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Spatio-temporal trends of longline fishing effort in the Southern Ocean and implications for seabird bycatch

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Abstract

Longline fisheries have expanded throughout the world's oceans since major commercial distant-water pelagic fleets began fishing for tuna and tuna-like species in the early 1950s. Along with the more recent development and expansion of demersal longline fleets for species such as Patagonian toothfish, these vessels are a major source of mortality to several species of seabird. Vessels can set many thousands of baited hooks in a day across many kilometres of water. These waters are often used as foraging areas by wide-ranging seabirds. Attracted by baits and offal, the birds can be caught on the baited hooks and subsequently drown. To provide a greater understanding of the potential impact of the Southern Ocean's longline fleets on seabird populations, this paper describes the trends in longline effort of the major pelagic and demersal fisheries in southern waters. The total reported effort from all longline fleets south of 30°S has been well over 250 million hooks per year since the early 1990s. However the spatial and temporal distribution of this effort has not been constant. While effort from the Japanese pelagic distant-water longline fleet declined through the 1990s, the Taiwanese fleet expanded dramatically. Likewise demersal fishing for toothfish increased markedly during the mid-1990s. These fisheries, along with substantial illegal longline fisheries, may be placing the long-term viability of many Southern Ocean species of seabird in jeopardy.

Keywords: Bycatch; Longline fishing; Patagonian toothfish; Seabirds; Tuna

1. Introduction

Albatrosses and other seabirds are incidentally caught during demersal and pelagic longline operations in both the Northern and Southern Hemisphere and the bycatch from these fisheries has been identified as a significant source of mortality for a number of species of seabirds (Brothers, 1991; Vaske, 1991; Gales, 1993; Murray et al., 1993; Klaer and Polacheck, 1997a; Cousins, 2001; Stehn et al., 2001; Baker et al., 2002; Nel et al., 2002a). Several species are attracted to the baits and offal discharge of fishing vessels, whereupon they attempt to remove the bait from hooks of longlines. Many subsequently become caught and drown (Brothers, 1991; Brothers et al., 1999).

This paper describes the trends in effort of the major longline fisheries operating in waters south of 30°S. This latitude was chosen as the northern boundary of the region of interest as southern oceanic seabirds, and especially albatrosses, are most common south of 30°S (Marchant and Higgins, 1990; Brothers, 1991). Where possible, trends in seabird bycatch and bycatch rates for the fisheries are also briefly documented. In order to assess the potential impact of different fisheries it is important to consider both effort and its associated bycatch. Brothers et al. (1999) present a more detailed description of seabird bycatch by fishery through to 1998, including species compositions and applied mitigation measures. The current paper focuses on effort trends but also provides bycatch data additional to, and updates, that presented in Brothers et al. (1999). Attention is also directed at horizontal set pelagic and demersal longline fisheries. Vertical set longlines, such as droplines and trotlines, while known to catch birds, generally have a much lower bycatch rate than horizontal set longlines (Environment Australia, 1998; Rubilar and Moreno, 2000).

Major commercial pelagic longline operations began in the early 1950s, targeting tunas and tuna-like species

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on the high seas of the Northern Hemisphere and equatorial regions (Caton and Ward, 1996; Stobberup et al., 1998). Competition for the tuna canning market from Taiwan and Korea led the Japanese to expand their operations southward in search of higher quality sashimi tunas during the late 1950s and 1960s (Caton and Ward, 1996). Southern expansion was hastened with the discovery of southern stocks of bluefin tuna *Thunnus maccoyii* and the development of longline vessels with deep freezers. The Japanese distant-water fleet began expanding rapidly into the Southern Ocean from the mid 1960s, while the Taiwanese, mainly targeting southern populations of albacore *T. alalunga*, gradually increased effort south of 30°S through the 1970s. The Japanese and Taiwanese fleets are currently the largest and most expansive pelagic longline fleets fishing the Southern Ocean.

Japanese-style pelagic longline vessels set around 3000 baited hooks per set, on mainlines that may be over 100 km in length (Baron, 1996). Sets are usually made on a daily basis and can take between 4 and 6 h, with hauls sometimes over 10 h (Caton and Ward, 1996; Brothers et al., 1998; Baird and Bradford, 2000; Baird, 2001). Major Southern Ocean demersal longline fisheries did not begin until the 1980s (Brothers et al., 1999). For example, the fishery for Patagonian toothfish *Dissostichus eleginoides* began in the southern Atlantic in the late 1980s, and expanded rapidly to include waters of many sub-Antarctic islands. Demersal vessels deploy many thousands of hooks in a set (e.g. up to 20 000 per set reported for the Chilean industrial toothfish fishery (Garcia, 2001)), on a mainline that is usually less in length than that of pelagic longlines, around 15 km in length. More than one set may occur in a day with setting taking between 1 and 4 h, and hauling between 8 and 13 h (Brothers et al., 1999; Baird, 2001).

The incidental catch of seabirds from the Southern Ocean will clearly vary according to the overlap between distributions of fishing effort (measured as number of hooks set) and the foraging distributions of Southern Ocean populations of seabirds. While this paper focuses on changes in reported fishing effort distributions, knowledge of the distributions of foraging populations of seabirds is also critical in any assessment of the potential impacts of the various Southern Ocean longline fleets. Many species of seabird, in particular albatrosses, are known to traverse widely across the southern oceans, and most, if not all, are likely to come in contact with pelagic and/or demersal longline fleets at some point during their lifetime (Prince et al., 1992; Nicholls et al., 1995; Croxall and Prince, 1996; Weimerskirch et al., 1993, 1997; Tuck et al., 1999).

Estimates of seabird bycatch are based on the product of an observed bycatch rate multiplied by the amount of effort in a fishery. Both components of this equation have undergone substantial changes since major commercial longline fisheries began. For example, the tuna longline fisheries for southern bluefin tuna (SBT) have undergone large changes in recent years (in part due to the imposition of catch quotas). These changes include shifts in areas and seasons of operation; technological improvement in fishing gear and related operational factors; the development of domestic longline fisheries in Australia and New Zealand using smaller-scale vessels; and the expansion into high seas southern bluefin tuna fisheries by longline vessels of nationalities other than Japan, principally Taiwan and Korea (Polacheck and Tuck, 1995; Tuck and Polacheck, 1997; Baird and Bradford, 2000; Gunn and Farley, 2000; Reid et al., 2001).

In many longline fisheries bycatch rates have recently changed through the increased use of mitigation measures, such as night setting, bird scaring devices, thawed baits, line weighting and management of offal (Brothers et al., 1999; Reid et al., 2001; SC-CAMLR-XX, 2001). However, many southern oceanic fleets' application of mitigation measures are either inconsistent or non-existent (Baird, 2001). Likewise, the level of on-board observation necessary to monitor bycatch adequately is also poor or non-existent (Cooper, 2000). This seriously impairs the ability of management bodies to control or even identify bycatch and ultimately reduce impacts on threatened seabird populations.

The spatio-temporal distribution of seabird populations would be expected to be neither homogeneous across the Southern Ocean nor to have followed the seasonal changes in the longline fisheries. Thus, trends in total longline effort are likely at best to provide only a qualitative indication of the relative changes in the levels of seabird bycatch. For quantitative assessments, integration of the spatial and temporal distributions of seabirds and fishing effort is required. Such assessments for seabirds are made problematic due to the lack of information about seabird foraging distributions (in particular juvenile and non-breeding birds) and comprehensive and accurate data on fishing operations (Tuck and Polacheck, 1997; Tuck et al., 2001; Baker et al., 2002). The collection of information on both of these components, in addition to further development and application of mitigation measures, should be seen as a high priority for the conservation of seabirds.

All effort statistics presented here are based on reported effort to the various agencies responsible for the management of the fisheries (Table 1). Data for the most recent years could possibly be incomplete and a real decrease in effort in those years should not be inferred. The quality of data reporting and maintenance varied greatly across data collection agencies. In some instances effort data were not collected from the initiation of the respective longline fisheries, records of effort were not measured using hook counts (or measured at all), were obtained with little or no spatial resolution, or, more infrequently, were not publicly available. The

Table 1
The source of data, nationality and years of data available (may not be inclusive; south of 30°S only) used for data summaries in this paper

Data source	Nation	Years available
Pelagic fisheries		
IOTC	France	1996–1997
	Korea	1975–1998
	Spain	1994–2000
	Taiwan	1967–1999
SPC	Korea	1976–1999
	Taiwan	1968–1998
IATTC	Korea	1977–1995
	Spain	1997–2000
ICCAT	Argentina	1967–1968
	Brazil–Japan (JV)	1977–1992
	Brazil–Taiwan (JV)	1991–1999
	Brazil	1973–1999
	Korea	1967–1999
	South Africa	1979–1984
	Spain	1987–1999
	Taiwan	1968–1998
	Uruguay	1981–1987
CCSBT (NRIFSF)	Japan	1952–2000
AFMA	Australia	1985–2001
	Australia–Japan (JV)	1989–1995
New Zealand Ministry of Fisheries	New Zealand	1991–1999
	New Zealand–Japan (JV)	1989–1995
Marine and Coastal Management	South Africa	1998–2001
Demersal fisheries		
AFMA	Australia	1997–2001
Western Australian Fisheries	Australia	1976–2001
MAFRI	Australia	1970–2000
New South Wales Fisheries	Australia	1984–2001
New Zealand Ministry of Fisheries	New Zealand	1989–2001
Marine and Coastal Management	South Africa—kingklip	1984–1988
	South Africa—hake	1996–2001
Universidad Austral de Chile	Chile	1991–1999
Falkland Islands Government Fisheries Department	Falkland Islands	1998–2000
CCAMLR	Multi-national within the CCAMLR statistical areas	1988–2001

Not listed are data from joint venture (JV) operations in the late 1990s between Brazil and several nations other than Japan and Taiwan. IOTC, Indian Ocean Tuna Commission; SPC, Secretariat of the Pacific Community; IATTC, Inter-American Tropical Tuna Commission; ICCAT, International Commission for the Conservation of Atlantic Tunas; CCSBT, Commission for the Conservation of Southern Bluefin Tuna; AFMA, Australian Fisheries Management Authority; MAFRI, Marine and Freshwater Resources Institute; CCAMLR, Commission for the Conservation of Antarctic Marine Living Resources; NRIFSF, National Research Institute of Far Seas Fisheries.

data summaries illustrated in this paper have not been adjusted in any way to account for missing data and provide a summary of the raw data supplied by the fishery agencies responsible for data collection. In addition, due to the high likelihood of under-reporting by some fleets and the substantial illegal, unreported and unregulated (IUU) fisheries in the Southern Ocean, the magnitude of effort reported here should only be considered a minimum. Even where estimates of bycatch and bycatch rates of seabirds are possible, they may also underestimate the actual mortality. The cutting of seabirds from the line prior to observation, birds being eaten by fish prior to hauling, and birds escaping and subsequently dying all contribute to the underestimation of total birds observed killed (Brothers, 1991; Klaer and Polacheck, 1997a). Brothers (1991) estimated that up to 27% of birds killed during pelagic longlining might be lost prior to or during hauling. The presence of an observer may also influence the bycatch mitigation practices of the fishing vessel, with unobserved cruises having potentially much higher bycatch rates.

The underestimation of both fishing effort and bycatch rates reinforces the point that estimates of bycatch are likely to be minimums and underestimate the total number of seabirds actually killed. Given the large and expanding fisheries employing longline gear throughout the Southern Ocean, the incidental catch of seabirds by demersal and pelagic longliners is likely to have had a substantial impact on seabird populations

(Brothers, 1991; Weimerskirch et al., 1997; Prince et al., 1998; Tuck et al., 2001; Nel et al., 2002a). Continued fishing at current levels without adequate mitigation measures could seriously jeopardise the long-term viability of many of these populations.

2. Major distant-water longline fleets

The following sections describe the effort trends and bycatch rates of the distant-water longline fleets fishing in southern waters (south of 30°S). The fleets are also described by area of operation within each oceanic region (southern Pacific, Indian and Atlantic Oceans).

2.1. Japanese distant-water longline fleet

The Japanese have been fishing tunas for centuries. With industrialisation and improved navigational techniques, commercial fishing operations developed in the early 1900s (Caton and Ward, 1996). During the 1930s fishing mainly concentrated in south-eastern Asia and the Hawaiian and Midway Islands. After Allied restrictions on areas of operation were lifted in 1951, Japanese industrial distant-water fleets rapidly developed and expanded to include the Indian, Pacific and Atlantic Oceans (Figs. 1a–d and 2a; Caton and Ward, 1996). Vessels during this period generally targeted yellowfin *Thunnus albacares*, albacore, bigeye *T. obesus* and swordfish *Xiphias gladius* for canning. With the development of the fresh tuna sashimi market and the discovery of higher value southern bluefin tuna stocks, effort concentrations began forming in the Southern Ocean (Stobberup et al., 1998; Ward and Elscot, 2000). The National Research Institute of Far Seas Fisheries (NRIFSF, Japan) maintains catch and effort data pertaining to the Japanese distant-water longline fishery. The Japanese dataset is generally considered the most comprehensive and accurate longline fisheries dataset of the major pelagic longline fishing nations.

Throughout the 1970s and 1980s reported Japanese effort in the Southern Ocean was maintained at around 100 million hooks per year, peaking at 126 million hooks in 1980 (Fig. 1a). Effort has since declined to around 60 million hooks per year, at least in part as a result of the imposition of restrictive catch limits on southern bluefin tuna. During the 2000 fishing season (1 April 2000–31 March 2001) the number of vessels targeting southern bluefin tuna was 199 (a 22% reduction from 1998). Of these vessels, 52 were on the high seas off Tasmania and New South Wales, 75 on the high seas off Cape Town and 72 in the southern Indian Ocean (Anon., 2001f). There have been marked seasonal changes in the fishery over time. While effort was spread relatively evenly throughout the year in the mid-1960s to early 1970s, the proportion of effort expended in the second (April–June) and third (July–September) quarters, began to increase into the late 1980s. During the 1990s, over 80% of the effort was concentrated in this period, with most of the remaining effort in the fourth quarter. This trend reflects the imposition of southern bluefin tuna catch limits and the fact that the Japanese quota year begins in April (the beginning of the second quarter). Historically, most effort in the southern bluefin tuna fishery was between 30 and 50°S, while in recent years effort has been more constrained between 35 and 45°S. Spatial effort concentrations have also changed over time, with large contractions in its extent. Effort within the southern central Indian Ocean, southwest Atlantic, east of New Zealand and southwest of Tasmania has dissipated, while concentrations off eastern and western Australia and southern Africa have strengthened (Fig. 2a,b; Polacheck and Tuck, 1995).

Japan, Taiwan and Korea have been the dominant distant-water longline fleets fishing in the southern Pacific Ocean since the early 1970s (Fig. 1b; Hampton and Fournier, 2000; Anon., 2001h). Japanese effort reached a peak in the Pacific Southern Ocean of over 50 million hooks in 1971 and declined to between 10 and 20 million hooks during the mid-1990s. Recent effort distributions of the Japanese fleet in the southern Pacific Ocean show strong concentrations in the Tasman Sea, but little to the east of 170°W in the Southern Ocean (Fig. 2b; Miyabe and Bayliff, 1998; Hampton and Fournier, 2000; Anon., 2001h).

The Japanese distant-water longline fishery in the Indian Ocean began in 1952. Effort was mainly north of 30°S during the 1950s, targeting yellowfin and albacore, however during the 1960s the fleet expanded over the whole of the Indian Ocean (Fig. 2a; Campbell et al., 1998). The spatial distribution of effort changed following the discovery of southern bluefin tuna stocks in southern waters, with strong concentrations forming off eastern South Africa and southwest of Australia (Fig. 2b). Japanese longline effort in the south central Indian Ocean had dissipated by the early 1980s (Fig. 2b; Anon., 1999a; Campbell et al., 1998). Japanese effort in the southern Indian Ocean peaked at just over 87 million hooks in 1985 and declined to between 20 and 50 million hooks per year since 1990 (Fig. 1c).

Japanese operations began in the Atlantic Ocean in 1956, though did not become prominent in the southern Atlantic Ocean until the early 1970s (Fig. 1d; Anon., 1999b). Estimates show approximately 220 vessels operating in the Atlantic Ocean in 2000 with bigeye representing 65% of the tuna catch. The main target fishery in the southern Atlantic is for southern bluefin tuna, with effort concentrations showing a strong band between 40 and 45°S and running from approximately 10°W into the Indian Ocean to 50°E (Fig. 2b; Anon., 2001d). Catch of southern bluefin tuna in the Atlantic Southern Ocean has ranged between 400 and 6200 t per

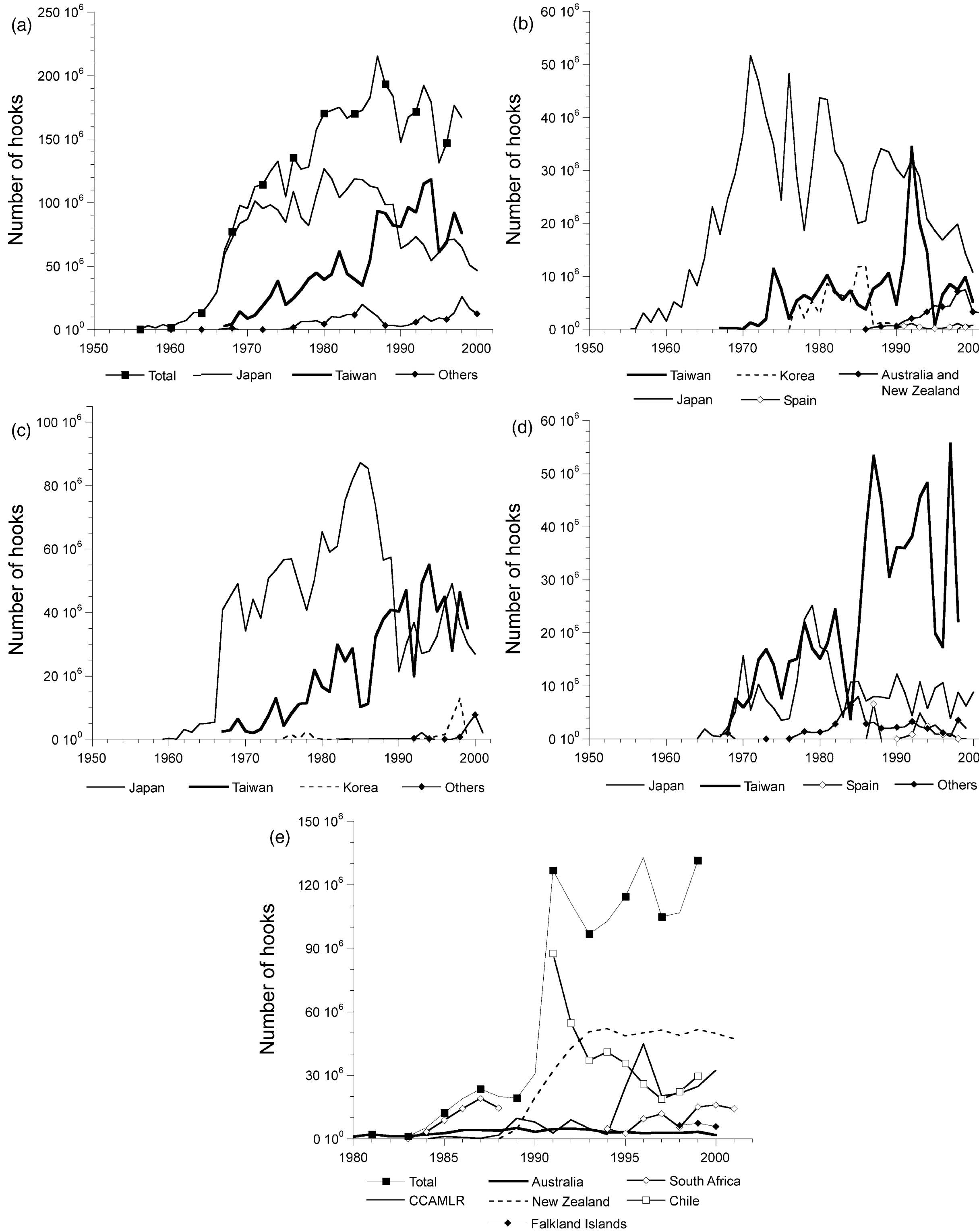

Fig. 1. (a) The annual reported hooks from pelagic longline fisheries in the Southern Ocean (south of 30°S). Due to recent data not being complete, total pelagic effort is only shown up to and including year 1998. (b) The annual reported hooks from pelagic longline fisheries in the Pacific Southern Ocean (south of 30°S; between 140°E and 70°W). (c) The annual reported hooks from pelagic longline fisheries in the Indian Southern Ocean (south of 30°S; between 20°E and 140°E). (d) The annual reported hooks from pelagic longline fisheries in the Atlantic Southern Ocean (south of 30°S; between 70°W and 20°E). (e) The annual reported hooks set from the demersal longline fisheries in the CCAMLR Convention Area and fisheries under the jurisdiction of Australia, New Zealand, South Africa and Chile since 1980. Due to recent data not being complete, total demersal effort is only shown up to and including year 1999. Effort from the artisanal dropline fisheries of Chile is not included. Source: CCAMLR, AFMA, MAFRI, WA Fisheries, New Zealand Ministry of Fisheries, the South African Department of Marine and Coastal Management, Falkland Islands Government Fisheries Department and Universidad Austral de Chile.

year, but in recent years is an area of less importance as far as southern bluefin tuna catch to Japan is concerned (Anon., 2001d). Effort peaked in southern waters in 1979 at just over 25 million hooks before declining to 4 million in 1983 and has remained between 4 and 12 million hooks per year since then.

Tori poles (poles with a streamer line attached to scare birds from the mainline during setting) were used voluntarily by Japanese fishers in the early 1990s and were made mandatory for vessels targeting southern bluefin tuna in 1997 (Anon., 1997). Other voluntary mitigation measures encouraged by the Fisheries Agency of Japan include the use of weighted lines and bait-casting machines, night line-setting and properly thawed baits. Educational material on how to avoid seabird capture is also distributed to fishers. Japan is also actively testing other mechanisms to avoid seabird bycatch, such as dyed baits, water-jets and experimenting with tori-line design.

Reports on incidental bycatch rates and the influence of mitigation measures used on longliners have been documented for Japanese vessels fishing within the Australian and New Zealand exclusive economic zones (EEZ) (Brothers, 1991; Murray et al., 1993; Baird, 1996; Klaer and Polacheck, 1997a,b; Takeuchi et al., 1997; Gales et al., 1998; Klaer and Polacheck, 1998; Baird and Bradford, 2000). Brothers (1991) estimated a catch rate of approximately 0.41 birds per thousand hooks from seven observed cruises during the winter of 1988 off Tasmania's east and south coast. Similar estimates of bycatch rate were found by Murray et al. (1993) within the New Zealand EEZ during 1988–1989. Approximately 4000 birds were estimated caught in 1989 in New Zealand waters (Baird, 1996). Bycatch rates and

(a)

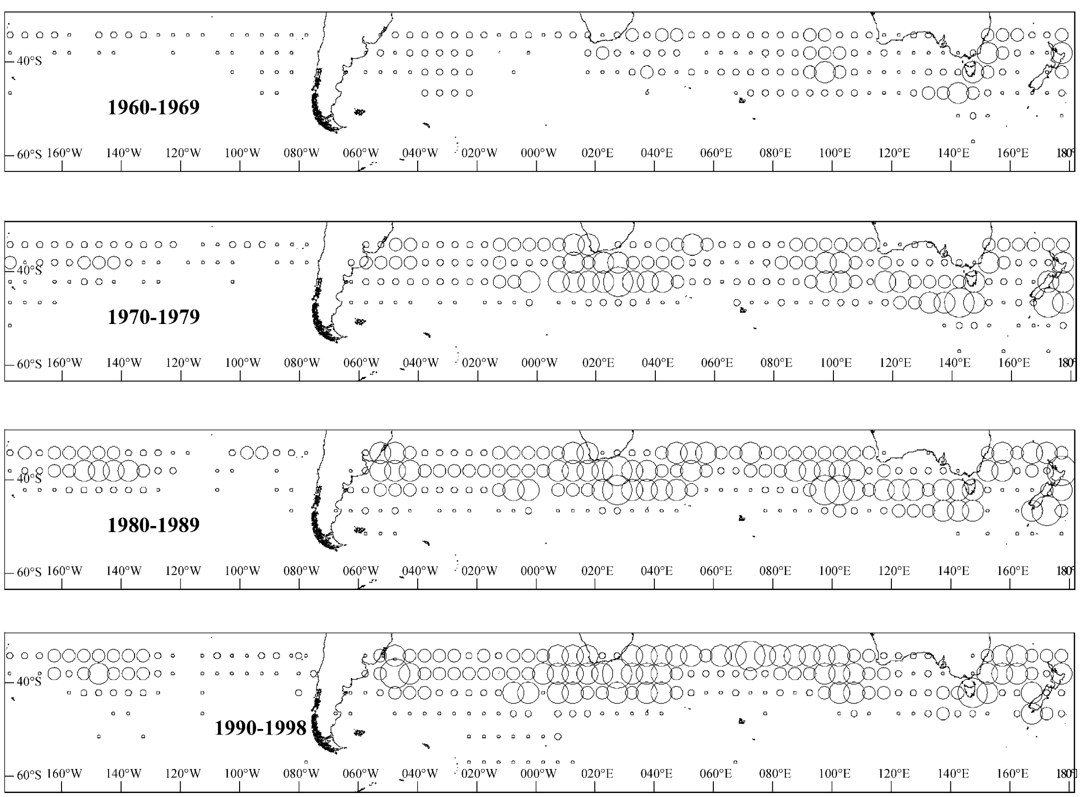

Fig. 2. (a) The spatial distribution of reported annual effort by five-degree square averaged across years 1960–1969, 1970–1979, 1980–1989, and 1990–1998, from pelagic longline fleets operating south of 30°S. Longline data are only that reported to the IOTC, ICCAT, SPC, IATTC, CCSBT and domestic New Zealand, Australian and South African fishery agencies. The circles represent levels of effort with diameter increasing according to the hook ranges: 1–10 000; 10 000–250 000; 250 000–1 000 000; 1 000 000–4 000 000; >4 000 000. (b) The spatial distribution of reported annual effort by five-degree square for year 1998 for all pelagic and demersal longline fleets operating south of 30°S for which spatially defined data were available. Shown are the distributions of pelagic effort for the longline fleets of Japan, Taiwan and all other nations combined. Pelagic longline data are only that reported to the IOTC, ICCAT, SPC, IATTC, CCSBT and New Zealand, Australian and South African fishery agencies. Demersal longline data are from CCAMLR (C2 dataset) and Australian, New Zealand, Falkland Islands and South African fishery agencies. Effort data at the five-degree square level for the Western Australian and New Zealand demersal fisheries were not available. As such whole-of-region information is presented. For WA this includes data west of 129°E and south of 30°S. For New Zealand the regions are displayed as northern (Fisheries Management Areas 1, 9, 10), southern (6), eastern (2, 3, 4), and western (5, 7, 8) areas. Effort data from the New South Wales demersal fishery and the substantial Chilean and Argentinean demersal fisheries are not included. The circles represent levels of effort with diameter increasing according to the hook ranges: 1–10 000; 10 000–250 000; 250 000–1 000 000; 1 000 000–4 000 000; >4 000 000.

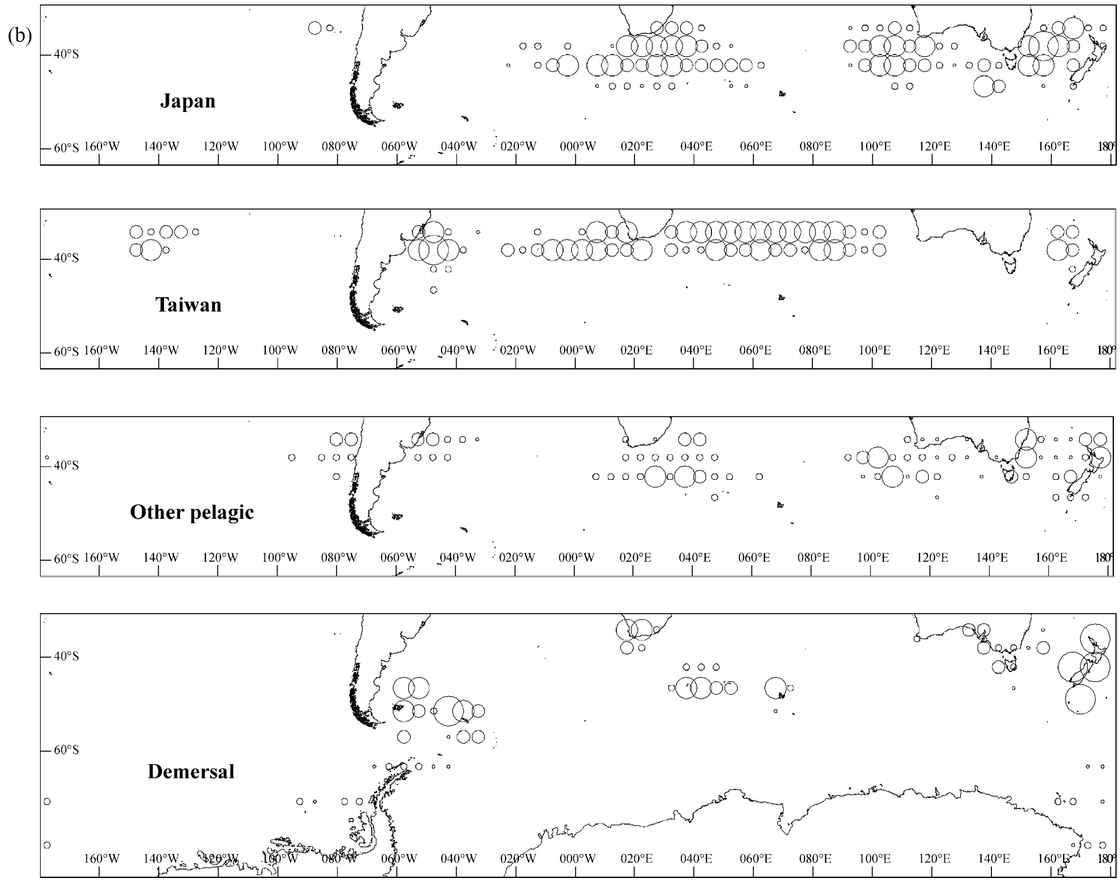

Fig. 2 (*continued*)

bycatch appear to have decreased since then. From 1992 to 1996 estimates of bycatch rate within the southern Australian EEZ varied between 0.1 and 0.3 birds per thousand hooks, with between 1000 and 3600 birds killed per year (Klaer and Polacheck, 1997b; Gales et al., 1998). The Japanese foreign fleet ceased longline operations within the Australian EEZ in 1997, coinciding with the largest estimated seabird bycatch rate of this fleet within the AFZ since 1988 (Baker et al., 2002). In New Zealand, bycatch rates ranged between 0.04 and 0.3 birds per set for 1991 and 1992 (depending on the area), with 629 and 185 birds estimated caught in each respective year (Murray et al., 1993; Baird, 1996). The decrease in estimated bycatch rate and total bird bycatch within the New Zealand and Australian EEZs from the late 1980s to early 1990s has been attributed to an increased use of bycatch mitigation devices and decreased effort (Klaer and Polacheck, 1997a; Brothers et al., 1999). It is also possible that seabird abundance has declined within the regions, however no quantitative assessments of seabird abundance are available to determine the contribution of changing abundances on seabird catch rates.

While the Japanese foreign fleet ceased longlining within the New Zealand EEZ in 1994/1995, approximately five Japanese vessels chartered to a New Zealand company have continued to fish in New Zealand waters since 1996/1997 (Baird and Bradford, 2000). These vessels have been fishing from March to August. Bycatch rates vary from year to year and differ depending on the area fished (Baird, 1996, in press). For the 2000 season bycatch rates varied between 0 (north western New Zealand) and 0.203 (north eastern New Zealand), with a catch rate of 0.03 birds per thousand hooks in the southern west coast area where most of the effort took place (Baird, in press). Recent declines in total bycatch have been attributed to the decrease in major operations within the EEZ and also the shift in effort from the northern east coast (East Cape), where catch rates appear higher, to the southern west coast (Baird, in press). Fig. 3a shows the annual reported effort of Japanese charter vessels in New Zealand waters.

The level of bycatch of seabirds on the high seas is largely unknown. For the Japanese fleet, the Real Time Monitoring Program (RTMP) was established in 1991 to provide improved information on catch and effort statistics and further biological sampling for the assessment of southern bluefin tuna stocks. The RTMP included an international observer program involving Australia, Japan and New Zealand on high seas longline

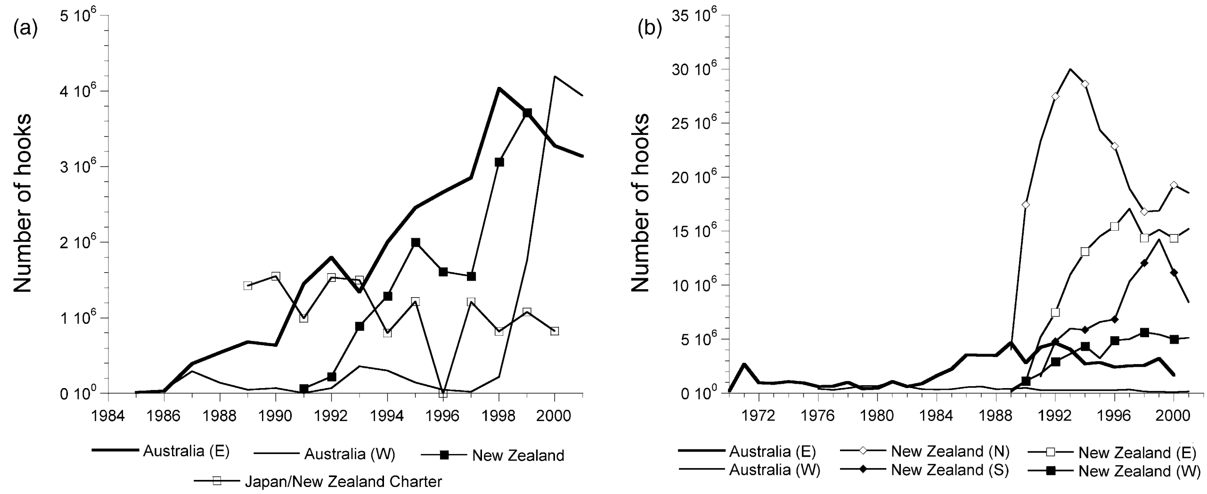

Fig. 3. (a) Annual number of hooks deployed south of 30°S by New Zealand domestic and Japan/New Zealand charter and Australian domestic pelagic fisheries. Australia (W) and Australia (E) refer to data west and east of 140°E respectively. Source: AFMA, New Zealand Ministry of Fisheries, and Baird (in press). (b) Annual number of hooks deployed south of 30°S by the Australian shark demersal longline fishery and New Zealand demersal longline fisheries. Australia (W) and Australia (E) refer to data west and east of 129°E, respectively. For New Zealand data, regions have been defined according to NZ Fisheries Management Areas (Baird, in press): North (Fisheries Management Areas 1, 9, 10), South (6), East (2, 3, 4) and West (5, 7, 8). Source: AFMA, MAFRI, WA Fisheries, and New Zealand Ministry of Fisheries.

vessels targeting southern bluefin tuna. In 1995, the objectives of the RTMP were expanded to include the collection of data on ecologically related species, including seabird bycatch and factors that may influence bycatch mitigation. The bycatch rate from observed vessels in that season averaged 0.28 birds per thousand hooks in the southeast Indian Ocean and 0.25 off South Africa (Anon., 1995; Polacheck and Betlehem, 1995). After 1995, the RTMP high seas observer program was changed to a national one run by Japan. Since then, estimates of seabird bycatch using data from high seas RTMP cruises have been provided to the Ecologically Related Species (ERS) working group of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Bycatch estimates (with 95% confidence intervals) for 1995, 1996 and 1997 for Japanese southern bluefin tuna operations between 35 and 45°S are respectively, 7223 (5787, 9225), 8649 (6923, 10 751) and 5551 (4294, 7100) (Takeuchi, 1998). The corresponding implied annual mean catch rates are approximately 0.25, 0.21 and 0.12 birds per thousand hooks. At this time, estimates since 1997 are not publicly available.

2.2. *Taiwanese distant-water longline fleet*

The Taiwanese distant-water fleet has increased in capacity markedly over the last decade and is currently one of the largest fleets fishing in the Pacific, Indian and Atlantic Oceans, with over 600 vessels operating worldwide (Haward and Bergin, 1996; Gunn and Farley, 2000). Effort in the Southern Ocean gradually increased from the late 1960s to over 40 million hooks per year by the mid-1980s (Fig. 1a). Effort then rose dramatically through the late 1980s and was often reported at over 80 million hooks per year. Reported Taiwanese effort south of 30°S peaked at nearly 120 million hooks in 1994. The main areas of concentration are in the central southern regions of both the Pacific and Indian Oceans and to the southwest of South Africa and east of Uruguay in the western Atlantic Ocean (Fig. 2b). Vessels are mainly targeting albacore, however the catch of southern bluefin tuna has more than tripled since the mid-1980s (Gunn and Farley, 2000; Huang, 2001). Gunn and Farley (2000) report that the number of large (>600 t), purpose-built longliners in the central Indian Ocean is increasing. These vessels appear to be replacing the smaller (300 t) traditional albacore longliners. The larger vessels are suspected of actively targeting southern bluefin tuna (Gunn and Farley, 2000). This increased capacity is also likely to have impacts on seabirds as more and larger vessels move into and sustain operations within southern waters. Gunn and Farley's (2000) monitoring of Taiwanese vessels in Port Louis (Mauritius) and Cape Town (South Africa) in the late 1990s also found that a large number of Taiwanese-owned vessels were operating under flags of convenience. Up to 15% of their global fleet of around 600 vessels could be operating as flag of convenience vessels. While the high seas fleet is being limited by the Overseas Fisheries Development Council of the Republic of China (OFDC) through the Council of Agriculture, the overflow of vessels in flag of convenience fleets could have significant implications for seabird bycatch in the Southern Ocean.

The Taiwanese longline fleet moved into the southern Pacific Ocean in the early 1970s, with effort remaining between 5 and 10 million hooks per year until the 1990s when a marked increase in effort is reported (Fig. 1b).

In 1992, reported effort had risen to over 30 million hooks, before reducing to between 6 and 8 million hooks per year in the late 1990s. The Taiwanese fleet shows a more central distribution (between 170 and 130°W) in the south Pacific than that of Japan, suggesting a greater relationship with the southern distribution of albacore than southern bluefin tuna. The central Tasman Sea is also an area of high concentration of Taiwanese effort in the South Pacific (Fig. 2b; Miyabe and Bayliff, 1998; Hampton and Fournier, 2000; Anon., 2001g,h).

Since the late 1980s the majority of Taiwanese catch of tuna and tuna-like species has been from the Indian Ocean (Haward and Bergin, 1996). The effort distribution of Taiwanese longliners in the Indian Ocean had generally been concentrated in the Bay of Bengal until the early 1980s when concentrations developed to the south of Madagascar. Further strong concentrations developed in the south central Indian Ocean (30–35°S and 60–95°E) and southeast of Africa (35–40°S and 35–50°E) during the early 1990s (Fig. 2b; Campbell et al., 1998; Chang, 2001). Approximately 100 vessels fish the south central Indian Ocean from June to September, mainly targeting albacore with a bycatch of southern bluefin tuna and other tunas. A smaller number of vessels (30–40) then move to the western Indian Ocean and into the eastern Atlantic from October to February (Lee et al., 1999; Gunn and Farley, 2000; Chang, 2001; Chang et al., 2001). The fishery to the east of South Africa is fished by between 20 and 30 vessels targeting southern bluefin tuna (Gunn and Farley, 2000). Reported effort in the southern Indian Ocean has progressively increased since the late 1960s, reaching over 55 million hooks in 1994 (Fig. 1c). While in general the Taiwanese Indian Ocean dataset is considered to be good, there are questions regarding the accuracy of the catch and effort statistics over the period 1990 to 1992 (Anon., 2001e).

Taiwanese distant-water longliners began expanding into the southern Atlantic Ocean during the early 1970s and, until 1986, annual effort deployed showed a similar magnitude to the Japanese fleet (between 10 and 25 million hooks per year). However, during the late 1980s Taiwanese effort increased dramatically, with over 53 million hooks reported in 1987. High levels of reported effort were maintained after this and while effort decreased in 1995 and 1996, reported effort increased to over 55 million hooks in 1997. The Taiwanese effort distribution in the Atlantic Southern Ocean shows strong concentrations to the southwest of South Africa (approximately 120 vessels) and off the coast of Uruguay and Argentina (Fig. 2b). These concentrations are further north (between 30 and 40°S) than areas fished by Japanese vessels, as the Taiwanese longliners are generally targeting albacore and not southern bluefin tuna (Gunn and Farley, 2000). Note that Taiwanese effort for 1994 south of 50°S reported to the International Commission for the Conservation of Atlantic Tunas (ICCAT) should be considered with due care (seen in Fig. 2a for years 1990–1998). This is due to the large recorded catch of albacore, which is generally not caught south of 45°S (Joseph et al., 1988).

Taiwan has recently introduced a scientific observer program for its high seas longline fleet that includes the reporting of seabird bycatch (D. Nel, personal communication). Taiwan also has a program of education for fishers to increase the awareness of seabird bycatch issues, and subsidises fishers to use tori lines (Chang et al., 2001; D. Nel, personal communication). Vessels are instructed to use the tori lines and set at night when fishing south of 30°S, and a reduction in bycatch rate has since been reported (from 0.15 to 0.036 birds per thousand hooks) (D. Nel, personal communication). However, catch rates and mitigation use have been poor in the recent past. Ryan and Boix-Hinzen (1998) report that, while all 25 Taiwanese longline vessels inspected in Cape Town in 1996 had tori lines, there was little uniformity in design and none met the design approved by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). None of the captains interviewed had had an observer on board and all expressed reservations about doing so. A survey of 60 distant-water vessels reported by Huang (2001) indicated that tori line use on Taiwanese vessels was poor (22% had used them), but that night setting, bait thawing and bait-casting machines were frequently used. There is very little information about seabird bycatch from Taiwanese longline vessels. Ryan and Boix-Hinzen's (1998) interviews suggest that bycatch may be substantial, with one captain reporting 100 birds caught in one day off Uruguay. Interviews with Taiwanese captains in the late 1990s documented in Gunn and Farley (2000) revealed that Taiwanese captains did not record seabird catches, and stated that they rarely caught seabirds. Further, the captains stated that most vessels do not use tori lines unless south of 35°S.

2.3. Korean distant-water longline fleet

The Korean tuna fishery began in the Indian Ocean in 1957 and spread to the Pacific Ocean in 1962 and the Atlantic Ocean in 1964 (Anon., 1980). The main target species have been the tropical tunas, yellowfin and bigeye. Globally, the Korean Indian Ocean fleet was strong until the late 1980s, when the Pacific Ocean took precedence (Haward and Bergin, 1996). Currently, there are major effort concentrations in equatorial regions, with concentrations in the Southern Ocean found in the eastern and western Indian Oceans, eastern Atlantic Ocean and central Pacific Ocean (Hampton and Fournier, 2000; Moon and Choi, 2001). The Ministry of Maritime Affairs and Fisheries (MOMAF) and the National Fisheries Research and Development Institute

(NFRDI) are responsible for the management and collection of fisheries related data. No information on seabird interactions with the Korean fleet was available at the time of production of this paper.

The Korean longline fleet began fishing in the southern Pacific region around 1966 (T. Lawson, personal communication). Through the late 1970s and early 1980s high levels of effort (between 5 and 10 million hooks per year) were expended in the central Pacific Ocean north of 45°S and off the east coast of New Zealand (Fig. 1b; Hampton and Fournier, 2000; Anon., 2001h). However, during the 1990s the Korean fleet concentrated its effort in more equatorial latitudes of the Pacific where bigeye and yellowfin were targeted (Anon., 2001h).

Reported effort in southern latitudes of the Indian Ocean was minimal until the 1990s when a small number of Korean vessels (one to three annually) began directing effort toward southern bluefin tuna (Ahn, 2001). These vessels moved south from more tropical latitudes, mainly during the winter months. By 1998 the number of vessels had increased to 19 (with over 13 million hooks set; Fig. 1c) and the vessels were fishing year-round. The annual Korean catch of southern bluefin tuna has decreased since 1998 with a decrease in vessel numbers targeting southern bluefin tuna (16 in 2000) as a result of voluntary regulation of the southern bluefin tuna fishery by the Government of the Republic of Korea (Ahn, 2001; Moon and Choi, 2001). Ahn (2001) states that until 1993 most Korean fishing operations for southern bluefin tuna were located in the southeastern Indian Ocean (35–45°S and 90–120°E). Thereafter, some operators moved to the southeastern Atlantic Ocean and southwestern Indian Ocean (30–45°S and 0–60°E). During the late 1990s fishing operations were concentrated in the southwestern Indian Ocean from March to September, with a shift to the eastern Indian Ocean from July to December (Fig. 2b; Moon and Choi, 2001). The quality of the Korean catch and effort statistics provided to the Indian Ocean Tuna Commission (IOTC) is poor. These data were not used during the 2001 Working Party on Tropical Tunas due to inconsistencies between database catch records and reported nominal catches (Anon., 2001e).

The Korean distant-water longline fleet has not played a large role in the Atlantic Ocean since the late 1980s, with a total catch of tuna and tuna-like species in the Atlantic of 292 t in 2000, compared to Japan, 35800 t and Taiwan, 50 000 t (Anon., 2001d). Reported Korean longline effort to ICCAT in the Atlantic Southern Ocean begins in 1967. Effort in southern waters was not substantial following this, apart from approximately 0.5 million hooks set in each of 1977 and 1978. After 1978 there is no reported effort until 1997. In 1999 just over 0.6 million hooks were reported. The catch of southern bluefin tuna reported to ICCAT, while small (62 t in 2000), increased substantially over the previous year (Anon., 2001d). According to Moon and Choi (2001), this catch was taken from the southeastern Atlantic from May to August.

2.4. Spanish distant-water longline fleet

The Spanish surface longline fleet targeting swordfish began fishing in the southeastern Pacific (FAO area 87) in 1990. Although the fishery was scientifically monitored from 1990, statistics based on a five degree square allocation are only available, at the present, from 1997 (Mejuto and García-Cortés, 2001). This fleet uses night sets to target swordfish in temperate and warm waters (mostly 17–18 °C sea surface temperature). Vessels mainly fish in the second half of the year but the fishing season is generally from April to December. Fishing areas were mostly east of 80°W and north of 40°S, although most of the fishing activity has traditionally occurred between 20 and 30°S (Fig. 2b; J. Mejuto and B. García-Cortés, personal communication). As such, Spanish effort in waters south of 30°S has not been great relative to other fleets and the overall Spanish fleet. Between 1997 and 2000 reported effort to the Inter-American Tropical Tuna Commission (IATTC) varied between 0.4 and 1.12 million hooks per year (Fig. 1b; J. Mejuto and B. García-Cortés, personal communication). Preliminary estimates of maximum nominal effort calculated from the total annual catch and annual mean catch rate (assuming 15% of the Spanish effort south of 30°S in the southeast Pacific, as reported for 1997) between 1990 and 1996 show between 0.174 and 1.12 million hooks per year (Fig. 1b; J. Mejuto and B. García-Cortés, personal communication).

Effort data for the Spanish surface longline fleet in the southwestern Atlantic (south of 30°S) reported to ICCAT indicates around 1 million hooks per year were set between 1991 and 1997, with the exception of 1993 and 1994 having 4.9 and 2.4 million hooks, respectively (Fig. 1d). Vessels were fishing throughout the year (with less effort in January and February) and mainly fishing north of 40°S and west of 30°W. While statistics of seabird bycatch from the Spanish fleet are not available, bycatch is likely to be minimal due to the preference for night setting. However, recognising the potential problem, the Spanish fisheries administration is considering implementing recommendations that follow those of CCAMLR for the prevention of incidental mortality (J. Mejuto and B. García-Cortés, personal communication).

2.5. Illegal, unreported and unregulated fishing of pelagic longline fleets

Increasing prices for tunas and billfish and restrictive catch quotas (for southern bluefin tuna for example) have led to the recent expansion of IUU fishing. These practices greatly undermine the ability of fisheries bodies to soundly manage target species and their ecosystems (FAO, 2001). In addition, as conservation measures designed to mitigate negative environmental interactions are unlikely to be adhered to, IUU fishing can be expected to have a substantial impact on target and bycatch species (SC-CAMLR-XX, 2001). As IUU fleets are particularly mobile, their ability to move between regions and avoid compliance measures is further reason for concern. By its very nature, IUU fishing catch and effort levels are difficult to estimate (further complicating assessments of impacted species). As such very little information is available on the IUU fleets, their catch and their effort distributions. Identifying illegal activity even by major oceanic body is problematic and estimates provided should be treated with due caution.

IUU fishing for bigeye in the Atlantic Ocean is believed to have begun in the early 1980s and increased substantially thereafter. Vessels flagged to Honduras, Belize, and Equatorial Guinea are thought to be responsible for the majority of the IUU catch of bigeye estimated by ICCAT (Anon., 2001d). Based on Japanese import statistics in 1998, of the nearly 72 000 t of bigeye caught by longline, 25 000 t was attributed to IUU fishing in the Atlantic. Although bigeye has a predominantly tropical distribution, areas of significant bigeye catch are found off the coasts of Uruguay and South Africa. Swordfish and northern bluefin tuna *Thunnus thynnus* are also subject to IUU fishing in the Atlantic (Anon., 2001d). To combat IUU fishing, trade documentation schemes have been established to monitor the import and export of northern bluefin tuna. Similar schemes will soon be established for bigeye and swordfish (Anon., 2002a).

The Indian Ocean has seen a marked increase in illegal fishing since the mid-1980s (Anon., 2000a). Large IUU longliners with deep-freezing capability flagged to Belize, Honduras and Equatorial Guinea, though mostly Taiwanese-owned, target albacore or sashimi species (Anon., 2000b). These vessels operate from ports in Mauritius, South Africa and Singapore (Anon., 2000b; Gunn and Farley, 2000). The estimated number of these vessels has increased from 17 in 1988 (when the first reports of a longliner flying a flag of convenience in the Indian Ocean were reported) to 141 in 1999. In 1999, the estimated unreported catch from large longliners in the Indian Ocean was 47 051 t. Of this unreported catch, the temperate water species albacore, swordfish and southern bluefin tuna respectively composed 10 546 t (compared to 39 389 t reported), 6898 t (32 851 t) and 692 t (12 326 t) (Anon., 2001a). Smaller longline vessels with operations based mainly in Indonesia, Malaysia and Thailand target the tropical tunas on trips lasting for a month or less. These vessels are almost entirely Taiwanese-owned (Anon., 2000b). Estimates from vessel records and port sampling programs in Malaysia and Thailand suggest around 34 000 t of unreported Indian Ocean tuna and billfish catch was landed by small fresh-tuna longliners in 1999 (Anon., 2001a).

Although the level of IUU fishing in the Pacific Ocean is uncertain, and there is the potential for considerable unreported catches, it is believed to be of less magnitude than that of the Atlantic or Indian Oceans. Trade documentation schemes are currently being considered by the Secretariat of the Pacific Community (SPC) for Pacific Ocean tuna species (Anon., 2002a,b).

Japanese import statistics of southern bluefin tuna suggest a low level of illegal fishing, which has decreased further since the introduction of the southern bluefin tuna trade information scheme in June 2000. However, the fishing activities of Honduras, Equatorial Guinea, Belize and Cambodia have been identified as diminishing the effectiveness of the conservation and management measures of the CCSBT. Catch reported in 2000 from the Philippines and Seychelles, believed to be Taiwanese flag of convenience vessels, was also of concern to the CCSBT (Anon., 2001a). The introduction to the CCSBT of Korea (October 2001) and to the extended CCSBT of Taiwan (August 2002) has reduced what would have been considered a large component of IUU fishing for southern bluefin tuna in the 1990s. Their membership should result in more controls on effort targeted at southern bluefin tuna and greater application of mitigation measures within their fleets.

The various commissions responsible for managing tunas in southern waters are considering several measures in additional to trade and catch documentation schemes in an attempt to reduce IUU fishing within their regions (Anon., 2000b, 2001a,c,d). These measures include sharing information about vessels that have been identified while IUU fishing, reducing fleet capacity, seeking the cooperation of flag states and ports, administering appropriate sanctions and increasing vessel monitoring and inspection systems (Anon., 2000b, 2001a). Many of these measures have been outlined in the FAO's international plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing (IPOA–IUU; FAO, 2001). The IPOA–IUU is a recent voluntary instrument whereby all states are encouraged to assess the level of IUU fishing within their area of jurisdiction and then implement measures to control the problem. No information was found on the real or potential impact of tuna IUU longline vessels on seabirds. However, the preponderance of Taiwanese-owned longline vessels allegedly involved in the pelagic IUU fleets and the anecdotal references to operational procedures and bycatch of Taiwanese vessels reported by Ryan and Boix-Hinzen (1998) and Gunn and Farley (2000) would suggest that the incidental mortality of seabirds from the pelagic IUU fleet could be substantial.

3. Longline fleets by region

Very little further information is available detailing long-term effort distributions and particularly seabird bycatch of the pelagic distant-water fleets of the Southern Ocean. Effort distributions for pelagic longline vessels targeting tunas and tuna-like species have been summarised for all fleets operating south of 30°S that provide data to the commissions responsible for the management of fisheries within the Indian Ocean (IOTC), Atlantic Ocean (ICCAT), and Pacific Ocean (SPC, IATTC). However, many local fisheries, which may also be setting demersal longlines, are not well represented in these datasets. The following sections describe by continental region the domestic pelagic and demersal longline fleets within these regions.

3.1. Longline fleets of Australasia

With the cessation of longline operations by the Japanese foreign fleet within the EEZs of Australia (in 1997) and New Zealand (in 1994/1995), the respective domestic fisheries expanded markedly (Fig. 3a; Baird and Bradford, 2000; Reid et al., 2001; Baird, in press). In New Zealand, domestic effort has increased north of 40°S where approximately 100 vessels target southern bluefin tuna and bigeye and to a lesser extent albacore and yellowfin (Baird and Bradford, 2000; Baird, in press). Vessels generally fish throughout the year in northern regions and during March–May targeting southern bluefin tuna in southern regions (Baird, in press). Fig. 3a shows the annual effort of domestic New Zealand vessels in waters south of 30°S. Domestic observer coverage on tuna longliners began in 1990/1991, peaked in 1995/1996 (8% observed of 2.3 million hooks), but has since declined to less than 0.5% of the more than 7.2 million hooks set in 1999/2000 (Francis et al., 2000; Baird, in press). Observer data in 1999/2000 were insufficient to provide estimates of bycatch for most areas other than the northern east coast, which showed a bycatch rate of 0.86 birds per thousand hooks (Baird, in press). As this region shows major concentrations of effort in the domestic pelagic tuna fishery, and is a known area of seabird abundance, the potential for substantial incidental takes of seabirds in this fishery is reason for concern.

Murray (2001) states that New Zealand regulations specify that all tuna longline vessels are required to use seabird-scaring devices, the minimum standard of which is that set by CCAMLR for tori lines. There is also a voluntary code of practice that encourages night setting, and for large tuna longline vessels (the Japanese charter vessels and a single domestic vessel) a limit on the total allowed bycatch of 'at risk' seabirds (Baird and Bradford, 2000). These large vessels have had 100% observer coverage in recent years. Coverage is likely to increase on the smaller domestic vessels in the future with changes in observer allocation (Murray, 2001).

Baird (in press) describes seabird interactions with the New Zealand demersal fishery for ling (kingclip) *Genypterus blacodes*. Longline fishing for ling began in the 1980s by small domestic longliners, but in the early 1990s the fleet expanded when several autoline vessels joined the fleet. In the 1999/2000 fishing year (1 October–30 September), nearly 30 million hooks were set by ling longliners. The greatest areas of concentration were to the west of the Chatham Islands (August–November) and south (November–December) and southeast (December–July) of the South Island in sub-Antarctic waters of the New Zealand EEZ between about 45 and 54°S (Baird, in press). Observers recorded 203 seabirds caught, with 19% of the 508 sets observed having seabird bycatch. The main areas of bycatch were from the southern and southwestern fishing regions. The majority of birds were caught between August and December, with most being petrels. A demersal longline fishery targeting snapper *Pagrus auratus* and bluenose *Hyperoglyphe antarctica* sets 1–2 million hooks per month in waters mainly to the north of the North Island. Effort in the New Zealand demersal longline fisheries has remained around 50 million hooks per year since 1993 (Fig. 1e and Fig. 3b).

The Australian domestic pelagic longline fishery for tunas and billfish began in waters off New South Wales during the 1950s (Larcombe et al., 2002). The fishery expanded in the mid-1980s to take advantage of Japanese markets, and in 1999 nearly 14 million hooks were set (Reid et al., 2001; Larcombe et al., 2002). However, much of this recent effort was north of 30°S. In southern latitudes, the fishery has been targeting bigeye and swordfish, and to a lesser extent southern bluefin tuna and yellowfin tuna (Campbell et al., 1998). For the east coast fishery, recent management restrictions on the allowable take of southern bluefin tuna as bycatch have led to a decrease in effort in southern waters. Recent effort in waters south of 30°S by the Australian east and west coast fleets has been approximately 2–4 million hooks per year (Fig. 3a).

Observer coverage on Australian domestic pelagic vessels has been very low, with less than 1% of effort observed over the last 5 years (A. DeFries, personal communication). However, observer coverage increased during 2002 in the east coast tuna and billfish fishery in order to monitor the effectiveness of two mitigation regimes in reducing bycatch rates. The experiment involved seven vessels using an underwater setting device, and 33 vessels using line weighting in combination with a double tori-line (M. Scott, personal communication). Data from these experiments have not been fully analysed, however a substantial bycatch of flesh-footed shearwaters *Puffinus carneipes* has been reported (B. Baker and B. Wise, personal communication). The Commission for the Conservation of Southern Bluefin Tuna has recently agreed that all members will conduct scientific observer programs on their southern bluefin tuna fishing fleets with a 10% level of coverage as the target (Anon., 2001a). As such the Australian Fisheries Management Authority (AFMA) is increasing observer coverage on Australian domestic longline vessels in the southern bluefin tuna fishery. Similarly, obligations under the Threat Abatement Plan (Environment Australia, 1998) have required the implementation of a number of seabird bycatch measures (night setting, offal management, bait thawing), complementing existing AFMA regulations introduced in 1995 requiring pelagic longline vessels to deploy tori lines when fishing south of 30°S (Reid et al., 2001). However, a recent survey of domestic fishers showed that about 67% complied with tori line use, 56% with line weighting and 26% with night setting (Baker, 2001). The domestic Australian fleet is thought to have a bycatch rate of about 0.1–0.2 birds per thousand hooks (Baker, 2001), although estimates ranging from 0.23 to 1.09 per thousand hooks have been reported based on a very limited number (10) of observed sets in 1994/1995 off the east coast (Anon., 1995; Whitelaw, 1995; Brothers and Foster, 1997).

Demersal longline fisheries in the south east of Australia are composed of the Commonwealth South-East Non-Trawl Fishery, mainly targeting ling, the Southern Shark Fishery targeting school shark *Galeorhinus galeus* and gummy shark *Mustelus antarcticus*, and small fisheries targeting scalefish within state waters (Larcombe et al., 2002). The shark longline fishery in southeastern Australian waters began in the late 1920s with longline catches reaching around 2500 t in the late 1960s. In the early 1970s gillnet began replacing longline as the preferred fishing gear for catching shark, and by 1999 the catch of school and gummy shark by longline had declined to 177 t (Punt et al., 2000, 2001; Larcombe et al., 2002). Until 1997 catch and effort statistics for the Southern Shark Fishery were collected by the South Australian, Victorian and Tasmanian fisheries agencies. The agencies passed all shark catch and effort data to the Marine and Freshwater Resources Institute (MAFRI). During 1997 the Commonwealth established a new logbook for shark fishers requiring them to submit their returns directly to the Commonwealth where the data is incorporated with other Commonwealth fisheries (McLoughlin et al., 2000). Effort statistics for the south eastern shark fishery were first collected in 1970 (Fig. 3b). Recent distributions of effort generally follow the southern Australian continental shelf (Fig. 2b) from south of the Eyre Peninsula (South Australia), eastward around southern Tasmania and north to Eden (New South Wales). The majority of effort in the south eastern longline fishery in recent years has occurred between September and January. Monitoring of the South-East Non-Trawl Fishery during 1999/2000 by AFMA recorded no seabird deaths from the 70 000 demersal longline hooks that were observed (A. DeFries, personal communication). However, seabird bycatch has been noted in the Australian demersal fisheries (Brothers et al., 1999) and the south east fishery is known to produce debris, including hooks and line, which may catch or entangle birds (Tilzey, 2000).

The demersal longline fishery for shark off Western Australia began in the 1940s, targeting gummy shark in waters south of Perth. Catches had reached approximately 400 t by the late 1960s before gillnetting took precedence in the early 1970s. Recent effort has concentrated in oceanic waters between Albany and Fremantle, with effort ranging between 0.1 and 0.2 million hooks set per year (Fig. 3b; R. McAuley, personal communication). The demersal (setline and trotline) fishery off New South Wales mainly catches gummy shark, carpet shark *Orectolobus* spp. and snapper. Reported effort in this fishery has declined from 11 432 days in the 1985/1986 season to 1849 days in 1999/2000 (New South Wales Fisheries Commercial Fishing Database; Tanner and Liggins, 1999, 2001). Hook counts are not recorded as a measure of effort in this fishery. While seabird bycatch has been observed, no data are available to quantify its level (D. Makin, personal communication).

3.2. Longline fleets of southern South America

Several nations target or have targeted tunas or billfish in waters south of 30°S in the southwestern Atlantic Ocean. These nations include Argentina, Panama, Uruguay, Brazil and Brazilian joint venture operations with Japan, Taiwan, Equatorial Guinea, Barbados, Belize, Portugal, USA and Honduras. Their combined reported effort to the ICCAT has remained below 10 million hooks per year since the mid-1970s (Fig. 1d). Very little long-term information is available for local South American longline fisheries.

Chilean commercial longliners in the eastern Pacific began directed fishing for swordfish within Chile's EEZ in the late 1980s. The fishery generally ranges between 19 and 33°S and because of government regulations to protect the artisanal fishery, beyond 120nm (Weidner and Serrano, 1997; Anon., 2001h; Ward and Elscot, 2000). Prior to 1996 most fishing was within Chile's EEZ however in 1996 fishing concentrated further north (at ~20°S) and outside of Chile's zone. The number of vessels targeting swordfish has declined substantially, from well over 100 in the late 1980s and early 1990s to about 20 vessels in 1997 and 1998. Longline vessel operations appear to respond to market forces and move between fishing locally for swordfish and more broadly for toothfish in sub-Antarctic waters (Ward and Elscot, 2000). A substantial artisanal fleet targeting swordfish also exists, but is dominated by driftnet vessels with only a few vessels deploying longlines (Weidner and Serrano, 1997). While Weidner and Serrano (1997) describe the potential impact of the swordfish fishery on various bycatch species, especially turtles, seabird bycatch was not listed. The more northerly distribution of sets and setting lines at night may contribute to a reduced incidence of seabird bycatch. However, of some concern is the anecdote from Ward and Elscot (2000) who state that Chilean fishers are known to seek seabird aggregations as being areas of good swordfish catch.

The Chilean industrial and artisanal demersal fleets operating in more southerly waters are also substantial. In 1999 approximately 29.5 million hooks were set in the industrial fisheries and a further 81.9 million hooks were set in artisanal fisheries (Fig. 4a; Garcia 2001). Fig. 4a shows the reported effort since 1991 in the Chilean demersal fisheries targeting toothfish, hake *Merluccius australis* and ling. The toothfish industrial fishery began in 1991, with vessels operating in waters between 47 and 57°S. Approximately 15 industrial longliners currently fish year round, apart from during 1 June to 31 August when a seasonal closure exists between 53 and 57°S (González et al., 2002). The artisanal fishery began in the 1970s, with catches peaking in the mid-1980s at 6000 t and remaining around 4000 t since then. Artisanal vessels are generally found north of 47°S to approximately 35°S, and within interior waters (C. Moreno, personal communication, González et al., 2002). As effort statistics for the artisanal fleet prior to 1991 were not available, annual landings of toothfish reported by González et al. (2002) are shown in Fig. 4b. Landings prior to 1991 should give a relative indication of the level of effort over time in the artisanal fishery for toothfish and an indication of the beginning of major operations. Note that catch data from the industrial fleet shown in Fig. 4b is only from latitudes between 47 and 57°S and within Chile's EEZ. The industrial fleet also directs their effort at hake from January to mid-March (González et al., 2002). The hake and ling fishery is concentrated between 41.5 and 57°S (Garcia, 2001). The artisanal fleet is a large component of this fishery, accounting for nearly 75% of the reported hooks set in 1999. Annual reported landings from industrial and artisanal fleets show a peak of 69 000 t of hake and 15 000 t of ling in 1988 (Fig. 4b). Catch for both fisheries has declined since then. As there is currently no observer program, there is little information about seabird bycatch from these vessels (Garcia, 2001). Rubilar and Moreno (2000) report that seabird bycatch in the artisanal hake fishery was 0.011 birds per thousand hooks estimated from the nearly 0.35 million hooks observed. Seabird bycatch is believed to be minimal in this fishery as the vessels use droplines or a series of droplines attached to a mother line that sinks rapidly. The artisanal toothfish fishery uses the same fishing method. Bycatch rates of both industrial and artisanal toothfish fisheries are currently under research (C. Moreno, personal communication).

Operations by Argentinean longline vessels on the Patagonian shelf have been reported by Schiavini et al. (1998). A longline fishery for hake *Merluccius hubbsi* and ling began in 1992, but moved to Patagonian toothfish in 1994. As effort statistics were not available, a relative indication of Argentina's level of effort targeting toothfish may be gained through a consideration of the production statistics reported to the FAO. Total production of toothfish by Argentina in waters outside of the CCAMLR region (FAO area 41; Fig. 5) is shown in Fig. 4b for years 1980–1999. This figure shows a marked increase in toothfish production between 1993

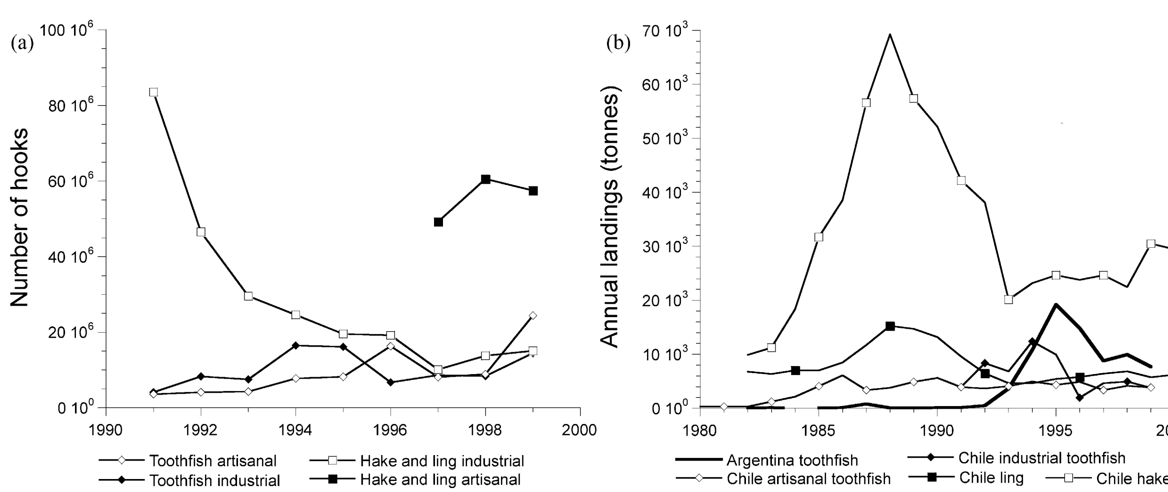

Fig. 4. (a) The annual reported number of hooks from the Chilean artisanal and industrial demersal fisheries for toothfish, hake and ling since 1991. Source: Universidad Austral de Chile. (b) Annual reported landings of Patagonian toothfish of Chilean industrial and artisanal fleets operating within their EEZ and landings reported to the FAO by Argentina for FAO area 41. Also shown are the reported landings of hake and ling from Chilean operations (industrial and artisanal fleets combined). Source: FAO, González et al. (2002), Anuarios estadístico de Pesca 1982–2001 Servicio Nacional de Pesca Ministerio de Economía, Republica de Chile.

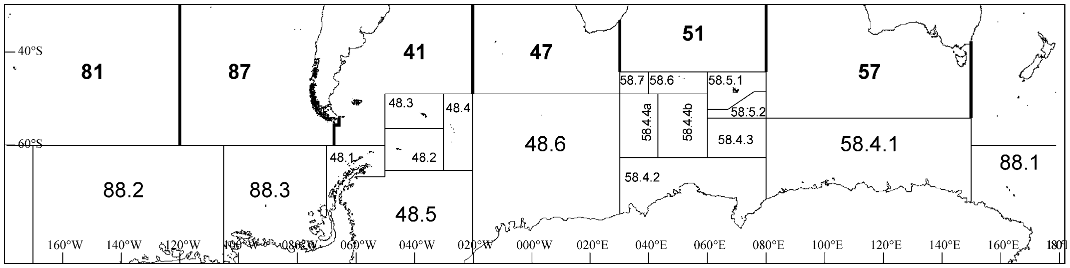

Fig. 5. Map of the Southern Ocean and Antarctica showing the boundaries of the CCAMLR statistical reporting areas and other FAO areas to the north (shown in bold).

and 1994, and a peak of nearly 20 000 t in 1995. Reported production since 1992 by Argentina of toothfish within the CCAMLR region (FAO area 48) has been less than 2% of that reported outside. Similar production figures for hake and ling were not available.

Between 1994 and mid 1995 Schiavini et al. (1998) estimate that 24 million hooks were set in Argentine waters within the southwestern South Atlantic (outside of the CCAMLR area). The main longlining areas were between 54–57°S and 50–67°W (toothfish) and between 43–50°S and 59–64°W (ling and hake) (Schiavini et al., 1998; Weidner et al., 1999). Reports of bird catch rates are variable, with anecdotal evidence suggesting that up to 50 birds per day per vessel or 10 birds per thousand hooks may have been caught in the longline fishery over this period. Estimates of bycatch for more recent years have declined. Gandini and Frere's (2001) estimates of seabird bycatch show 30–40 birds per day per vessel and 2–3 birds per thousand hooks, while estimates in 2001 are less than 1 bird per day per vessel (P. Gandini and E. Frere, personal communication). This recent reduction is believed to be due to a change in targeting to ling from the more southerly distributions of toothfish. Furthermore, the recent increase in the application of mitigation measures, and night setting for ling, would also have reduced the bycatch rate (P. Gandini and E. Frere, personal communication). In 2001 there were six vessels operating in Argentine waters, down from nine vessels in 2000 (Gandini and Frere, 2001), and 19 reported by Schiavini et al. (1998) in the mid-1990s. The total effort for the year 2001 up to October was just less than 22 million hooks (P. Gandini and E. Frere, personal commincation). While longline effort since the early 1990s has concentrated almost exclusively on the more profitable demersal fisheries (Fig. 4b), pelagic longline fishing for tunas and swordfish occurred during the 1960s and 1970s and to a lesser extent the 1980s (Weidner et al., 1999). Catch records reported to ICCAT for Argentine longliners targeting tuna and tuna-like species exist between 1960 and 1977, however, effort records are few. Less than 2 million hooks have been reported (during years 1967 and 1968 only). Vessels appeared to be targeting albacore and to a lesser extent swordfish and bigeye tuna.

Regulated longlining operations targeting toothfish in waters surrounding the Falkland Islands began in 1994. Prior to this, limited longlining targeting other species occurred, in addition to sporadic poaching by foreign vessels (J. Barton, personal communication). Effort recorded for years 1998, 1999 and 2000 was 6.25, 7.28 and 5.83 million hooks respectively. Concentrations of effort were mainly to the north east and south east of the islands and within the Falkland Islands Outer Conservation Zone (R. Grzebielec, personal communication; Fig. 2b). In 2001, there were five longline vessels registered, of which two fished locally (SC-CAMLR-XX, 2001). These vessels used a system of three to four tori lines in addition to several other voluntary mitigation techniques to reduce seabird bycatch. A program of full time observers was established in 2001 for Falkland Islands registered vessels. While bycatch rates on foreign owned longline vessels have been substantial, recent increases in mitigation use have greatly reduced bycatch (Brothers, 1995; SC-CAMLR-XX, 2001). However, total mortality associated with the local trawl fleet may be of a comparable magnitude to mortality due to longlining. Mitigation devices for these vessels are currently being tested (J. Barton, personal communication). Of great concern is the reported 25% decline in the Black-browed albatross *Diomedea melanophrys* population over the last 20 years (from 506 000 to 382 000 pairs). The population at the Falkland Islands represents 70% of the world population and the decline has been attributed to 'at-sea' factors such as the major regulated and unregulated longline fisheries of the Patagonian shelf and those fisheries reaching as far north as Brazil (Neves and Olmos, 1998; SC-CAMLR-XX, 2001).

The Uruguayan pelagic longline fishery was initiated in 1968 with the purchase of its first longliner (Weidner et al., 1999). Catches of tunas and swordfish were minimal through the 1970s until 1982 when joint venture operations began with foreign fleets. However, from 1986 to 1994 effort declined dramatically following the collapse of the joint venture agreements. Only one vessel was operating in 1991, compared with 15 in 1984 and 1985 (Stagi et al., 1998; Weidner et al., 1999). By 2000 effort had increased to nine vessels (Stagi, 2001). Reported effort from Uruguayan vessels to ICCAT exists between 1981 and 1987, during which a total of about 17.3 million hooks were reported. Of this, 14 million hooks were set during the years of joint venture operations from 1983 to 1985. Effort was mainly north of 40°S and west of 45°W. Swordfish was the dominant catch species, with smaller catches of bigeye, yellowfin and albacore tunas. High effort concentrations of all pelagic fleets reporting to ICCAT are found off the Uruguayan coast (a major area of upwelling) and high seas between 30 and 40°S and west of 40°W (Fig. 2b). During the period 1986–1998 between 10 and 30 million hooks per year were reported set in this region, mainly targeting albacore. Reported seabird bycatch rates on tuna vessels within Uruguayan waters have been quite large (up to 10.5 birds per thousand hooks in the early 1990s) but have recently reduced to less than 0.3 birds per thousand hooks (Stagi, 2001). A demersal fishery for rays and hake began with a single vessel in 1994 (Stagi et al., 1998). Although the bycatch rate is generally lower than that of the tuna fishery, many more hooks are being set. Observations in 1995 recorded catch rates of Black-browed albatrosses of up to 0.6 birds per thousand hooks (Stagi et al., 1998).

The pelagic and demersal longline fisheries of Brazil also are known to catch seabirds (Neves and Olmos, 1998; Neves, 2001). Demersal longline fishing targeting tilefish *Lopholatilus villarii*, namorado *Pseudopercis numida* and groupers *Epinephelus spp*. began in the early 1990s (Neves and Olmos, 1998). Neves (2001) states that this fishery is currently fishing between 23–34°S and 52–41°W and setting approximately 3.2 million hooks per day from 50 vessels. Estimates of seabird bycatch range between 2201 and 6226 birds per year (based on data between 1994 and 1997), with a bycatch rate of 0.10 to 0.32 birds per thousand hooks. The pelagic fishery targeting swordfish and other tunas fishes between 20–33°S and 51–39°W with 89 vessels in 2000 (up from 32 vessels in 1999). The annual estimated seabird bycatch from this fishery ranges between 4502 and 8325 birds, with a bycatch rate of 0.095–1.35 birds per thousand hooks. This bycatch rate is down from 3.82 birds per thousand hooks estimated by Vaske (1991) from observations of five winter cruises in southern Brazil. Neves and Olmos (1998) explain that this reduction is due to the current greater propensity to set at night (targeting swordfish and sharks) and that Vaske's study was only during winter, a period of greater seabird abundance in Brazilian waters. ICCAT records of Brazilian and Brazilian joint venture operations show between 1 and 5 million hooks set per year between 1978 and 1999 south of 30°S. Recent effort has concentrated north of 40°S and west of 30°W. Much of this effort is within the five degree block centred on 32.5°S and 47.5°W (Fig. 2b).

3.3. Longline fleets of southern Africa

In addition to the distant-water fleets of Japan, Taiwan and Korea, the southern waters surrounding Africa are also fished by French, Spanish and South African pelagic longliners. French and Spanish longliners are reported fishing in the western Indian Ocean but rarely south of 35°S. The French reported approximately 0.1 million hooks in total to the IOTC from southern latitudes over 1996–1997, and Spanish longliners targeting swordfish reported approximately 2 million hooks in total over the years 1994–1999. An experimental South African pelagic longline fishery began in November 1997 when thirty permits were issued. Although intended as a tuna-directed fishery, the fleet initially targeted swordfish, but by 2000 was concentrated on yellowfin tuna (Anon., 1999b; Ryan et al., 2002). The main fishing areas are along the shelf edge of the western Agulhas Bank and west coast, the east coast (east of Durban) and offshore in the eastern Atlantic Ocean along the Walvis Bay Ridge (Anon., 2001b). Total reported effort increased from 0.23 million hooks in 1998 to nearly 1.5 million hooks in 2000 (Fig. 6). While fishing occurs throughout the year, the main fishing periods have been during October through February and May through July. Catches are expected to increase as vessels, facilitated by the recent introduction of super freezers, move into international waters (Anon., 2001b). Approximately 17% of South African pelagic longline hooks were observed in 1999, with a mean bycatch rate of 0.77 birds per thousand hooks (Ryan et al., 2002).

In 1983, an experimental demersal longline fishery directed at deep-water kingklip *Genypterus capensis* stocks was initiated off the South African coast (Punt and Japp, 1994). From data recorded between the summer of

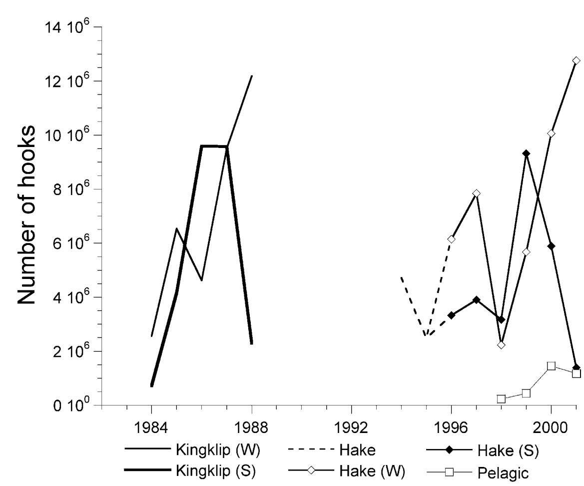

Fig. 6. The annual reported effort in the South African domestic demersal (kingklip, hake) and pelagic longline fisheries. The demersal effort for kingklip includes months November and December of the previous year. Year 1988 does not include data from months August–October. (W) and (S) refer to the west (west of 20°E) and south coast (east of 20°E) fisheries, respectively. From 1996 the displayed hake-directed effort has been split into the west and south coast fisheries. Source: the South African Department of Marine and Coastal Management, Japp (1989), Brothers et al. (1999).

1983/1984 and winter 1988, effort varied between 3.3 million hooks in the 1983/1984 season (1 November to 31 October) and 19 million hooks in the 1986/87 season (Fig. 6). Effort was concentrated during autumn and winter in the west coast fishery (west of 20°E) and then targeted late winter and spring spawning aggregations in the south coast fishery (east of 20°E) (Japp, 1989). However, the fishery was not sustainable and was closed in 1990 (Punt and Japp, 1994). A new experimental demersal fishery targeting Cape hakes (*Merluccius capensis* and *M. paradoxus*) began in 1994 (Barnes et al., 1997). Reported effort since the fishery was upgraded to a commercial fishery in 1996 has varied between 5.5 million hooks in 1998 and 16 million hooks in 2000 (Fig. 6). Recent effort concentrations follow the shelf edge off the west and south coasts (Fig. 2b). Catch rates of white-chinned petrels *Procellaria aequinoctialis* were substantial (0.44 birds per thousand hooks, 8000±6400 birds estimated killed annually) but have since declined as a result of increased use of mitigation measures (Barnes et al., 1997; Brothers et al., 1999). Between 15 and 20% of all voyages in the hake and tuna longline fisheries are currently monitored by onboard scientific observers (R. Tilney, personal communication).

4. The fishery for Patagonian toothfish within the CCAMLR region

4.1. The regulated fishery

The Patagonian toothfish is a large, long-lived, bottom-dwelling species inhabiting the waters adjacent to sub-Antarctic islands, oceanic ridges and continental landmasses. Patagonian toothfish is a highly prized table fish with significant imports to Japanese, North American and European Union markets. The fishery for Patagonian toothfish began in the mid-1980s in the South Atlantic Ocean. By the mid-1990s the fishery had expanded from the Falkland Islands and South Georgia to include the waters surrounding several sub-Antarctic Indian Ocean islands. The more southerly distributed Antarctic toothfish, *Dissostichus mawsoni,* is also targeted by some demersal longliners, but currently comprises less than 5% of the annual reported catch of *Dissostichus* species in the CCAMLR Area (Lack and Sant, 2001). Vessels fishing for toothfish are predominantly demersal longliners, however trawl operations have existed at the Kerguelen Islands and are exclusively used at Heard and McDonald Islands and Macquarie Island to avoid the incidental bycatch of seabirds to which longlining is prone (Wienecke and Robertson, 2002). The Macquarie Island fishery is managed by the Australian Fisheries Management Authority and does not fall within the jurisdiction of CCAMLR. However, management regulations for this fishery have adhered to or surpassed the principles set by CCAMLR.

The Commission for the Conservation of Antarctic Marine Living Resources is responsible for the management of Antarctic marine living resources that fall within the boundaries of the CCAMLR Convention Area, which is loosely defined as lying within the Antarctic convergence zone (Fig. 5). CCAMLR's management of Antarctic resources includes the managing and monitoring of fisheries and their ecosystems within the CCAMLR Area and reducing seabird bycatch in these fisheries. In 1994/1995 CCAMLR conservation measures were established requiring that every cruise targeting Patagonian toothfish within CCAMLR waters carry an observer. The observer's tasks include the monitoring of fishery operations, catch and ecosystem interactions. Vessels are also monitored for their compliance to CCAMLR conservation measures that attempt to minimise incidental mortality from longline fishing (Conservation Measure 29/XIX). Requirements under this conservation measure include the setting of lines at night, having appropriately weighted lines, thawing baits, and the use of a streamer (tori) line during deployment of the longline (Koch, 2001).

The demersal longliners of the Patagonian toothfish fishery generally set between 5000 and 15 000 baited hooks per set. The majority of longline vessels in the legal fishery are from Chile, Argentina, France, UK and South Africa (Lack and Sant, 2001; SC-CAMLR-XX, 2001). Fig. 7 shows the annual reported effort from the regulated fishery in each of the main areas managed under the CCAMLR conservation measures. The fishery surrounding South Georgia has been the principal area of fishing, with effort in Kerguelen waters showing a dramatic increase during the mid-1990s. Other regions with increasing levels of effort include Subarea 88.1 and Division 58.4.4 (Figs. 2b, 6 and 7).

While the impact of fishing on toothfish stocks has been substantial, there is also a significant bycatch of seabirds (Lack and Sant, 2001; SC-CAMLR-XX, 2001). The sub-Antarctic islands adjacent to the fishery are the breeding habitat for numerous populations of Southern Oceanic seabirds. The surrounding waters are essential foraging areas during their breeding stages and many species traverse widely across the Southern Ocean during juvenile and non-breeding life-stages. Table 2 shows the estimated bycatch of seabirds from the legal fishery within Subareas 58.6 and 58.7 (combined) and 48.3 between 1997 and 2000. There has been a marked reduction in bycatch for Subarea 48.3 since 2000. This has largely been due to the restriction of fishing to winter months (from 15 April–31 August to 1 May–31 August) and to improved compliance with CCAMLR's conservation measures. Restricting the season has avoided periods of high interaction with brooding seabirds. Other regions where the restricted season applies are

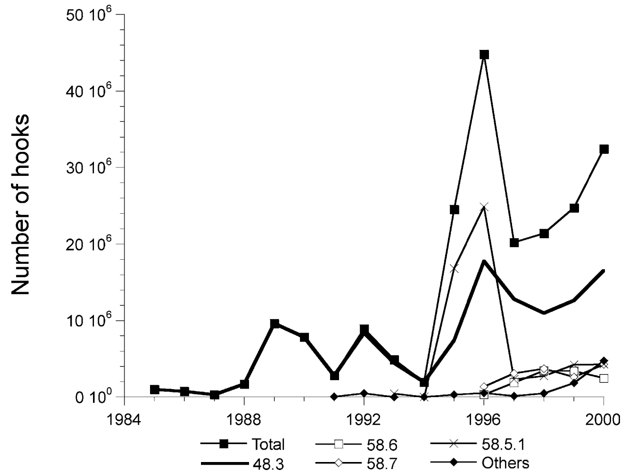

Fig. 7. The annual (calender year) number of reported hooks in the regulated fishery for *Dissostichus* spp. for each of the main CCAMLR Areas where longline fishing occurs. Data are taken from C2 and STATLANT databases of CCAMLR. Where discrepancies in monthly hook counts between these data sets occurred, the larger of the two was used to calculate the annual totals displayed. Data for the 'others' category includes a total of 2.8 million hooks from outside of the CCAMLR statistical reporting areas (FAO Areas 41, 47 and 51).

58.6, 58.4.3, 58.4.4, 58.5.1, 58.5.2 and 48.4. The increased level of bycatch for Subareas 58.6 and 58.7 in 2000 has been attributed to poor compliance with night setting conservation measures and an increased level of effort in close proximity to islands during the breeding season (SC-CAMLR-XIX, 2000). In the subsequent year, when bycatch decreased, compliance improved and vessels targeted seamounts further from the islands (SC-CAMLR-XX, 2001).

Fig. 8a–d shows the trends in annual reported effort from the pelagic longline fisheries for tuna and tuna-like species and that reported from demersal longline fisheries in the region surrounding key island breeding areas of Southern Ocean seabirds. Variations in fishing magnitude and relative importance of gear type are clearly evident. The areas surrounding the Crozet Islands and Prince Edward Islands show a strong regional link to the pelagic longline fleets of the Indian Southern Ocean. In contrast, the South Georgia and Kerguelen regions show little pelagic longlining occurring in close proximity to these islands.

Weimerskirch et al. (1997), Prince et al. (1998) and Nel et al. (2002b) suggest a strong link exists between the pelagic tuna fishery and the Crozet Islands wandering albatross *Diomedea exulans* population. During the 1970s and early 1980s the distribution of pelagic longline effort was in close proximity to the Crozet Islands (Figs. 2a and 8a), and corresponded to a period of rapid decline in the breeding population (Weimerskirch et al., 1997). During the same period, the South Georgia population declined at a much slower rate (Croxall et al., 1990). However, from the mid-1980s pelagic longline effort decreased around the Crozet Islands. This decline in effort, combined with minimal demersal longlining and the growing application of mitigating devices may, to some extent, explain the recovery in Crozet Island breeding pairs of wandering albatross (Weimerskirch et al., 1997; Tuck et al., 2001). However, recent information from within the EEZs of both the Crozet and Kerguelen Islands shows very large catch rates of seabirds (up to 8.5 birds per thousand hooks), mostly white-chinned petrels, from the expanding local fisheries for toothfish (SC-CAMLR-XX, 2001). The Patagonian shelf is a key foraging area for South Georgia wandering albatrosses and the recent increases in longlining off South America (including the large unregulated fishery), may be contributing to their continued decline (Croxall and Prince, 1996; Prince et al., 1998).

For the regulated toothfish fishery of the Prince Edward Islands, Nel et al. (2002c) state that increased implementation of mitigation measures, and effort directed further from the islands, may have led to the decrease in bycatch rates from 0.19 birds per thousand hooks in 1996/1997 to 0.034 in 1999/2000. Since then, bycatch rates have reduced further and in the 2001/2002 season were 0.001 birds per thousand hooks (B. Watkins, personal commication). Effort within the Prince Edward Islands EEZ increased from approximately 4.8 million hooks in 1996/1997 to 8.0 million hooks in 2000/2001, before declining to 2.9 million in 2001/02 (Ryan and Watkins, 2001; Nel et al., 2002c; B. Watkins, personal commincation). In addition, during 2001/2002 no deaths were reported from the 67500 hooks set outside of the EEZ in Area 51 and the 1.3 million hooks set in Area 47 by a South African flagged vessel (B. Watkins, personal communication). Nel et al. (2002a) describe recent major declines in populations of seabirds on Marion Island and suggest that the recent increases in Indian Ocean tuna longlining and local illegal fishing for toothfish could be contributing factors. Between 8500 and 18500 birds were estimated killed in the legal and illegal fisheries for Patagonian toothfish in waters surrounding the Prince Edward Islands between 1996 and 2000 (Nel et al., 2002c). However, Nel et al. (2002b) suggest that tuna longline fishing is the single most important factor threatening the wandering albatross populations due to the more northerly foraging distributions of the female wandering albatrosses during chick-rearing and non-breeding life-stages.

Table 2
The total estimated seabird bycatch from the legal demersal fishery for *Dissostichus eleginoides* in Subareas 58.6 and 58.7 (combined) and 48.3 from 1997 to 2001 (SC-CAMLR-XX, 2001)

CCAMLR area	1997	1998	1999	2000	2001
48.3	5755	640	210[a]	21	30
58.6, 58.7	834	528	156	516	199

[a] Excludes data from a line-weighting experiment cruise.

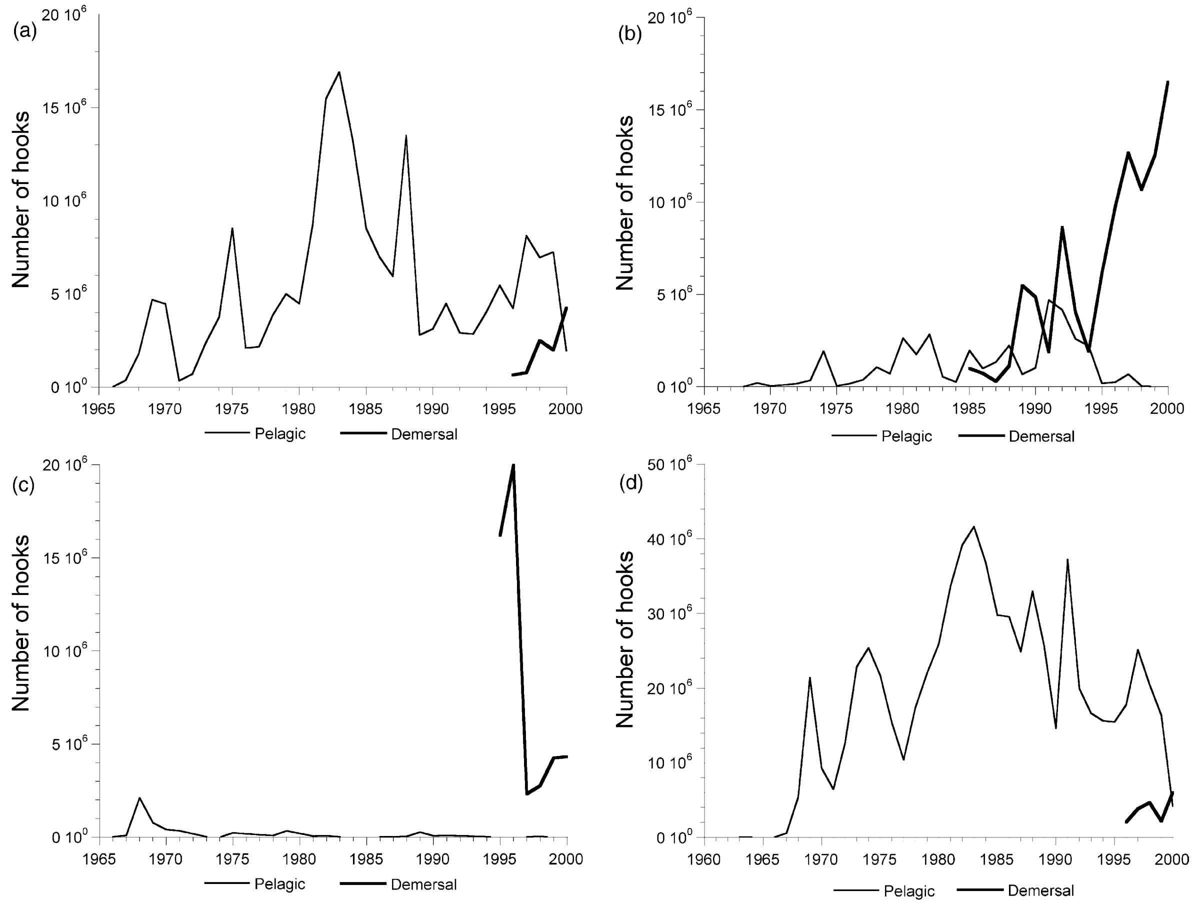

Fig. 8. (a) The annual reported hooks from pelagic and demersal longline fisheries in the region surrounding the Crozet Islands (35–60°S; 40–65°E). Demersal data are from the C2 dataset of CCAMLR. (b) The annual reported hooks from pelagic and demersal longline fisheries in the region surrounding South Georgia (40–65°S; 50–25°W). Demersal data are from the C2 dataset of CCAMLR. (c) The annual reported hooks from pelagic and demersal longline fisheries in the region surrounding the Kerguelen Plateau (40–60°S; 60–80°E). Demersal data are from the C2 dataset of CCAMLR. (d) The annual reported hooks from pelagic and demersal longline fisheries in the region surrounding the Prince Edward and Marion Islands (35–60°S; 25–50°E). Demersal data are from the C2 dataset of CCAMLR and may not include all records from Area 51, which falls outside of the CCAMLR statistical reporting areas.

4.2. Illegal, unreported and unregulated fishing of toothfish

The high value of toothfish has made it an attractive target of IUU fishing. IUU fishing in waters surrounding South Georgia is believed to have started in the late 1980s or early 1990s. IUU fishing began in other regions in the mid-late 1990s (Table 3).

The impact of IUU fishing on the stocks of toothfish is believed to be substantial. CCAMLR estimates suggest that IUU fishing may account for well over 30% of the recent total estimated catch (Table 4; Lack and Sant, 2001; SC-CAMLR-XIX, 2000). Estimates of IUU toothfish catch are based on vessel sightings and product landings and while clearly subject to large uncertainty are known to be substantial (Lack and Sant,

Table 3
The estimated date at which IUU fishing began in each CCAMLR statistical area (SC-CAMLR-XIX, 2000)

CCAMLR area	Associated island or bank	Sovereignty	Estimated start of IUU fishing
48.3	South Georgia	UK	1991[a]
58.6	Crozet Islands	France	April/May 1996
58.7	Prince Edward and Marion Islands	South Africa	April/May 1996
58.5.1	Kerguelen Islands	France	December 1996
58.5.2	Heard and McDonald Islands	Australia	February/March 1997
58.4.4	Ob and Lena Banks	–	September 1996

[a] Note that SC-CAMLR-XV (1996) shows IUU data from the 1989/1990 split year.

Table 4
Estimated catch and effort in the regulated and unregulated fishery for *Dissostichus eleginoides*, and estimated seabird bycatch from the unregulated fishery (SC-CAMLR-XVI, 1997; SC-CAMLR-XVII, 1998; SC-CAMLR-XVIII, 1999; SC-CAMLR-XIX, 2000; SC-CAMLR-XX, 2001)

Split year	CCAMLR area	Reported catch (t)	Estimated unreported catch (t)	Reported legal hooks (000s)	Estimated IUU hooks (000s)	Estimated IUU seabird bycatch
2000/2001	48.3	3259	300	12 634	996	1600–7500
	58.6	1476	660	5744	16 500	10 500–25 000
	58.7	732	150	5639	2344	1500–3500
	58.5.1	5215	3300	6091	13 983	8900–21 200
	58.5.2	1765	1649	0	6987	4500–10 600
	58.4.4	164	1540	2160	24 445	9300–22 300
	88.1	660	Probably low	3662	n.e.	n.e.
	Total	13 271	7599	35 930	65 255	36 300–90 100
1999/2000	48.3	4694	396	11 811	1238	1900–9300
	58.6	688	1980	3319	24 444	15 500–40 100
	58.7	720	220	4194	1692	1100–2600
	58.5.1	5009	2100	6167	8898	5700–13 500
	58.5.2	2579	800	0	3390	2200–5100
	58.4.4	0	1050	0	16 667	6400–15 200
	88.1	751	Probably low	2134	n.e.	n.e.
	Total	14 441	6546	27 625	56 329	32 800–85 800
1998/1999	48.3	4291	640[a]	10 979	2065	3000–16 000
	58.6	1912	1748	4381	19 200	12 000–29 000
	58.7	205	140	2107	1400	1000–2000
	58.5.1	5402	620	1583	6022	2000–4000
	58.5.2	5451	160	0	5611	500–1000
	58.4.4	0	1845	0	1845	3000–7000
	88.1	297	Probably low	1412	n.e.	n.e.
	Total	17 558	5153	20 462	36 143	21 500–59 000
1997/1998	48.3	3258	0	6085	0	0
	58.6	175	1765	826	13 450[b]	9000–20 000[b]
	58.7	576	925	n.a.		
	58.5.1	4741	11 825	215	53 786[c]	34 000–82 000[c]
	58.5.2	2418	7000	0		
	58.4.4	0	900	0	n.e.	n.e.
	88.1	41	Probably very low	242	n.e.	n.e.
	Total	11 209	22 415	7368	67 236	43 000–102 000
1996/1997	48.3	2389	0	7037	0	0
	58.6	333	18 900	816	53 792–73 846[b]	17 000–107 000[b]
	58.7	2229	11 900	n.a.		
	58.5.1	4681	2000	n.a.	n.e.	n.e.
	58.5.2	837	7200–12 000	0	n.e.	n.e.
	Total	10 469	40 000–44 800	7853	53 792–73 846	17 000–107 000

Note that legal catch from Divisions 58.5.1 and 58.5.2 includes that from trawl fisheries. Reported legal hook counts are taken from the STATLANT dataset of CCAMLR. No hook counts available in the STATLANT database = n.a., no estimate = n.e.

[a] The estimate of an additional 1920 t of catch from three vessels is not included (SC-CAMLR-XIX, 2000). The value of 640 t is taken from Table 55 of SC-CAMLR-XVIII (1997). Table 6 of the same report shows IUU catch of between 300 and 400 t.

[b] Estimate for Subareas 58.6 and 58.7 combined.

[c] Estimate for Divisions 58.5.1 and 58.5.2 combined.

2001). Table 4 shows the estimated regulated and IUU catch from the CCAMLR Area from the 1996/1997 split year (July–June) to the 2000/2001 split year by Subarea and Division. Table 5 shows estimates of IUU catch of toothfish from Subarea 48.3 (surrounding South Georgia) from 1989. Corresponding estimates of effort and seabird bycatch are also shown in Table 4. Impacts of IUU fishing on seabirds are thought to be greater than can be reasonably sustained by their populations (SC-CAMLR-XX, 2001). The estimates of seabird bycatch tabled here are minimums and maximums across the various assumptions considered in CCAMLR's analysis. The assumptions leading to these estimates are numerous and the annual reports of the

Table 5
The estimated IUU catches (t) of *Dissostichus eleginoides* from Subarea 48.3 and adjacent Rhine and North Banks between 1989/1990 and 1994/1995 (SC-CAMLR-XV, 1996)

CCAMLR area	1989/1990	1990/1991	1991/1992	1992/1993	1993/1994	1994/1995
48.3	345	565	3470	2500	6145	2870

Scientific Committee of CCAMLR should be consulted for the details of their derivation (SC-CAMLR, 1997–2001). The minimum estimate utilises a mean seabird catch rate from the regulated fishery and should be considered as a more central tending estimate of bycatch rather than a minimum. The maximum is based on the largest seabird catch rate from a cruise in the regulated fishery in 1997 (prior to more widespread application of mitigation measures). Estimates in 1996/1997 and 1997/1998 indicate that up to 100000 seabirds may have been taken as incidental catch from the unregulated fishery. Species composition estimates in the unregulated fishery for 1999/2000 show a potential bycatch of 7000–15 000 albatrosses, 1200–2300 giant petrels, and 19 300–36 700 white-chinned petrels (SC-CAMLR-XIX, 2000).

To help combat IUU fishing, the toothfish catch documentation scheme was introduced in May 2000 to assist the identification of the origin of toothfish entering world markets and ensure that catch is taken in accordance with CCAMLR conservation measures (Lack and Sant, 2001; SC-CAMLR-XX, 2001). Subsequent improved knowledge of the total catch by area has also assisted stock assessments. However, the scheme relies upon the cooperation of participating States to verify that the catch has been taken in an appropriate manner and the degree to which some States are complying with the regulations is uncertain (SC-CAMLR-XX, 2001). Also, in order to overcome the scheme's impositions, toothfish catch has allegedly been misreported from regions outside of the CCAMLR statistical areas, in particular Area 51 (Fig. 5; SC-CAMLR-XX, 2001; Anon., 2002a). These fish are believed to be from illegal longline operations within the Convention Area. The potential habitat of toothfish within Area 51 is likely to be relatively small, however in 2001, 12028 t were reported caught from this area. This compares to 3992 t from the key CCAMLR fishing grounds of Subarea 48.3 (Fig. 7; SC-CAMLR-XX, 2001). The scheme has also led to the introduction of a market with reduced prices for toothfish without verified toothfish documentation (Anon., 2002a). Further tools being considered to reduce illegal fishing are the increased use of vessel monitoring systems and listing toothfish under the Convention for International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Anon., 2002a).

CCAMLR reports that even though estimated catches of toothfish from IUU fishing, and hence effort, have decreased, this may be due to the increased prevalence of misreporting and high seas transhipment rather than a real decrease in IUU effort (Lack and Sant, 2001; SC-CAMLR-XX, 2001). Transhipment makes tracking of catches more difficult, and accordingly catches are underestimated by an unknown amount. Estimates of IUU toothfish catch and effort presented here are incomplete and should only be considered as an indication of the minimum potential effort expended while fishing for Patagonian toothfish in sub-Antarctic waters. While substantial uncertainties exist in the estimates of effort and bycatch, the potential for large, unsustainable impacts on seabird populations is reason for considerable concern (SC-CAMLR-XX, 2001).

5. Conclusion

Many Southern Ocean species of seabird have shown marked declines in abundance over the last three to four decades (Croxall et al., 1990; Gales, 1993; Weimerskirch et al., 1997; Nel et al., 2002a). The incidental catch of seabirds from longlines has been implicated in these declines (Brothers, 1991; Gales, 1993; Prince et al., 1998; Cooper, 2000; Nel et al., 2002b). Because many seabirds are long-lived, have low reproductive rates and show delayed maturity, any additional mortality can have a severe impact on their sustainability. To gain insights into the potential impact of longlining on Southern Ocean seabirds, an understanding of the historical and current distributions of longline effort and associated bycatch rates is important. This paper documents what is known of the effort distributions for the major longline fleets of the Southern Ocean. Where possible corresponding bycatch and bycatch rates of seabirds are discussed, along with measures taken by the fisheries to monitor and mitigate fishery induced mortality.

Since major operations in southern waters began in the early 1960s, the longline fleets of Japan and then Taiwan have dominated pelagic longline fishing for tunas and billfish across all southern oceans. Other nations such as Korea and Spain also have distant-water longlining fleets operating south of 30°S, but currently at a much smaller scale. Recent years have seen the expansion of local pelagic fisheries, largely within their exclusive economic zones, of Australia, New Zealand and South Africa. The pelagic fisheries' southern extent is typically to 45°S and directed at temperate water species such as albacore, swordfish and southern bluefin tuna. Pelagic longline vessels generally operate on the high seas, and the highly migratory habit of many species of seabirds, in particular albatrosses, often leads to interactions between these vessels and foraging birds. Demersal vessels pose an addition threat. The demersal longline fisheries for Patagonian toothfish, hake and ling rapidly developed during the 1990s. The fleets of Chile, Argentina, New Zealand and those fishing under the jurisdiction of CCAMLR are the principal operators in the Southern Ocean. As these vessels target finfish species that inhabit shelf and slope waters, they pose a serious threat due to their proximity to the breeding sites of many species of seabirds.

The spatial and temporal distributions of effort in the pelagic and demersal fisheries have changed markedly over time. These distributions also differ between fleets (often depending on target species) and within a fleet over a season. Apart from a period of increased Taiwanese activity in the early 1990s, the pelagic longline effort within the southern Pacific Ocean has declined markedly since the early 1970s. Effort in the southern Atlantic Ocean has remained high since the late 1980s, almost solely due to Taiwanese operations, while a reduction in Japanese effort in the late 1980s has coincided with an increase in Taiwanese effort in the southern Indian Ocean. Changes in the magnitude of effort and the major fleets of influence can have substantial implications for interactions with seabirds (Tuck et al., 2001; Nel et al., 2002b). For example, the decrease in Japanese effort in the southern Indian Ocean (showing a more southerly distribution than Taiwanese albacore operations) is believed to have influenced the recovery of Crozet Islands' wandering albatross populations (Weimerskirch et al., 1997; Tuck et al., 2001). However, these birds, and many other Southern Ocean populations, are now increasingly threatened by the expansion of demersal fisheries. It is also important to note that while some fisheries may be placing large numbers of hooks in the water, the actual total bycatch or species-specific impact may not be as substantial as other fisheries deploying less effort. This is due to the many factors that may influence bycatch rates (Brothers, 1991; Klaer and Polacheck, 1998; Brothers et al., 1999; Baird and Bradford, 2000). These factors include the type of gear used, time of day at which setting occurs, the application or otherwise of mitigation measures, and the season and areas fished. Impacts also differ depending on the particular species encountering the vessel. As such, assessing the potential impact on seabird populations from the hook counts presented in this paper should be considered with caution.

Recognising the overlap between distributions of effort and seabird abundance can have great beneficial consequences for minimising fisheries related mortality. For example, seabird mortality in the regulated demersal longline fishery at South Georgia has been virtually eliminated by modifying the time of fishing to avoid periods when birds are brooding (SC-CAMLR-XX, 2001). The introduction of bird-scaring devices, line-weighting and night setting has also greatly reduced seabird bycatch in longline fisheries. However, for successful management to occur, adequate systems of monitoring are required to identify and then mitigate potential areas of interaction. Unfortunately, while increases in monitoring effort have occurred, for many longline fisheries observer coverage is grossly inadequate (Cooper, 2000; Baird, 2001; Baker et al., 2002). Improvements in observer coverage have recently occurred or are planned for South African, Australian and New Zealand domestic fisheries as well as fleets fishing for southern bluefin tuna (Environment Australia, 1998; Anon., 2001a; Murray, 2001; R. Tilney, personal communication). However, the pelagic vessels of Korea and Taiwan and the demersal vessels of South America are poorly monitored and action to remedy this situation is imperative (Cooper, 2000; Baird, 2001). Where scientific observer programs exist, it is essential that tasks not only include the recording and validation of fishery-related information, but also monitoring interactions with bycatch species. It is critical that observer programs are designed and implemented to provide independent and representative information to avoid misinterpretation of results. Frequently, documentation on the details of design and implementation of observer programs is insufficient to evaluate whether the sampling design, selection of observers and choice of vessels to be observed is likely to provide robust and reliable estimates. In addition, most observer programs are conducted at the national level and access to data is highly confidential. This prevents transparent and independent review.

The quality of fishing effort statistics maintained by the responsible fishery agencies varied greatly. In some cases, made particularly obvious where fine-scale data were obtained, it was clear that records of effort were missing or, more rarely, duplicated. In this paper, wherever possible, duplications of effort (both within and between agencies) were removed, however missing records were not replaced with estimated values. As such, effort reported in this paper is likely to underestimate the true level. The absence of adequate fisheries monitoring from the initiation of fisheries, incomplete log-book records of effort, effort not reported in terms of hooks and the partial compilation of recent data all contribute to the underestimation of hook counts presented here. Long-term datasets for some fisheries were also not obtained (e.g. shark and ray fisheries of southern Africa and South America, the demersal fisheries of Argentina).

The deficiencies in the effort statistics outlined above are unfortunate but may be accounted for in some circumstances (as more data become available for example).

Of greater concern is the deliberate under-reporting and misreporting of effort, and effort in illegal fisheries. Attempts have been made to obtain information on IUU fishing, however it clearly has not been taken account of adequately within the figures presented here. Restrictive quotas and the high price for tunas and toothfish have led to a marked increase in IUU fishing since the 1990s. This uncontrolled effort is placing extreme pressure on target and incidentally caught species and undermines attempts to manage stocks in an ecologically sustainable manner. As illegal vessels are unlikely to be implementing bycatch mitigation measures to the same level as those regulated by conservation measures, the potential impact of these vessels on seabirds may be substantial. Increased naval patrols in sub-Antarctic waters have, to an extent, been effective at limiting illegal toothfish catch, but are hindered by the remoteness of the fishing grounds (SC-CAMLR-XX, 2001). Catch documentation schemes, such as those implemented by CCAMLR (toothfish), ICCAT (northern bluefin tuna), IOTC (bigeye tuna), and the CCSBT (southern bluefin tuna), have helped combat IUU fishing by improving the monitoring of imports and exports of species (Anon., 2002a). However, these schemes rely upon the cooperation of all States involved in the fisheries. In this regard, the FAO's IPOA-IUU provides several diplomatic and legal measures to diminish IUU fishing and urges all States to adopt these measures in a timely manner (FAO, 2001). Clearly, there is an urgent need to control illegal fishing in the Southern Ocean and a high priority should be given by all nations and regional fisheries management organisations to quantify the problem and develop and implement additional methods to reduce illegal fishing.

Several international policies to protect seabirds from incidental mortality associated with fishing have recently been developed or implemented (Haward et al., 1998; Cooper, 2000; Baker et al., 2002). These include the listing of species under the appendices of the Bonn Convention (the Convention for Conservation of Migratory Species of Wild Animals) the development of an Agreement on the Conservation of Albatrosses and Petrels (ACAP) and the FAO's International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA—Seabirds). While each vary in their focus, these instruments encourage countries to assess, monitor and mitigate seabird bycatch within their area of jurisdiction and cooperate efforts for those species that are migratory. Adoption of these instruments and the expeditious implementation of their guidelines should be seen as a high priority for all nations.

This paper has highlighted not only the extent and magnitude of longline fisheries in the southern waters, but also the deficiencies in management of some of these fisheries relating to both fishery and seabird bycatch monitoring and regulation. These deficiencies include the poor recording of effort statistics, a lack of adequate at-sea monitoring and an inability to control illegal fishing. While effort statistics presented in this paper will underestimate the true level, it is clear that longline effort in southern waters has increased markedly since the late 1960s and early 1970s. The total reported effort from all longline fleets is now well over 250 million hooks per year and has been since the early 1990s. In addition, recent substantial increases in illegal fishing have occurred in both the pelagic and demersal longline fisheries. Estimates of bycatch from IUU fishing for toothfish alone would suggest that current levels of seabird mortality are not sustainable (SC-CAMLR-XX, 2001). When combined with the impacts from regulated fisheries, some of which show either inconsistent use of mitigation measures or none at all, the long-term viability of many Southern Ocean species of seabird may be in jeopardy.

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