, point out gaps in the information needed to accurately quantify bycatch rates, and evaluate the potential impact of these fisheries on Black-footed Albatross populations in the North East Pacific using population projection matrix models.

METHODS

1. Halibut

The licensed commercial halibut fishery in British Columbia is open from 15 March to 15 November each year and occurs in the nearshore and offshore waters[1]. Hooks are generally spaced 2-3 m apart, baited by hand, and soak for 5 to 24 hours at a depth of 14-241m (Smith 2002). The halibut fisheries in Canada and the United States are managed by the International Pacific Halibut Commission (IPHC) who carries out annual stock assessments and recommends quotas to Canadian and US Federal agencies responsible for the marine fisheries.

An observer program was initiated in the Canadian halibut fishery by Fisheries and Oceans Canada (DFO) late in 1999 to more accurately estimated total catch (retained and discarded catch)[2]. The first complete year of observer coverage was 2000 and we used observer data supplied by DFO to estimate albatross bycatch between 2000-2002. Total fishing effort (hook hauled) were supplied by IPHC staff, and 2002 data were treated as preliminary. Summaries of fishing effort by IPHC statistical area were generated from the IPHC[3]; we excluded from our analyses all sets where information was missing from the logbooks. We summarised all IPHC halibut fishing effort data (2000-2001) in each statistical area by year only because data by season was unavailable.

2. Rockfish

Rockfish species are targeted by the ZN licensed ëhook and lineí fishery, as well as by the permitted seamount fishery. The permitted seamount fishery of British Columbia has been closed since 2000 and vessel confidentiality agreements prevent us from reporting data from 1998-99. We thus focus this report on the commercial ZN fishery that takes place year-round in the nearshore waters of BC. The ZN fishery is open from 1 April to 31 March[4] but data were summarized by calendar year for this report to allow

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[1] www.iphc.washington.edu

[2] www.dfo-mpo.gc.ca/csas/Csas/English/Research_Years/2002/2002_108e.htm.

[3] www.iphc.washington.edu/halcom/commerci.htm

[4] www.pac.dfo-mpo.gc.ca/ops/fm/mplans/mplans.htm

comparisons with the halibut fishery. The ZN fishery is managed directly by DFO and has included limited observer coverage since 1999. Thus, all data on fishing and observed effort were obtained from DFO. Data were excluded from the analyses where locations and/or number of hooks were missing, or where locations were recorded incorrectly. As a result, an unknown but small proportion of hooks were not accounted for in the results. To match the resolution of the halibut fishery, data were segregated by IPHC statistical areas using standard GIS techniques in ArcGIS (ESRI 2001, version 8.1).

3. Albatross abundance

Data on the abundance of Black-footed Albatross were provided by the Canadian Wildlife Service (CWS). Seabirds were counted opportunistically from a DFO research vessel traveling along pre-determined transects off the coast of British Columbia from 1982 to 2001. Birds were counted from the bow in a 180_ forward-facing field to an approximate viewing distance of 250m on either side. Observations were made from the bridge deck (approximately 15m above the surface of the water) and continued as long as the ship was in motion during daylight hours (for details, see Morgan et al. 2001). We analysed the CWS albatross records with respect to the IPHC statistical areas and were summarised as birds per square kilometer, with a 500m depth contour overlay.

4. Albatross bycatch

Seabird bycatch is typically reported as the numbers of birds caught per 1,000 hooks hauled. This methods take into account unequal sizes of sets observed and the total number of hooks in observed and unobserved sets (Lewison and Crowder 2003), yet treats hooks as independent sampling units. To treat hooks as related sampling units requires knowledge of the number of trips and sets as well as the number of hooks within each set. As these data were not available to us for all fisheries, we used the birds per 1,000 hooks bycatch rate. If bycatch occurs in areas with known observer and fisheries effort, a temporal-spatial explicit bycatch rate can be extrapolated, assuming a proportional take of birds per 1,000 hooks over a particular time, and for a particular area. However, extrapolation of bycatch rates within or to areas where no birds were reported caught ,or where observer coverage was absent, is problematic due not only to the obvious absence of the required data, but also due to the temporal and spatial patchiness of bird abundance. When seabird bycatch rates are unknown, a large number of assumptions have to be made in order to carry out a regional and temporal unspecific bycatch rate extrapolation based on larger-scale fishing effort and temporally and spatially unresolved seabird abundance. As result, this patchiness increases the uncertainty of the estimate.

In this report, we present, wherever possible, spatially and/or temporally explicit bycatch rates. Where non-explicit extrapolations were attempted, we tried to account for historical differences in fishing effort in different areas, and calibrated the estimates based on generally known patterns of albatross abundance, thus defaulting to a more general approach (Fig. 1). In order to match all data to one scale, we used the IPHC statistical areas for the spatial analysis (Fig. 2) and determined all fishery and observer efforts, as well as seabird abundances, for each of these areas. In addition, due to the temporal differences in seabird abundance, we divided, where possible, the data into four seasons (December-February: winter, March-May: spring, June-August: summer, September-November: fall).

The following specific assumptions were made and calculations carried out:

1. Bycatch rates and extrapolations were only calculated for those IPHC statistical areas with known (observed) Black-footed Albatross occurrence (Figure 2).
2. Halibut fishery (Mar-Nov): For 2000 and 2001, the number of hooks hauled were available by area on a yearly basis only. In order to calculate area-specific bycatch rates where birds were reported caught, we divided the total, annual number of hooks in that area by 3, assuming fishing effort to be equal among seasons. Because it appears that most halibut fishing effort was in the summer (from set information; DFO observer data), we assume this to be a conservative number. For 2002, we were provided with a preliminary yearly, area-unspecific estimate for fishing effort. We thus calculated the average proportion of hooks hauled per area relative to the total number of hooks hauled in each area from the two previous years and partitioned the 2002 estimate accordingly.
3. Rockfish (Jan-Dec): no birds were reported caught in 2000 and 2001 however observer coverage was extremely low (Table 2). We thus applied the average yearly bycatch rate calculated for 2002 to 2000 and 2001. However, longline fishing fleets in BC are increasingly using seabird avoidance devices and it was mandatory in the halibut fishery in 2002. So, using 2002 estimates to back-calculate previous years estimates, based on hooks, will likely underestimate BFAL catch, if you make the assumption that these devices actually work (Yamanaka, L. pers.comm.).
4. Three different bycatch rates were calculated:
    a. **Low estimate**. This estimate was based solely on the bycatch rate for the area where birds were caught by extrapolating to the total number of hooks set that year, in that area. This assumes that the zero bycatch rate for all other areas where hooks were set is representative regardless of the observer coverage.
    b. **Moderate estimate**. This calculation assumes that zero bycatch rates were underestimates of true bycatch. So, an average bycatch for those ëzero areasí was calculated from the total number of birds caught and hooks observed per year. These values differ from those presented in Table 2 because only areas with albatross occurrence were considered, reducing the number of hooks; yet all birds reported were caught in those areas.
    c. **High estimate**. The low and moderate estimate do not take into account the different Black-footed Albatross abundances between IPHC areas. Assuming a proportional relationship between bird abundance and bycatch rates, we scaled the moderate estimates by the yearly average of bird abundance for each statistical area, based on the abundance

from which the original bycatch rate originated. Although there is a clear seasonal component in the bird abundance data overall, there is insufficient seasonal information for the fisheries in each area. Thus, we were not able to scale bycatch rates by seasonal abundance and applied yearly values.

Finally, we calculated the total proportion of hooks set in the IPHC areas where albatross occurred, as well as the proportion of hooks observed in those areas, relative to the total number of hooks observed.

5. Black-footed Albatross

Demographics

Black-footed Albatross nest in 12 colonies throughout the North Pacific. Current population size is about 300,000 birds, 96% of which are found in the Northern Hawaiian Islands (NHI). The majority of birds breed on two of these islands and have been studied extensively since the 1950s (Cousins and Cooper 2000). Although adults may return to colonies at 2-3 years of age, Black-footed albatross do not usually breed before the age of seven and often only breed every second year. Breeders return to their colonies in late October and lay a single egg in mid-November to early December. Chicks typically hatch between mid-January and early February (Rice and Kenyon 1962) and shortly thereafter adults begin making extended foraging trips of up to 10-28 days at sea (Anderson and Fernandez 1998) ranging over thousands of ocean kilometers (Hyrenbach et al. 2002). In June, adults depart from the colony, leaving the chick to fledge on their own in late July.

Adults and successful fledglings disperse over the open ocean of the North Pacific. During the egg-laying and incubation period (December-February), their distribution is concentrated around the colonies, but already more widely dispersed towards the North and West in March. During April-June, birds move northward towards the area south of the Aleutian Islands and off the west coast of the United States and Canada, where they remain until July and August. In the fall, birds gradually return to the southeast in the vicinity of the Hawaiian Islands chain (Cousins and Copper 2000). No age-specific differences in the timing or distribution of birds in the summering areas has been detected, although some observations suggest that non-breeding age birds may occur further north and east than adult breeders.

Population model

Census of the large Black-footed Albatross colonies in the Hawaiian islands (71% of the world population) have been carried out regularly since 1992 (Cousins and Cooper 2000). The number of breeding pairs has been roughly stable between 1992 and 1999 (Fig. 16, 17 and 19 in Cousins and Cooper 2000). Most of the demographic parameters for these colonies originate from studies carried out in the 1960s and 1970s, although more recent information has been collected (Pyle 2000). To estimate the impact of the estimated bycatch mortality incurred by Black-footed Albatross from demersal longline fisheries off the coast of British Columbia, and allow a comparison to population-level effects (indicated by mortality estimates from the international pelagic longline fishery; Lewison and Crowder 2003), we developed a stochastic (demographic and environmental based on measured values), age-structured, pre-breeding, Lefkovitch population projection matrix to model population dynamics (Lefkovitch 1965, McDonald and Caswell 1993, Caswell 2001), based on published demographic values from the NHI (Cousins and Cooper 2000, Lewison and Crowder 2003, Table 1).

The computer model was written in Matlab (MathWorks Inc.) and consisted of three age classes. We defined juveniles as birds less than 1 year of age, immature birds are those between 1 and 6 years, and breeding birds as those that are 7 years and older (Cousins and Cooper 2000). Stochasticity in survival rates and fecundity were taken from ranges of published values and the proportion of breeders was assumed to be 0.785 (Table 1, Cooper and Cousins). Stochasticity in bycatch mortality estimates were based on the estimated range of values by Lewison and Crowder (2003) and from values estimated in the present study. For all runs, random uniform numbers within each range were drawn for each projection. In the absence of quantitative evidence, equal mortality for each age class and sex was assumed (see Lewison and Crowder 2003). Density-dependent effects were not considered in this model because 1) historical, population levels indicate that this population is not near carrying capacity, and 2) our projection time was restricted to 20 years; we assumed it was unlikely that populations levels would rise to historical levels in this time frame, given observed trends.

The effects of anthropogenic mortality on a population are most easily determined by comparing survival rates between affected and unaffected populations. Although the demographic data were mainly collected in the 1960s and 1970s, current observed trends in the Hawaiian population match the predicted trajectories of an intrinsic growth rate (λ) of approximately 1 (*see below*). Since we assume that Black-footed Albatross have sustained mortality in the Northeast Pacific fisheries since the 1970s, it thus follows that these demographic values are those of a population that is already affected by anthropogenic mortality. In other words, we are not aware of any populations of Black-footed Albatross that are not subjected to some anthropogenic mortality. In addition, we were most interested in quantifying the relative effects of bycatch on this particular population. As a result, the evaluation of bycatch mortality on population dynamics occurred in three phases, mirroring the approach taken by Wiese et al. (In review).

In phase one, we determined the stable age distribution (w), the reproductive value vector (v), and the intrinsic growth rate of the deterministic matrix (λ_d; Caswell 2001). We calculated the initial population vector (n) by distributing the estimated breeding population among the stable age distribution (w) based on the known proportion of breeders (Pb_a). These calculations resulted in the base values used for comparison during phase three. We also used the Heyde-Cohen equation to calculate the growth rate (with 95% confidence intervals) for the stochastic matrix (λ_s) based on a 20 year projection period (Heyde and Cohen 1985) and compared our model to observed values for λ. A 20-year projection time was chosen because we considered it a time frame relevant for management purposes and because we did not consider density-dependent processes that may apply over longer-term projections and population trends.

In phase two, using n as the initial vector, we projected the stochastic population matrix over 20 years in two, half-year stages (Fig. 3): the breeding season to the middle of summer, and the summer to pre-breeding phase at the colony. During stage one, young were produced, and individuals from each age class were removed based on the square root of the observed annual survival rates (). Between stages individuals killed due to bycatch were removed from the population in a stochastic, but density-independent, age-class specific manner During stage two, this population was further reduced based on the square root of observed annual survival rates. In essence, this model killed the same birds twice: once explicitly between stages due to bycatch, and once implicitly throughout the projection by using survival rates of a population that is already affected by anthropogenic mortality. The overall growth rate after these two projections was calculated by running 10,000 simulations, or until the mean and median stochastic growth rates were equal.

In phase three, we examined the relative impact of bycatch-related mortality on Black-footed Albatross population dynamics by varying both juvenile and adult survival rates until the growth rate again matched the baseline λ_s determined during phase one. In order to estimate population growth in the absence of bycatch mortality, the explicit, fishery related mortality introduced between stages in phase two was removed and the stochastic matrix was projected with the increased survival rates. Relative decreases in potential population growth due to estimated bycatch mortality were thus calculated.

RESULTS

1. Halibut

Fishing and observer effort

Between 2000-2002, fishing effort within the IPHC statistical areas increased from 6.14 to 7.85 million hooks hauled per year, but varied substantially between statistical areas (Appendix 1, Table 2). Due to incorrect logbook entries, some sets could not be assigned to a particular area so our values differ somewhat from those reported by the IPHC (Appendix 2).

Between 36 and 45 % of all hooks hauled were located on the shelf, where albatross have been observed (i.e. statistical areas 60, 70, 80, 90, 100, 110, 120, 130, and 131) (Table 2, Fig.2).

Total observer coverage increased between years, from 3.0 to 19.2% (Table 2). These rates were comparable to observer coverage for the shelf areas alone, although they differed markedly between areas and from year to year (Table 3).

2. Rockfish

Fishing and observer effort

Between 2000-2002, fishing effort within the IPHC statistical areas decreased from 4.28 to 2.23 million hooks hauled per year, but varied substantially between areas (Appendix 1, Table 2 and 4). Between 50.0 and 60.0 % of total hooks hauled were in the IPHC statistical areas on the shelf (Table 4).

Observer coverage increased between years from 0.4% to 12.8% (Table 2). Like the halibut fishery, these rates were comparable to the number of observed sets for the shelf areas alone, although they differed markedly between areas and from year to year (Table 4).

3. Albatross bycatch

Halibut

One or two Black-footed Albatross were reported caught in observed sets from the commercial halibut fishery between 2000 and 2002 (Table 2). All birds were caught along the shelf area (less than 500 m depth), specifically in areas 80, 90 and 100 (Table 3). Area-specific bycatch rates ranged between 0.0069 and 0.0524 birds per 1,000 hooks. Based on the number of hooks set, this translated into a low estimate of 8, 5 and 5 Black-footed Albatross in 2000, 2001 and 2002, respectively (Table 3). Taking into account statistical areas with zero birds reported caught, we estimate that 9, 29 and 55 albatross were accidentally killed in the halibut longline fishery of British Columbia from 2000-2002. Scaled to yearly mean area specific seabird abundance , our high estimates are 13, 49 and 84 birds killed in 2000, 2001 and 2002, respectively (Table 3).

Rockfish

No Black-footed Albatross were reported caught in 2000 and 2001, and nine birds were reported in 2002 (Table 2). All birds were caught in IPHC statistical area 90 and based on the number of hooks hauled in that area, we estimate that up to 17 birds may have been caught in 2002 (Table 4). Extrapolating this mortality to the entire shelf area, we estimate that 107, 86, and 58 birds may have been killed by the rockfish longline fishery off the coast of British Columbia in 2000, 2001 and 2002, respectively. Scaled to yearly mean area specific seabird abundances, our high estimates are 169, 123, and 93 birds killed in 2000, 2001 and 2002, respectively (Table 4).

4. Total bycatch mortality and impacts on Black-footed Albatross populations

We estimate that the (combined) halibut and rockfish demersal longline fisheries in British Columbia accidentally kill between 67 and 162 Black-footed Albatross annually (range of moderate estimates). This estimate, however, may be as low as 22 (combined low estimate for 2002 when observer coverage was ~ 20%) and as high as 253 (high estimate 2000).

Black-footed Albatross populations

The intrinsic growth rate from the deterministic matrix was $\lambda_d = 1.006$, while stochastic growth was $\lambda_s =$ 1.005 per annum (95 % confidence interval: 0.990-1.018; Fig.4). Removing all estimates (low, moderate and high) of mortality from Canadaís Pacific demersal longline fishery did not have a detectable impact on the predicted growth rate of the population projection model.

In contrast, removing mortality of Black-footed Albatross from the International longline fisheries (5,200-13,800 birds/year, Lewison and Crowder 2003) resulted in a relative increase of survival for each age class by 3.9 percent. That is, we estimate that juveniles would have a survival rate of 62.3%, sub-adults (ages 1-6) 83.1% and breeding adult birds 96.6% in the absence of bycatch. With these increased survival rates, the population would grow at an estimated λ_s of 1.04 per annum (95% confidence interval: 1.03-1.06) (Figure 4). Adding the low and high range of the highest Canadian bycatch mortality estimates to these international estimates would result in an increase in survival of 0.1% per age class (from 3.9 to 4.0%), but would not have a detectable impact on the predicted stochastic growth rate of the population in the absence of bycatch mortality.

DISCUSSION

Bycatch is one of the most significant issues affecting fisheries management today (Hall et al. 2000). Longline fisheries have been implicated in population declines of a number of albatross species and hence much current effort is focusing on accurately assessing mortality, and on developing methods to reduce bycatch (Thompson and Hamer 2000).

To accurately determine the number of birds killed by a particular fisheries it is essential to know fishing effort, observer effort, number of birds caught, bird abundance, and spatial and temporal information for all of these. The most recent estimate of international (excluding Canada) bycatch mortality to Black-footed Albatross ranges between 5,200 and 13,800 birds per year (Lewison and Crowder 2003). This range represents the uncertainty in many of the required parameters (e.g. fishing effort) because such data is not available or collected.

After Canada assessed the need to formulate a National Plan of Action, it was essential that seabird mortality in its waters be assessed. Since Black-footed Albatross are the most commonly reported species caught in British Columbia, the estimated bycatch rates are specific to this species. Here, we present for the first time an estimate of annual bycatch mortalities for Black-footed Albatross in the Canadian Pacific halibut and rockfish longline fisheries. Using all available data, we estimated that between 67 and 162 Black-footed Albatross are killed annually during longline fishing in water less than 500m. This estimate may be as low as 22 or as high as 253 depending upon the support for the assumptions used to build the model.

The total, absolute estimated mortality of Black-footed Albatross in Canadian waters is roughly two orders of magnitude smaller than some pelagic longline fisheries in the Pacific (United States: 2,000; Japan and Taiwan: 3,200 to11,800, Lewison and Crowder 2003). This difference is a reflection of a much smaller fishing effort in Canada. However, we do not know the relative risk of fishing mortality from the international fisheries because bird bycatch is not reported or available. If we compare our estimated bycatch rates for BC with the Alaskan groundfish demersal longline fishery we find that they are at least half the amount (BC: 0-0.05 birds/1,000 hooks; Alaska: 0.089 birds/1,000 hooks, NMFS 2001). The difference between Alaska and BC can be explained by the greater abundance of Black-footed Albatross in the waters off Alaska (Cousins and Cooper 2000).

To have a negative effect on populations, mortality from human activities (such as bycatch, hunting or oiling) must be, at least in part, additive, and not simply compensatory to natural mortality (Anderson and Burnham 1976, Fox 2000). Compensatory mortality assumes anthropogenic sources kill the ìdoomed surplusî - the proportion of the population that would have died due to natural causes, regardless (Singer et al. 1997, Banks 1999, Boyce et al. 1999). In general, it is assumed that all or part of the ìdoomed-surplusî is killed when density-dependent factors are present, which is most likely to occur when populations are near carrying capacity (Allen et al. 1998, Boyce et al 1999). As described earlier, this does not seem to be the case for Black-footed Albatross since they are not reported to be at carrying capacity. Thus, most anthropogenic mortalities on long-lived seabirds, including by-catch, harvest and mortality due to oil pollution, can be considered additive (Boyd 2000, Wiese et al. *in review*).

Black-footed Albatross are considered a vulnerable species by the IUCN criteria due to a projected population decline of 20% over the next three generations, or approximately 45 years (Croxall and Gales 1998). Data collected during the breeding bird censuses since 1992 (Cousins and Cooper 2000) and subsequent population projections based on available demographic information do not support this decline. Yet there is no doubt that sustained adult mortality inflicted by humans can cause severe population declines in seabirds (Moloney et al. 1994, Weimerskirch et al. 1997, Tasker et al. 2000, Tuck et al. 2001, Ainley et al. 2001), or affect populations in different ways. Although current Black-footed Albatross populations seem stable, some stochastic projections predict declining populations. As shown by the observed parameters in the early 1980s (Cousins and Cooper 2002), and similar examples elsewhere (Duffy 1983), the coincidence of unfavourable environmental conditions with large sustained anthropogenic impacts, can cause population declines, even when species are abundant. At the very least, decreased population growth, even when no declines are present, increase the vulnerability of these populations to changes in their environment and other pulse perturbations (Dunnet 1982, Ford et al. 1982, Takekawa et al. 1990).

Our model points out these vulnerabilities. Population projections in the absence of bycatch mortality in the North Pacific project a yearly increase of Black-footed Albatross populations in the Hawaiian Islands of up to 4 percent. Coincidentally, this is also the rate proposed by Cousins and Cooper (2000) as the near maximum potential for population growth for a population with a generation time between 20 and 30 years. Such observations further support the accuracy of our model.

Depending upon particular behavioural or ecological circumstances, population-level effects may have been under- or over-estimated in our model. Effects will be over-estimated if the incidental capture of young birds is greater than adults. Conversely, impacts may be under-estimated because the break-up of pairs (from widowing) was not considered in this model. Alternatively, there are compensatory mechanisms, such as a reduction in the age of first breeding, that might reduce the impact of sustained mortality. However, such effects are generally difficult to detect and subject to a lag time (Cousins and Cooper 2000, Lewison and Crowder 2003). To ensure a continuously stable or potentially increasing Black-footed Albatross population in the North Pacific, careful monitoring at colonies and the use of bycatch reduction measures in the Canadian and International longline fishery is needed.

INFORMATION GAPS

To improve the estimated bycatch rates, data on seasonal and area-specific fishing effort are needed, as well as continuous and representative observer coverage (as in 2002) and additional albatross at-sea information for all seasons, in all fishing areas. Fisheries effort must be available so that spatial and temporal variation in numbers of hooks set can be built into the analysis. As well, the number and location of Black-footed Albatross must be known, especially within those areas where there is a high degree of spatial and temporal overlap with longline fisheries (eg. shelf and shelf break).

This study only included the halibut and rockfish longline fisheries but there are other hook and line fisheries in British Columbia that should be examined for total bycatch of birds, for example sablefish, lingcod and dogfish. We do not know the effort or coverage of these fisheries, nor whether seabirds are caught and to what extent.

With respect to assessing the effects of mortality on the Black-footed Albatross in the North Pacific, we were limited by the lack of available data for age-specific vulnerability to mortality and as previously mentioned, this may over or under-estimate the population level effects.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Although the Canadian component of the overall estimate of bycatch mortality on Black-footed Albatross is small, this mortality adds to the general, worldwide concern for the long-term population stability of Black-footed Albatross in the North Pacific. Patterns of albatross abundance in British Columbia (Morgan et al. 2001) indicate that fishery observer programs should focus their effort in the IPHC shelf areas, particularly during the summer when bird densities and the potential for incidental catch are high. We agree with Chardine (1998), that at-sea seabird bycatch monitoring should continue to increase and remain an integral part of fisheries activities in Canadian waters. We encourage the National Seabird Bycatch Working Group to continue working towards the reduction of the incidental capture of seabirds in Canadian longline fisheries.

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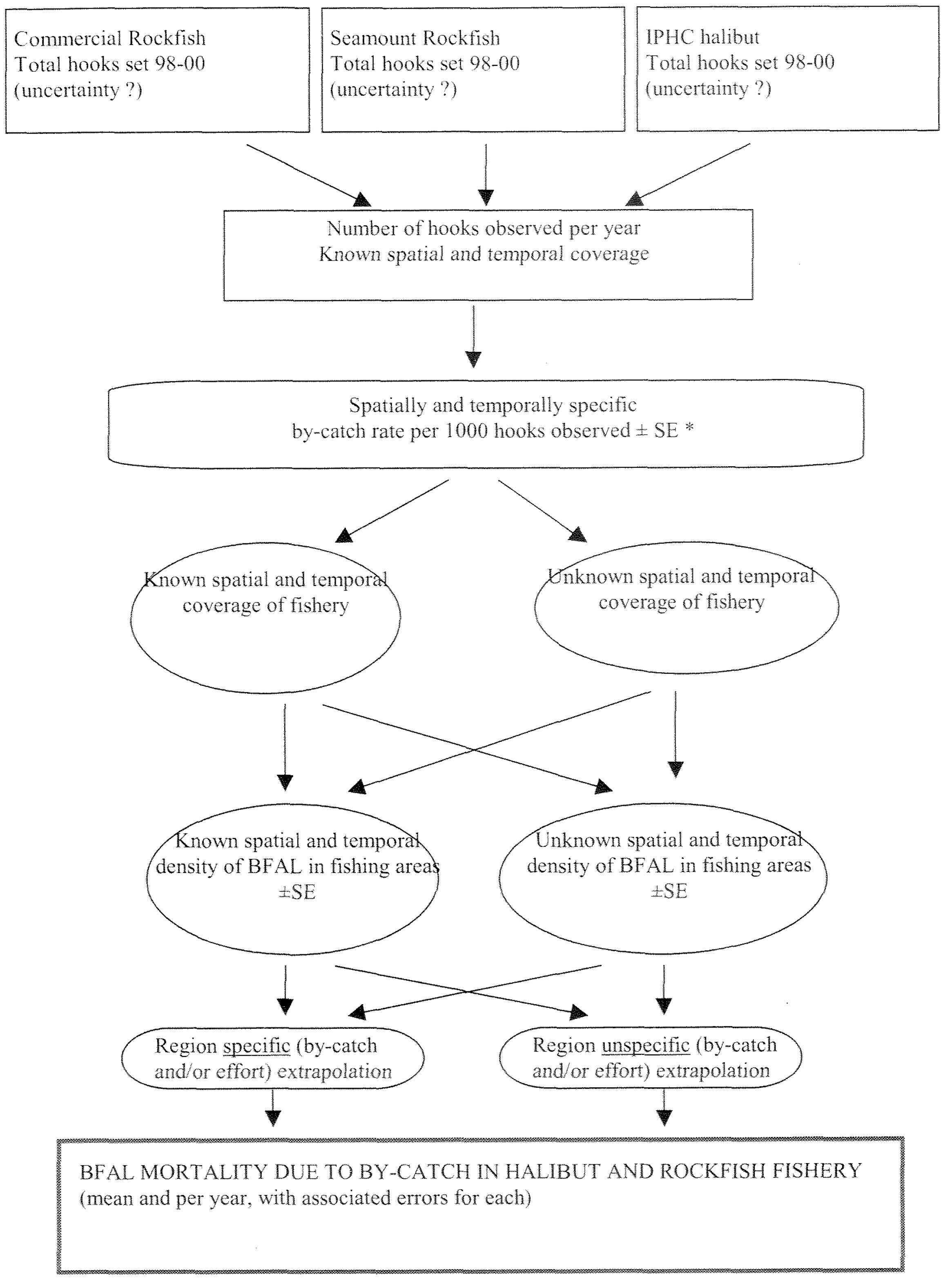

Figure 1. Black-footed Albatross (BFAL) bycatch estimation flow-chart using traditional per 1,000 hooks bycatch rate, with hook as the unit.

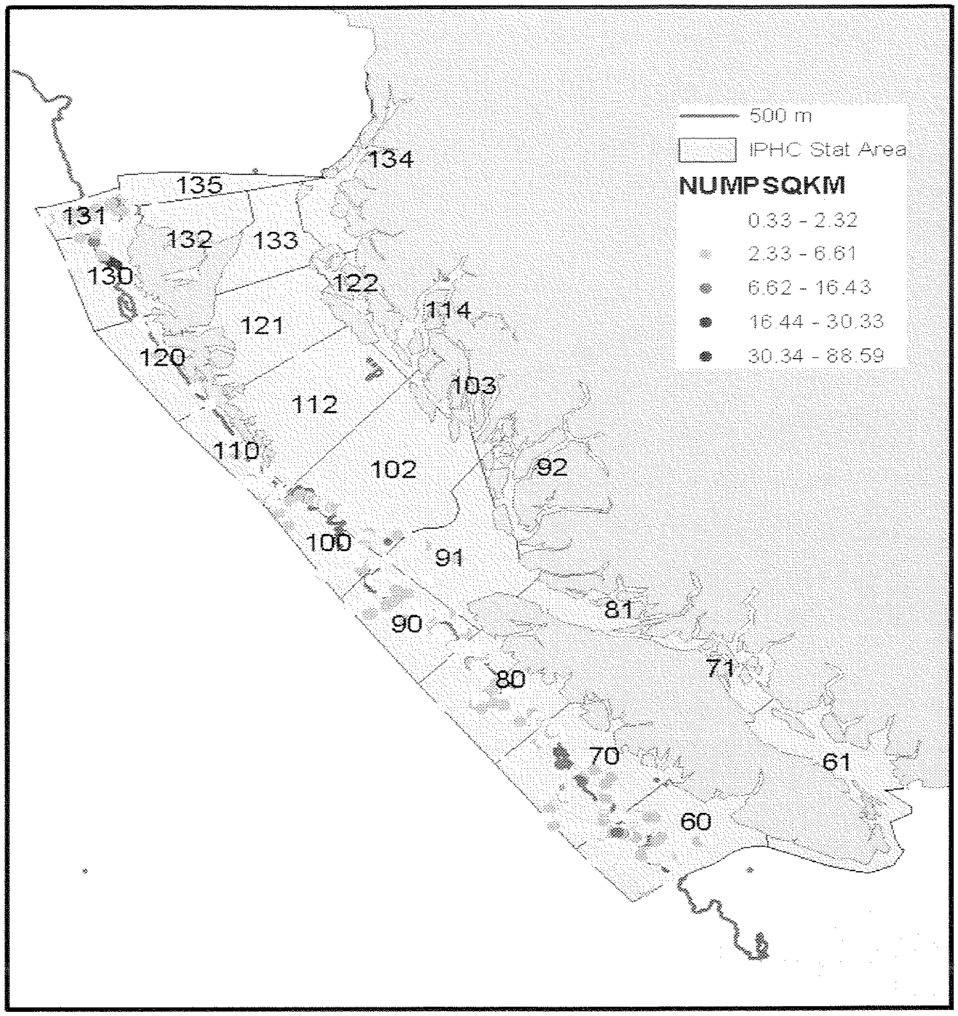

Figure 2 . International Pacific Halibut Commission (IPHC) statistical areas in British Columbia, Canada and observed Black-footed Albatross densitiess per square kilometer (1982-2001; Morgan et al 2001) to the 500 m depth contour (shelf break).

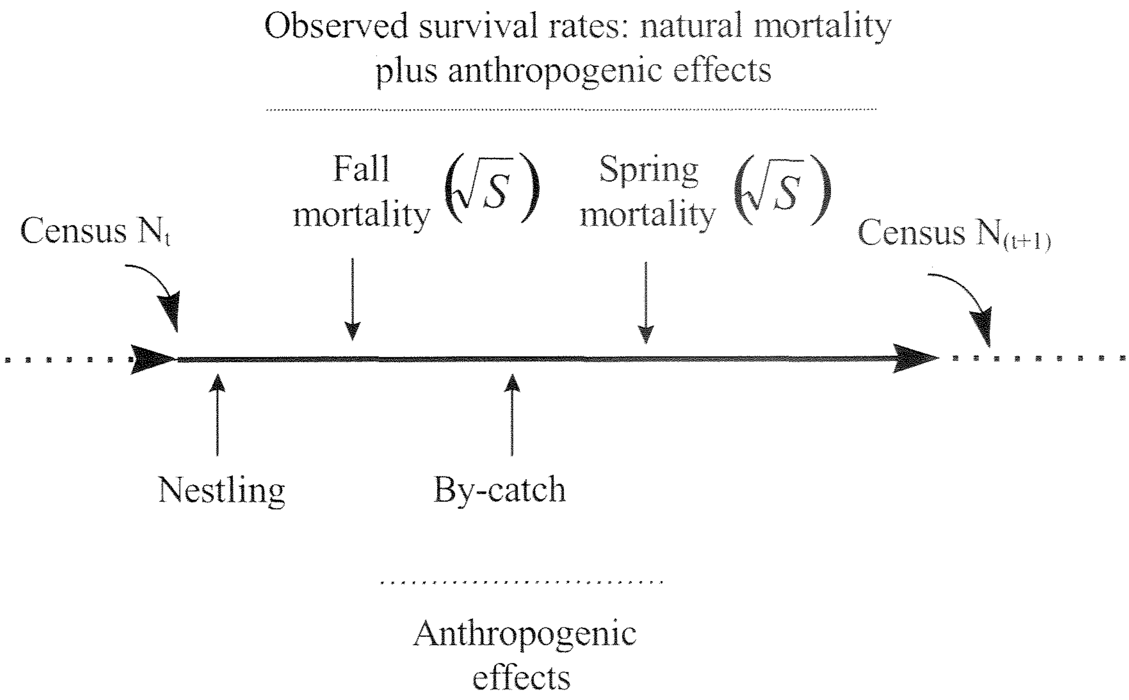

Figure 3. Schematic for two-staged population matrix projection during phase two (see methods for details) of model for the effects of fisheries on Black-footed albatross (adapted from Wiese et al. *in review*).

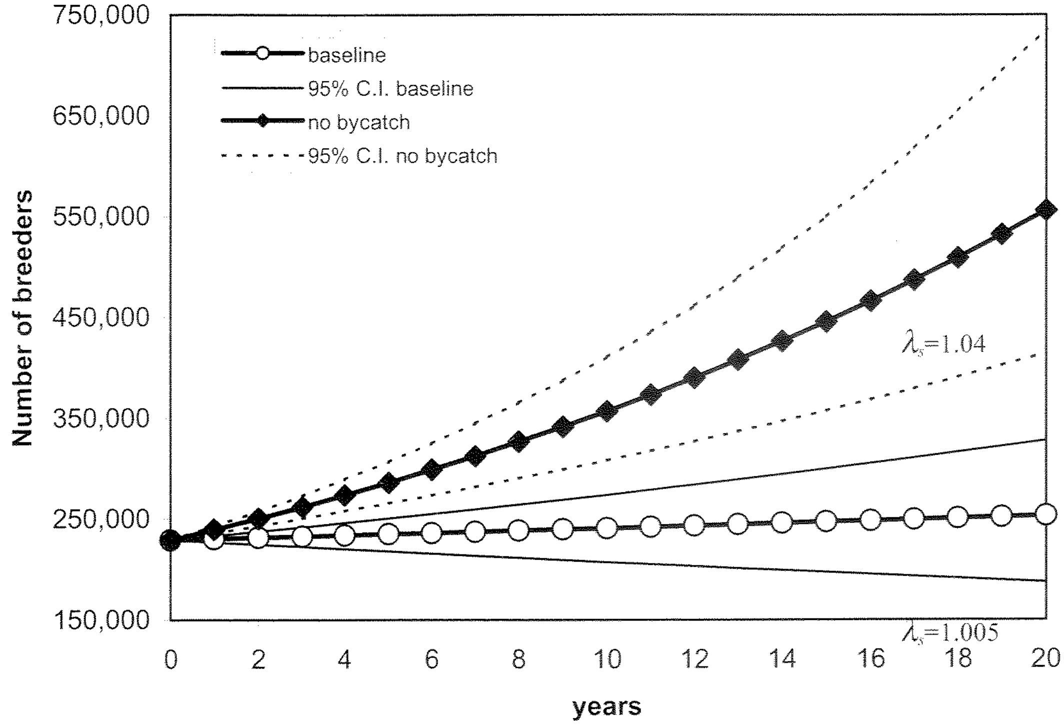

Figure 4. Black-footed Albatross population trajectory models for the Hawaiian Islands based on current demographic values (baseline) and the estimated population growth in the absence of bycatch mortality in North Pacific. 95% Confidence intervals are shown.

Table 1. Summary of demographic parameters used for the pre-breeding population model of Black-footed Albatross in the Northern Hawaiian Islands. All data were taken from Cousins and Cooper (2000) and/or Lewison and Crowder (2003).

Parameter	***Value***	***Stochasticity***
Population size N (breeding birds)	151,900	
Survival of juveniles (0-1 year) S_0	0.6	0.582-0.618
Survival of 1-6 year olds S_1	0.8	0.776-0.824
Survival of breeders (7+ years old) S_2	0.93	0.872-0.958
Proportion breeders Pb_a		
S_0	0.000	
S_1	0.000	
S_2	0.785	0.6-0.8
Fecundity m_a		
m_0	0.00	
m_1	0.00	
m_2	0.22	0.1-0.25

Fertilities calculated as $F_a = Pb_a * m_a * S_0$

Table 2. Annual fishing effort, observer coverage and bycatch of Black-footed Albatross in two Canadian Pacific demersal longline fisheries. Data are restricted to IPHC statistical areas along the shelf (Fig. 2). Ranges are shown in parentheses.

Fishery	**Source**	***Parameter***	***2000***	***2001***	***2002***
Halibut (L)	IPHC	No. hooks hauled (million), logbooks	6.14	6.17	7.85
	IPHC	Proportion of hooks in shelf areas	0.36	0.45	0.40
	DFO	No. hooks observed	0.184	0.639	1.50
	DFO/IPHC	Proportion of observed hooks that occur in shelf areas	0.38	0.48	0.52
	DFO	Percent hooks observed	3.0	10.2	19.2
	DFO/IPHC	Percent hooks observed in shelf areas	2.7 (0.0-6.0)	10.5 (3.2-20.3)	22.5 (9.1-34.4)
	DFO	No. BFAL reported caught	1	2	1
	DFO	BFAL bycatch/1,000 hooks observed (range for each IPHC area)	0.0054* (0-0.0524)	0.0032* (0-0.0496)	0.0007* (0-0.0069)
Rockfish (ZN)	DFO	No. hooks hauled (millions), logbooks	4.28	3.61	2.23
	DFO/IPHC	Proportion of hooks in shelf areas	0.60	0.57	0.50
	DFO	No. hooks observed	0.016	0.069	0.285
	DFO/IPHC	Proportion of observed hook that occur in shelf areas	0.00	0.51	0.75
	DFO	Percent hooks observed	0.4	1.9	12.8
	DFO/IPHC	Percent hooks observed in shelf areas	0.0	1.7 (0-8.3)	19.1 (0-52.5)
	DFO	No. BFAL reported caught	0	0	9
	DFO	BFAL bycatch/1,000 hooks observed * (range for each IPHC area)	0*	0*	0.0316* (0-0.0967)

* these rates are traditionally presented but represent large underestimates of the true magnitude as well as the temporal and spatial nature of the bycatch (see Results for details and explicit bycatch values)

Table 3. Actual and estimated fishing and observer effort for halibut fishery in IPHC areas located along the shelf break off the coast of British Columbia (Fig. 2). Low, moderate and high estimates for the number of Black-footed Albatross killed in this fishery are presented based on birds caught and observer effort, fishery effort along the entire shelf area, and reported bird density, respectively (*see* Methods for details).

IPHC area	# observed hooks	# hauled hooks (year)	% observed	# birds observed caught	bycatch rate/1,000 hooks	mean BFAL/km2	# BFAL killed (low)	# BFAL killed (mod.)	# BFAL killed (high)
2000									
60	22,706	379,317	5.99	0	0	2.27	0	5	6
70	0	177,929	0.00	0	0	2.09	0	3	3
80	19,071	439,627	4.34	1	0.0524	1.97	8	23	23
90	6,115	181,530	3.37	0	0	1.57	0	3	2
100	7,829	419,857	1.86	0	0	1.85	0	6	6
120	0	111,509	0.00	0	0	1.12	0	2	1
130	662	360,876	0.18	0	0	5.37	0	5	14
131	13,942	573,732	2.43	0	0	7.04	0	8	29
Total	**70,325**	**2,644,377**	**2.66**	**1**	**0.0142**		**8**	**55**	**84**
2001									
60	40,706	386,000	10.55	0	0	2.27	0	3	3
70	7,988	252,802	3.16	0	0	2.09	0	2	2
80	22,528	463,463	4.86	0	0	1.97	0	3	4
90	24,924	157,001	15.88	1	0.0496	1.57	3	8	8
100	30,826	468,082	6.59	1	0.0141	1.85	2	7	7
110	7,933	67,792	11.70	0	0	1.25	0	0	0
120	17,673	87,002	20.31	0	0	1.12	0	1	0
130	60,641	394,865	15.36	0	0	5.37	0	3	8
131	88,075	585,245	15.05	0	0	7.04	0	4	16
Total	**301,294**	**2,862,252**	**10.53**	**2**	**0.0066**		**5**	**29**	**49**

Table 3. continued

IPHC area	# observed	# hauled	%	# birds	bycatch	mean	# BFAL	# BFAL	# BFAL

	hooks	hooks (year)	observed	observed caught	rate/1000 hooks	BFAL/km2	killed (low)	killed (mod.)	killed (high)
2002									
60	55,028	486,531	11.31	0	0	2.27	0	1	1
70	82,420	272,037	30.30	0	0	2.09	0	0	0
80	89,442	573,715	15.59	0	0	1.97	0	1	1
90	19,664	215,904	9.11	0	0	1.57	0	0	0
100	176,437	814,520	21.66	1	0.0069	1.85	5	6	6
110	21,128	82,812	25.51	0	0	1.25	0	0	0
120	13,700	126,859	10.80	0	0	1.12	0	0	0
130	74,072	479,754	15.44	0	0	5.37	0	1	2
131	253,579	736,755	34.42	0	0	7.04	0	1	4
Total	**785,470**	**3,496,425**	**22.46**	**1**	**0.0013**		**5**	**9**	**13**

Table 4. Actual and estimated fishing and observer effort for rockfish fishery in IPHC areas located along the shelf break off the coast of British Columbia (Fig. 2). Low, moderate and high estimates for the number of Black-footed Albatross killed in this fishery are presented based on birds caught and observer effort, fishery effort along the entire shelf area, and reported bird density, respectively (see Methods for details). * indicates that the bycatch rate from 2002 was applied to this year.

IPHC area	# observed hooks	# hauled hooks (year)	% observed	# birds observed caught	bycatch rate/1000 hooks	mean BFAL/km2	# BFAL killed (low)	# BFAL killed (mod.)	# BFAL killed (high)
2000									
60	0	124,500	0.00	0	0.0000	2.27		5	8
70	0	354,240	0.00	0	0.0000	2.09		15	20
80	0	467,821	0.00	0	0.0000	1.97		20	25
90	0	339,460	0.00	0	0.0000	1.57		14	14
100	0	58,400	0.00	0	0.0000	1.85		2	3
110	0	199,605	0.00	0	0.0000	1.25		8	7
120	0	476,230	0.00	0	0.0000	1.12		20	14
130	0	507,820	0.00	0	0.0000	5.37		21	73
131	0	30,750	0.00	0	0.0000	7.04		1	6
Total	**0**	**2,558,826**	**0.00**	**0**	**0.0420***			**107**	**169**
2001									
60	0	143,886	0.00	0	0.0000	2.27		6	9
70	5,960	379,209	1.57	0	0.0000	2.09		16	21
80	0	200,962	0.00	0	0.0000	1.97		8	11
90	0	386,297	0.00	0	0.0000	1.57		16	16
100	0	104,404	0.00	0	0.0000	1.85		4	5
110	0	216,546	0.00	0	0.0000	1.25		9	7
120	7,904	332,246	2.38	0	0.0000	1.12		14	10
130	21,403	256,910	8.33	0	0.0000	5.37		11	37
131	0	37,834	0.00	0	0.0000	7.04		2	7
Total	**35,267**	**2,058,294**	**1.71**	**0**	**0.0420**			**86**	**123**

Table 4 continued.

IPHC area	# observed hooks	# hauled hooks (year)	% observed	# birds observed caught	bycatch rate/1000 hooks	mean BFAL/km2	# BFAL killed (low)	# BFAL killed (mod.)	# BFAL killed (high)
2002									
60	11,377	41,426	27.46	0	0.0000	2.27	0	2	3
70	33,650	164,173	20.50	0	0.0000	2.09	0	7	9
80	9,895	91,429	10.82	0	0.0000	1.97	0	4	5
90	101,961	194,140	52.52	9	0.0967	1.57	17	19	19
100	540	75,615	0.71	0	0.0000	1.85	0	3	4
110	26,486	134,321	19.72	0	0.0000	1.25	0	6	4
120	30,328	108,665	27.91	0	0.0000	1.12	0	5	3
130	0	281,322	0.00	0	0.0000	5.37	0	12	40
131	0	31,680	0.00	0	0.0000	7.04	0	1	6
Total	**214,237**	**1,122,771**	**19.08**	**9**	0.0420		**17**	**58**	**93**

Appendix 1. Summary of halibut and rockfish longline fishery effort in British Columbia by International Pacific Halibut Commission (IPHC) statistical area, including bird abundance data. Data available from Ken Morgan upon request.