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Orea Anderson, Cleo Small, John Croxall, Euan Dunn, Ben Sullivan, Oli Yates, Andy Black

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REVIEW

Global seabird bycatch in longline fisheries

Orea R. J. Anderson[1,*], Cleo J. Small[1], John P. Croxall[2], Euan K. Dunn[1], Benedict J. Sullivan[1], Oliver Yates[3], Andrew Black[1,4]

[1]BirdLife International Global Seabird Programme, Royal Society for the Protection of Birds, Sandy, Bedfordshire, SG19 2DL, UK

[2]BirdLife International Global Seabird Programme, BirdLife International, Wellbrook Court, Girton Road, Cambridge, CB3 0NA, UK

[3]BirdLife International Global Seabird Programme, Casilla 145, La Serena, Chile

[4]*Present address:* Fisheries Department, Falkland Islands Government, PO Box 598, Stanley, FIQ 1ZZ, Falkland Islands

ABSTRACT: Bycatch in longline fisheries is believed to govern the adverse conservation status of many seabird species, but no comprehensive global assessment has been undertaken. We reviewed the extent of seabird bycatch in all longline fisheries for which data are available. Despite the many inadequacies and assumptions contained therein, we estimated that at least 160 000 (and potentially in excess of 320 000) seabirds are killed annually. Most frequently caught are albatrosses, petrels and shearwaters, with current levels of mortality liable to be unsustainable for some species and populations. Where realistic comparisons can be made, with data from the 1990s, there is evidence of substantially reduced bycatch in some key fisheries. Reductions stem from decreased fishing effort (especially in illegal, unreported and unregulated fishing in the Southern Ocean), and greater and more effective use of technical mitigation measures, notably in demersal fisheries. However, bycatch problems in other fisheries have also emerged. Current concerns include those with previously unidentified bycatch problems (e.g. Spanish Gran Sol demersal fleet) and those where bycatch was identified, but where persistent data gaps prevented adequate assessments of the scale of the impact (e.g. Nordic demersal fisheries). Future assessments will only achieve greater precision when minimum standards of data collection, reporting and analysis are implemented by longline fishing fleets and the relevant regional fishery management organisations. Those fisheries in which bycatch has been substantially reduced demonstrate that the problem of seabird bycatch could be reduced to negligible proportions by enforced implementation of appropriate best-practice mitigation devices and techniques.

KEY WORDS: Bycatch · Seabirds · Albatrosses · Global · Threats · Marine conservation

INTRODUCTION

Seventeen of the 22 species of albatross are threatened with extinction (IUCN 2010), with the key threat to most species recognised as incidental mortality (bycatch) associated with fisheries (Robertson & Gales 1998). A further 7 species of petrel (*Procellaria* and *Macronectes* spp.) listed under the Agreement on the Conservation of Albatrosses and Petrels (ACAP), face similar threats (ACAP 2009). All of these procellariiform species are extremely wide-ranging, and their distributions overlap considerably with areas targeted by the world's fishing fleets (BirdLife International 2004). Albatrosses and petrels, along with other seabirds, come into conflict with fisheries when they forage behind vessels for bait and fish waste. The incidental mortality of seabirds on longlines was first reported from bird band recoveries in the early 1980s

*Email: orea.anderson@rspb.org.uk

(Morant et al. 1983, Croxall et al. 1984), resulting from birds being caught and drowned on hooks while trying to snatch bait as the lines are set (Brothers 1991). More recently, the threat posed by trawl fisheries (whereby seabirds can become entangled in nets during shooting and hauling, or are killed by collision with warp cable as they forage behind the vessel) has also become apparent (Bartle 1991, Weimerskirch et al. 2000, Sullivan et al. 2006). Even in comparison with other seabird species, Procellariiformes are highly K-selected, so increases in adult mortality readily have significant adverse impacts on a population, several times more so than the loss of young birds (Croxall & Rothery 1991, Véran et al. 2007, Igual et al. 2009). However, quantifying the scale of the problem is difficult due to the diverse and remote nature of many of the world's fisheries, the lack of systematic reporting, and the nature of seabird bycatch rates themselves, which can be highly variable. Nevertheless, several reviews have concluded that recent and/or current reported levels of seabird bycatch are demographically unsustainable for the populations involved (Croxall et al. 1998, Tuck et al. 2001, Arnold et al. 2006, Barbraud et al. 2009, Thompson et al. 2009, Rivalan et al. 2010).

Historically, fishermen have had mixed relationships with seabirds. Aggregations of birds have been used to indicate profitable fishing grounds (Crawford & Shelton 1978), whereas catching non-target species, like seabirds, results in time lost through removing dead birds from hooks/nets, and fish catches foregone due to bait loss; these are detrimental to fishing activities and their economic efficiency. There is therefore, at least potentially, a common interest from conservation and fishery management perspectives alike in addressing this problem. In recent years, an effective response has emerged from the increasing variety and efficacy of technical measures designed to mitigate, and even eliminate, incidental catches of seabirds (e.g. Brothers et al. 1999, Bull 2007, FAO 2008, BirdLife International & ACAP 2009). Despite this, there is considerable evidence that many fisheries do not use recommended best-practice mitigation measures (e.g. FAO 2008), which likely results in rates and levels of bycatch which may not have changed substantially since the problem was first identified.

Despite bycatch in fisheries being the main contributory factor influencing the adverse conservation status of many albatross and petrel species, there have been few attempts either to estimate the full magnitude of the problem, or to indicate which data may be sufficiently reliable to provide baselines for future comparisons. While several papers have reviewed seabird bycatch rates in longline fisheries in various regions (e.g. Brothers 1991, Dunn & Steel 2001, Bugoni et al. 2008a, Rivera et al. 2008), only 1 attempt has been made to collate seabird bycatch data from longline fisheries on a global scale (Nel & Taylor 2003). Furthermore, that study focused only on fisheries catching globally threatened seabirds (i.e. those listed on the IUCN Red List in 2000), and did not attempt to estimate an overall global bycatch level. In addition, most of the data available to Nel & Taylor (2003) related to years prior to 2000. Considerable new data have been reported since then, and several new longline fisheries, thought likely to interact with seabirds, have commenced. All this makes a new and comprehensive review very timely. Such a review also needs to provide clear explanations of the interpretations and extrapolations inherent in working with sparse data provided in a wide variety of formats and with highly variable completeness and accuracy.

The present study aims to (1) review published and unpublished seabird bycatch data for longline fisheries worldwide and provide a comprehensive annotated archive of such information for future comparisons; (2) generate new estimates of seabird bycatch (including at a global scale) and compare these with previous reviews; (3) identify reasons for changes and emerging bycatch problems; (4) highlight continuing data gaps; and (5) indicate future challenges and provide recommendations for priority actions.

METHODS

Data on seabird bycatch. We reviewed the available published and unpublished literature on seabird and longline fishery interactions to obtain a comprehensive inventory of the most recent estimates (up to 2009) for seabird bycatch from longline fisheries around the world. All bird species caught on longlines were included in the review.

Where available, bycatch data from several years were combined in order to calculate an average number of seabirds caught per year in each fishery. Where changes in fisheries practice were obvious (e.g. implementation of new mitigation measures), data were selected to reflect the current situation, as far as data availability allowed.

In some cases, extracting relevant data was relatively straightforward. However, in many cases, assumptions, estimations and extrapolations were required. These are described in full in the Supplement (available at www.int-res.com/articles/suppl/n014p091_supp.pdf) for each fishery examined (see Table 1). Two important examples are as follows. Firstly, for fisheries where seabird bycatch rate data (usually expressed as birds per unit effort, BPUE) were reported, but only for a sample of a fishery (a common

event), these were scaled up to the level of the whole fishery using the relevant ratio of fishing effort. This assumes that bycatch rates are homogeneous across the areas and times in question. Secondly, for several key fishing fleets, no data are available on seabird bycatch. In those cases where bycatch rates were available from an analogous fishery (in terms of fishing method, target species and geographical area), and data were available on the magnitude and distribution of effort of the fishery in question, an extrapolation was made on this basis.

In order to provide some indication of the accuracy of the estimate of average number of birds killed in each fishery, a range around this figure was derived for as many fisheries as possible. Some sources included estimates of standard deviation or confidence limits around mean seabird bycatch rates. However, many did not or could not provide such estimates, and upper and lower ranges were more commonly available. Where range values were not provided in the source, these were calculated based on the upper and lower BPUE rates reported and the range in fishing effort across years (lower estimate = lowest BPUE × lowest total fishing effort; upper estimate = highest BPUE × highest total fishing effort). Where the required input variables were not available, no range was estimated. For estimating seabird bycatch associated with illegal, unreported and unregulated (IUU) fishing, data were taken from the review by the Marine Resources and Assessment Group (MRAG 2005).

Data reliability. We devised a measure to indicate how reliably the estimated values may reflect the true total seabird bycatch in each fishery. A scoring system was developed to account for the 3 main sources of error observed to occur within the datasets, each of which was scored as 'Poor', 'Medium' or 'Good'. The final classification of reliability was based on the lowest ranking in any of the 3 categories.

(1) Age of bycatch data: 1986–1994 = Poor, 1995–1999 = Medium, 2000–2009 = Good.
(2) Source of bycatch data: all bycatch data derived from another fishery = Poor; bycatch data partially derived from another fishery = Medium; all data derived directly from the fishery in question = Good.
(3) Accuracy: this reflects several different variables as follows: (i) the level of observer coverage from which a bycatch estimate was calculated (<5% = Poor, 5–20% = Medium, >20% = Good), where percent coverage is ideally defined as the proportion of hooks monitored relative to fleet fishing effort, but may also represent the proportion of sets or vessels monitored; (ii) the spatial and temporal extent of the observer coverage from which a bycatch estimate was calculated (low relative spatial and temporal coverage of observer effort = Poor; low relative spatial or temporal coverage of observer effort = Medium; high relative spatial and temporal coverage of observer effort = Good); (iii) the extent of spatial and/or temporal variability in the bycatch rates across the fishery, where known (i.e. high spatial and temporal variability = Poor; high spatial or temporal variability = Medium; low spatial and temporal variability = Good). Given that sources did not always report on all of these sub-categories, the overall score for 'Accuracy' was based on the sub-category into which the majority of variables (i) to (iii) fell. If only 2 sub-categories were reported on and their scores differed, an informed opinion was taken as to which category was most representative of the data source as a whole.

Comparison with previous reviews. Results were compared with the review by Nel & Taylor (2003). Since that study focused only on fisheries catching threatened seabird species (predominantly albatrosses and petrels), it did not cover all the fisheries discussed in our review.

Data verification. Data were split by country and/or region and sent to relevant seabird and fishery experts for review (see 'Acknowledgements').

RESULTS

The results of the review of seabird bycatch in longline fisheries are shown in Table 1. Data were collected on 68 fisheries, and cover those operating in exclusive economic zones (EEZs) as well as the high seas. Extrapolated data are indicated in Table 1 in square brackets. Full notes on how each estimate was derived are provided in the Supplement. In relation to the data reliability score, 15 estimates were scored as having a 'Good' level of reliability, 23 were scored as 'Medium', and 30 were scored as 'Poor' (see Table S1 in the Supplement).

The sum of the estimated average number of seabirds killed in the 68 longline fisheries in Table 1 equals ca. 160 000 seabirds killed globally each year in fisheries for which data are available. The 10 fleets with the highest levels of seabird bycatch are shown in Fig. 1 and include the Spanish hake fleet in the Gran Sol area, the Japanese pelagic tuna fleet in the North Pacific, the Namibian hake fleet and the Nordic demersal fleets. The data reliability score for 9 of the top 10 fleets was 'Poor'.

The sum of the upper ranges of the 68 fisheries equals ca. 320 000 seabirds killed per year. This value is heavily influenced by the Norwegian demersal fleet (estimated average of 6514 birds caught each year, but with an upper range of 101 380 birds yr^{-1}). Other fleets

Table 1. Current levels of seabird mortality associated with longline fisheries worldwide. IUU: illegal, unregulated unreported fishing; EEZ: exclusive economic zone; HS: high seas; IPHC: International Pacific Halibut Commission; IATTC: Inter-American Tropical Tuna Commission; ICCAT: International Commission for the Conservation of Atlantic Tuna; IOTC: Indian Ocean Tuna Commission; WCPFC: Western and Central Pacific Fisheries Commission. Fishery type – D: demersal; P: pelagic. Fishery scale – Ind: industrial; Art: artisanal. Target species: Al: albacore; Ba: bass; Bf: billfish; Bl: bluefish; Bn: bluenose; Br: bream; Co: cod; Do: dolphinfish; Fin: finfish; Gf: groundfish; Gr: grouper; Gu: gurnard; Had: haddock; Ha: hake; Hal: halibut; Hp: hapuka; Ki: kingclip; Ln: linefish; Li: ling; MM: mahi mahi; Rf: rockfish; Sa: sablefish; Sc: scalefish; Sh: shark; Sk: skate; Sn: snapper; SBT: southern bluefin tuna; Sw: swordfish; Ra: ray; To: toothfish; Tu: tuna; Tus: tusk; Wf: wreckfish. Reliability – P: Poor; M: Medium; G: Good. BPUE: birds per unit effort (in birds per 1000 hooks). Fishing effort (FE) is given in hooks yr^{-1} (or %, where indicated). Data in square brackets are extrapolated

Country	EEZ or HS	Location	Fishery type	Fishery active (mo)	Fishery scale	Target species	Mean FE	Range in FE	Observed FE	Mean BPUE	Annual total bycatch	Range in total annual bycatch	FE period	Bycatch data period	Reliability	Source
Angola	Both	S Angola, Benguela Current, S Atlantic	P	All	Ind	Tu, Sw, Sh, Gr, Ln	3500000		0	[0.07]	[245]		2000–2004	2004, 2006	P	Petersen et al. (2007, unpubl.)
Argentina	EEZ	Patagonian shelf	D	All	Ind	To, Ki	[1440000]			0.04	[58]		2009	1999–2001	M	E. Frere (pers comm.), Favero et al. (2003)
Australia	EEZ	Southern and Eastern Australia	D	All	Ind	Sc, Sh	6700000		270166	[0.001]	10		2007	2002–2005	M	Baker & Finley (2008)
Australia	EEZ	Eastern Australia	P	All	Ind	Tu, Bf	8443782		455964	0.0248	[209]		2007	2007	G	Baker & Finley (2008), Lawrence et al. (2009)
Australia	EEZ	Western Australia	P	All	Ind	Tu, Bf	1500000		200000	0.023	50		2004	2004	M	AFMA (2007), Baker et al. (2007)
Brazil	Both	SW Atlantic	P	All	Ind	Sw, Tu	9000000		788446	0.229	[2061]	[324–4878]	2006	2001–2007	M	Bugoni et al. (2008a)
Brazil	EEZ	Itaipava	P	Oct–Feb	Art	Do	497 boats	227–497 boats	40717	0.15		[Max. 9107]	2006	2001–2006	P	Bugoni et al. (2008b)
Canada	EEZ	Gulf of St Lawrence	D		Ind	Gf		[10000–20000 sets yr^{-1}]	5–10%	[0.0072]	[~150]	[~100–200]	2001	2001	M	DFO Canada (2007)
Canada	EEZ	Atlantic	D		Ind	Hal, Ha, Sk			3–10%	0.016	500			1986–1999	M	Cooper et al. in DFO Canada (2007)
Canada	EEZ	Scotia Shelf, Grand Banks	P		Ind	Tu, Sw			3–10%	0.032	1400			1986–1999	M	Cooper et al. in DFO Canada (2007)
Canada	EEZ	British Columbia (IPHC)	D	Mar–Nov	Ind	Hal	7515000		8.1%	[0.0071]	54		1999–2002	1999–2002	M	Smith & Morgan (2005)
Canada	EEZ	British Columbia	D		Ind	Rf	[4146000]		[5.9%]	[0.017]	72		1999–2002	1999–2002	M	Smith & Morgan (2005)
CCAMLR	HS	Convention Area (excl. sub–areas listed below)	D	All	Ind	To	30330900		[43%]	0	0		2007–2008	2007–2008	G	CCAMLR (2008)
CCAMLR	EEZ	French EEZ 58.6 (Crozet)	D	Sep–Aug	Ind	To	4524240		24.6%	0.0305	131		2007–2008	2007–2008	G	CCAMLR (2008)
CCAMLR	EEZ	French EEZ 58.5.1 (Kerguelen)	D	Sep–Aug (excl. Feb–Mar)	Ind	To	21134790		24.6%	0.0585	1244		2007–2008	2007–2008	G	CCAMLR (2008)
Chile	EEZ	NW Patagonia, S Chile, S Pacific	D		Art	Ha	1800000		330632	0.03	[54]		2002	1999, 2002	G	Moreno et al. (2006)
Chile	EEZ	NW Patagonia, S Chile, S Pacific	D		Art	To	19570000	17680000–21460000	88280	0.047	437		2002	2002	P	Moreno et al. (2006)
Chile	EEZ	S Chile, S Pacific	D	Sep–Dec	Ind	To	4137000		1508500	0	0		2006	2006	G	Moreno et al. (2008)
Chile	Both	FAO Area 87	P	Mar–Nov	Ind/Art	Sw	2500000		90000	[0.29]	[725]	517–923	2007	2007	M	Moreno et al. (2007)

(Continued on next page)

Table 1 (continued)

Country	EEZ or HS	Location	Fishery type	Fishery active (mo)	Fishery scale	Target species	Mean FE	Range in FE	Observed FE	Mean BPUE	Annual total bycatch	Range in total annual bycatch	FE period	Bycatch data period	Reliability	Source
China	HS	E Pacific Ocean	P	All	Ind	Tu	43289000		304390	[0.02]	[866]		2003	2003	P	Dai et al. (2006), IATTC (2006)
China	HS	Indian Ocean	P	All	Ind	Tu	35285000		0	[0.00]	[0]		2006	2002–2006	P	Xu et al. (2007), Huang et al. (2008c)
China	HS	W Pacific Ocean	P	All	Ind	Tu	26103000		96070	[0.00]	[0]		2001	2008	P	Dai & Zhu (2008)
Chinese Taipei	HS	Atlantic Ocean	P	All	Ind	Tu	112909000	59799000–160643000	15602000	0.0075	936	634–1364	2002–2006	2002–2006	M	Huang et al. (2008a)
Chinese Taipei	HS	Pacific Ocean	P	All	Ind	Tu	118206000	82978000–145106000	5348000	[0.045]	1660	544–2628	2002–2006	2002–2006	M	Huang et al. (2008b)
Chinese Taipei	HS	Indian Ocean	P	All	Ind	Tu	253412000	197793000–281473000	6407000	0.048	1512	332–3763	2002–2006	2002–2006	P	Huang et al. (2008c)
Faroes	Both	N Atlantic	D	All	Ind	Co, Had, Tus	153106000		0	[0.02]	[3062]	Upper range [10000]	1997–1998	1997–1998	P	Dunn & Steel (2001)
Iceland	Both	N Atlantic	D	All	Ind	Co, Had, Tus	367000000		0	[0.02]	[7340]	Upper range [20000]	2007	1996	P	Dunn & Steel (2001), ICES (2009)
Japan	HS	Mainly south of 20°S	P	All	Ind	SBT	[26361073]		[1607229]	[0.23]	[6299]	[1163–14182]	2006–2007	2006–2007	M	Minami et al. (2009)
Japan	HS	N Pacific	P	All	Ind	Tu, Sw			0		14540			1994–2000	P	Crowder & Myers (2001)
Korea	HS	E Pacific Ocean (IATTC waters)	P	All	Ind	Tu	36345000		51533	[0.02]	[727]		2004–2005	2004–2005	P	IATTC (2006), Moon et al. (2005)
Korea	HS	Atlantic Ocean (ICCAT waters)	P	All	Ind	Tu, Al	670000		0	[0.10]	[67]		2002–2006	2002–2006	P	ICCAT (2008), Huang et al. (2008a)
Korea	HS	Indian Ocean (IOTC waters)	P	All	Ind	Tu	2556115		0	[0.038]	[97]		2002–2006	2002–2006	P	IOTC (unpubl. data), Huang et al. (2008c)
Mediterranean	EEZ	Maltese waters	D	All	Art	Sh	[~1460 fishers]		146 fishers	1.41 fisher^{-1}	1220		2006	2006	P	Dimech et al. (2008)
Mediterranean	EEZ	Mediterranean	P	All	Ind	Sw, Tu, Al	19489389		0	[0.0133]	[259]	[40–448]	2002–2006	1999–2000	P	ICCAT (2008), Valeiras & Caminas (2003)
Namibia	EEZ	Benguela Current, S Atlantic	D	All	Ind	Ha	120000000		456000	[0.145]	20200	Upper range 30650	2000–2003	2006	P	Petersen (2008)
Namibia	Both	Benguela Current, S Atlantic	P	All	Ind	Tu, Sw, Sh	2900000	2500000–3500000	>30770	0.07	206		2002–2004	2004, 2006	P	Petersen et al. (2007, unpubl.)
New Zealand	EEZ	NE and SW EEZ predominantly	P	All	Ind	Tu, Sw	3719000		955519	0.196	715	567–883	2006–2007	2006–2007	G	Abraham & Thompson (2009)
New Zealand	EEZ	Campbell Plateau, Chatham Rise	D	All	Ind	Li, Bn, Hp, Ba, NZ Sn	38164000		2344205	0.026	1122	579–1777	2006–2007	2006–2007	M	Abraham & Thompson (2009)
Norway	Both	NE Atlantic	D	Winter	Ind	Had, Tus	[221613000]		760000	0.02	[4432]	[2216–8865]	2007	1996–1999	P	Dunn & Steel (2001), Løkkeborg (2003)
Norway	Both	NE Atlantic	D	Summer	Ind	Had, Tus	[90518000]		[126700]	0.023	[2082]	[1177–101380]	2007	1996–1999	P	Dunn & Steel (2001)
Peru	Both	Ilo, Callao, Salaverry	P	All	Art	Sh, MM	63250000		354222	0.0028	190		2002	2005–2006	P	Pro Delphinus (2006), J. Mangel et al. (unpubl.)
Peru	HS	12–18° S	D	All	Ind	To	[1017868]						2003		P	Goya & Cardenas (2003)
Russia	Both	W Bering Sea, E Kamchatka	D	May–Aug	Ind	Co, Hal, Rf	[69225000]		[2700000]	[0.092]	[6314]		2003–2004	2003–2004	P	Artyukhin et al. (2006)
Russia	Both	Sea of Okhotsk	D	May–Aug	Ind	Co, Hal, Rf	[26219000]		1100000	0.011	[288]		2004	2004–2005	P	Artyukhin et al. (2006)
South Africa	EEZ	Benguela Current, S Atlantic	D	All	Ind	Ha	30000000	15200000–43600000	450000–4000000	0.0075	225	107–327	2000–2006	2000–2006	M	Petersen (2008)

(Continued on next page)

Table 1 (continued)

Country	EEZ or HS	Location	Fishery type	Fishery active (mo)	Fishery scale	Target species	Mean FE	Range in FE	Observed FE	Mean BPUE	Annual total bycatch	Range in total annual bycatch	FE period	Bycatch data period	Reliability	Source
South Africa	EEZ	Indian Ocean (Asian fleet)	P		Ind	Tu	2846000		2846000	0.05	141		2008	2008	G	P. G. Ryan et al. (unpubl.)
South Africa	EEZ	Atlantic Ocean (Asian fleet)	P		Ind	Tu	341000		341000	0.103	35		2008	2008	G	Ryan et al. (2009)
South Africa	Both	S Atlantic, Indian Ocean (domestic fleet)	P	All	Ind	Sw	1300000	800000–2600000	9.8%	0.23	[299]	[176–624]	1998–2005	1998–2005	M	Petersen et al. (2007, unpubl.)
Spain	HS	E Pacific Ocean (IATTC waters)	P	All	Ind	Sw	6496008		2153000	0.04	[260]		2002–2003	1990, 1998–2005	P	Mejuto & Garcia–Cortes (2005), Mejuto et al. (2007a)
Spain	HS	W Pacific Ocean (WCPFC waters)	P	All	Ind	Tu, Sw	[4415260]		1129000	0.032	[141]		2005	1990–2005	P	Mejuto et al. (2007a,b), Lawson (2007)
Spain	HS	SW Indian Ocean	P	All	Ind	Tu, Sw	6546607		531916	[0.0056]	[37]		2006	2004–2005	M	Ariz et al. (2006), IOTC (unpubl. data)
Spain	HS	S Atlantic	P	All	Ind	Sw	2580000		[15602000]	[0.10]	[258]		2002–2006	2002–2006	P	ICCAT (2008), Huang et al. (2008a)
Spain	EEZ	W Mediterranean	P	All	Ind	Sw, Tu, Al	10864660		4786466	0.038	[413]	[33–989]	2000–2008	2000–2008	M	García–Barcelona et al. (2009)
Spain	EEZ	Columbretes Islands, Mediterranean	D and P		Ind	Ha, Br, Sw	4100000		[88812]	[0.425]	[1743]	656–2829	1998–1999	1998–1999	P	Belda & Sanchez (2001)
Spain	EEZ	Gran Sol, SW Ireland	D	165 d yr^{-1}	Ind	Ha, Br	[55860119]		238025	1.008	56,307		2006–2007	2006–2007	P	P. Arcos (SEO/BirdLife) (pers. comm.)
UK	EEZ	Falkland Islands (Islas Malvinas)	D	All	Ind	To	9355201		1693585 [18.1%]	0.002	16	8–24 [8]	2005–2006	2005–2006	M	Falklands Conservation (unpubl.)
UK	EEZ	South Georgia	D	Mar–Jul	Ind	To	16155379		100%	0	0		2008	2008	G	CCAMLR (2008)
UK	EEZ	Tristan da Cunha	P	All	Ind	Tu			0		[164]	[151–177]	1990–1998	1990–1998	P	Cuthbert et al. (2005)
UK	EEZ	Tristan da Cunha	D	All	Ind	Bl	[907454]		100%	[0.09]	[86]		2005–2008	1996–2008	G	N. Glass (pers. comm.)
Uruguay	Both	S Atlantic	P	Jan–Dec	Ind	Sw, Tu, Sh	1186243		648000	0.42	[498]	[130–2942]	2006	1998– 2004	M	Jimenez et al. (2009)
USA	EEZ	Alaska	D		Ind	All Gf (excl. Hal)	265431600			[0.019]	5138		2006	2002–2006	M	NOAA (2006)
USA	EEZ	Alaska	D		Ind	Hal	[35580316]		0	[0.0071]	[253]		2004–2010	1998–1999	P	IPHC (unpubl. data), Smith & Morgan (2005)
USA	EEZ	Alaska	D	All	Ind	Sa			21–52%		[78]			2002–2008	G	Heery et al. (2010)
USA	Both	NW Atlantic, Gulf of Mexico, Caribbean	P		Ind	Tu, Sw, Sh	8160000		4375000	0.027	230	139–333	2002–2006	1992–2004	M	Hata (2006)
USA	Both	Hawaii	P		Ind	Tu	33600000		100%	0.004	125		2005	2005	G	Clemens (2006), Rivera et al. (2008)
USA	Both	Hawaii	P		Ind	Sw	1300000		>20%	0.04	69		2005	2005	G	Clemens (2006), Rivera et al. (2008)
USA	HS	US West Coast	P	Sep–Jun	Ind	Sw, Tu			100%	0.23				2005	G	L. Enriquez (pers. comm.)
IUU	HS	South of 30° S	P		Ind	Tu, Sw					[4533]	[2739–6326]	2001–2002	2001–2002	P	MRAG (2005)

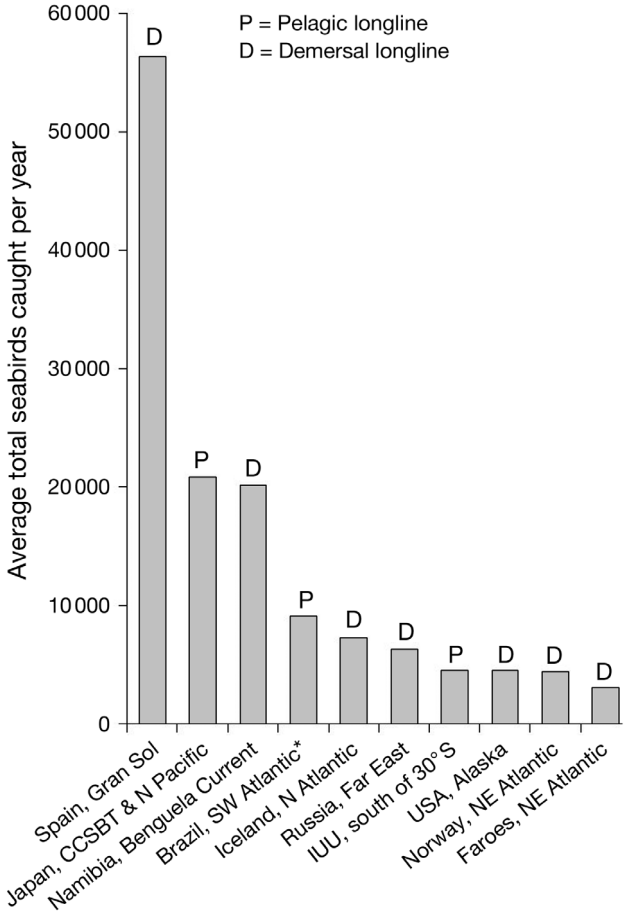

Fig. 1. Fishing fleets with the highest estimated average total numbers of seabirds killed per year. For further details on particular fleets, see the supplement at www.int-res.com/articles/suppl/n014p091_supp.pdf. The asterisk indicates the maximum total seabirds caught per year. Spain: Gran Sol, Northeast Atlantic hake fishery; Japan: Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and North Pacific estimates combined; Namibia: demersal hake fishery; Brazil: NW Atlantic pelagic fishery; Iceland: North Atlantic groundfish fishery; Russia: Far East groundfish fishery; IUU: illegal, unregulated and unreported pelagic longline activity south of 30° S; USA: Alaskan demersal fishery (excluding halibut); Norway: NE Atlantic groundfish fishery; Faroes: NE Atlantic groundfish fishery

with large ranges in estimates include the Icelandic, Faroese, Russian and Namibian demersal fleets.

It was not possible to calculate a lower range of the global estimate of seabird bycatch because of the type of extrapolations required by the data. For example, if a fishery reported variable bycatch rates of 0.00 to 0.44 birds per 1000 hooks, the lower estimate would result in an estimate of 0 bycatch, regardless of any variation in fishing effort.

Sources varied considerably in terms of availability of species-specific bycatch data, and a global estimate of numbers caught by species or species group was not possible. However, the data available indicate that the vast majority of birds caught in longline fisheries were of the albatross (Diomedeidae), petrel and shearwater (Procellariidae) families, along with some species of gulls and terns (Laridae), gannets and boobies (Sulidae) and cormorants (Phalacrocoracidae). Data indicate that northern fulmar *Fulmarus glacialis*, great shearwater *Puffinus gravis* and white-chinned petrel *Procellaria aequinoctialis* are among those caught in the highest numbers, notably in the Spanish (Gran Sol), Nordic, Russian and Namibian demersal fisheries. For fleets operating south of 20° S and in the North Pacific, albatrosses and *Procellaria* petrels form a larger proportion of the bycatch. While these species may be being caught in lower numbers, the impact on their populations may be greater, as a result of their very low reproductive rates and, in most cases, relatively small population sizes. For some of the burrow-nesting petrels and shearwaters, such as the great shearwater, population trends are virtually unknown, and there may be an impact of bycatch on their populations that is currently unrecognised.

DISCUSSION

Scale of global seabird bycatch in longline fisheries

This review indicates that total annual seabird bycatch in longline fisheries is likely to be in excess of 160 000 birds yr^{-1}, and could be as high as 320 000 birds yr^{-1}, based on the average and upper range estimates, respectively, of the longline fisheries for which there are data. It should also be noted that the data reliability score (largely governed by levels of observer coverage) for 9 of the top 10 fleets was 'Poor', the exception being the Alaskan demersal groundfish fleet. It is uncertain whether this would result in bycatch estimates that were typically too low or too high. Nevertheless, the sum of the average estimates is very likely to be conservative, not only due to remaining data gaps (outlined below), but also because observed bycatch rates significantly underestimate actual total bycatch (Gales et al. 1998, Brothers 2008). Brothers (2008) reported only 50% of all birds observed caught during line setting were retrieved when the line was hauled aboard because of dead birds dropping off hooks prior to hauling.

The impact of this loss, on an annual basis, is impossible to assess without detailed species-specific population data. However, previous species-specific studies have assessed bycatch as a threat to relatively common species, such as black-browed albatross *Thalassarche melanophrys* and black-footed albatross *Phoebastria nigripes* (Arnold et al. 2006, Véran et al. 2007). For

already highly globally threatened species, such as the Endangered Amsterdam albatross *Diomedea amsterdamensis* and the Critically Endangered Tristan albatross *D. dabbenena*, the impact of bycatch has been highlighted as a driving factor in population declines (Wanless et al. 2009, Rivalan et al. 2010). Greater understanding of species-specific impacts is vital. As an example, the Uruguayan pelagic longline fishery catches many fewer birds than the Spanish Gran Sol fishery. However, albatrosses make up >80% of all seabird bycatch in Uruguay (Jimenez et al. 2009). Many of these birds are wandering albatrosses *D. exulans* from South Georgia, and these losses alone are sufficient to account for much of the continuing (and recently increased) pattern of decline seen in South Georgia wandering albatross populations in recent decades (Croxall et al. 1998, Tuck et al. 2001, Poncet et al. 2006, Phillips et al. 2010).

Comparisons with previous estimates

Full details of comparisons with previous estimates from Nel & Taylor (2003) are provided in Table S2 in the Supplement, and key elements are summarised in Table 2. The comparison highlights changes that have occurred in some fisheries between the mid-1990s and mid-2000s. Where there have been decreases in total numbers of birds caught since Nel & Taylor (2003), the causative factors can be categorised as follows (these categories are also used in Table 2):

(1) Greater or more effective use of mitigation measures;
(2) Changes in fishing practices, particularly using gear or methods less likely to catch seabirds;
(3) Reduction in fishing effort within a particular fleet;
(4) Collapse of a particular fishery as a result of overfishing of target species;
(5) New data available with various and/or unidentifiable causative factors for decrease in bycatch (e.g. varying sample sizes, locations, methodologies).

Where there have been increases in total numbers of birds caught by a fishery, the causative factors can be categorised as follows (categories used in Table 2):

(6) No entry for the fishery in Nel & Taylor (2003) because of an unknown bycatch problem, but new data now available;
(7) No estimate for the fishery in Nel & Taylor (2003) because of a lack of data reportage, but new data now available;
(8) Increase in fishing effort within a particular fleet.

The main fleets for which there have been major decreases in bycatch between the 2 review periods include the following.

Demersal longline fleets operating in Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) waters. Seabird bycatch in the CCAMLR region has decreased substantially in recent years, predominantly due to a decrease in IUU demersal longline activity, which has in turn stemmed from increased enforcement and international policing of the region. The drop in IUU longline activity has led to a reduction in bycatch of ca. 67 000 birds yr^{-1} since the early 2000s. Meanwhile, bycatch in the regulated fisheries has also been substantially reduced, due to the implementation of a comprehensive suite of mitigation measures, including closed seasons (Croxall 2008).

New Zealand demersal ling fleet, South Africa licensed Asian pelagic tuna fleet and the US Alaskan demersal groundfish and Hawaiian pelagic tuna and swordfish fleet. These countries have implemented FAO National Plans of Action (NPoA-Seabirds) (Anon. 2001, 2004, 2008), which require the use of seabird bycatch mitigation measures backed up by observer programs. Comparisons with previous figures for the fleets of these 3 countries indicate a reduction in estimated bycatch of ca. 4000, 17 000 and 15 000 birds yr^{-1}, respectively.

Japanese distant water southern bluefin tuna *Thunnus maccoyi* fleet. The latest estimates point to a potential reduction in total seabird bycatch of ca. 11 000 birds yr^{-1} since estimates from the late 1990s and early 2000s. This stems from (1) a reduction in reported fishing effort from 43 million to 26 million hooks yr^{-1} and (2) a reduction in reported average bycatch rates from to 0.37 to 0.23 birds per 1000 hooks. However, the uncertainty surrounding the new bycatch estimate remains high, with an upper range of ca. 14 182 birds yr^{-1} (Minami et al. 2009).

Uruguayan pelagic industrial fleet for tuna, swordfish and sharks. The total fishing effort for this fleet appears to have declined considerably since the previous estimate (20 million hooks previously, 1.2 million hooks currently). The drop in estimated bycatch from ca. 6000 to ca. 500 birds yr^{-1} reflects this reduction in effort. The upper range on this estimate remains at ca. 3000 birds yr^{-1}.

Brazilian demersal hake and pelagic tuna and swordfish fleets. The collapse of the demersal hake fishery has led to a reduction of ca. 4000 birds killed each year. In the tuna fishery, the estimated number of birds killed per year has also reduced by ca. 4000, in this case as a result of new data and the implementation of mitigation measures. It should be noted that seabird bycatch in the Itaipava fleets is an issue that has emerged since previous estimates, and could amount to up to ca. 10 000 birds killed each year.

These results suggest an overall decrease in seabird bycatch of ca. 127 500 birds killed each year in the fish-

Table 2. Current and previous (Nel & Taylor 2003) estimates of numbers of seabirds killed per year in longline fisheries, with likely causes of change between the 2 periods. CCAMLR: Commission for the Conservation of Antarctic Marine Living Resources; IUU: illegal, unregulated, unreported fishing; IATTC: Inter-American Tropical Tuna Commission; EEZ: exclusive economic zone; WCPFC: Western and Central Pacific Fisheries Commission; UKOT: UK Overseas Territories. Fishery type – D: demersal; P: pelagic. NA: not available. HIMI: Heard and Macquarie Islands. Figures in square brackets are extrapolated from other data. Categories for 'Reason for change' are listed in the 'Discussion'. For further information see Table S2 in the Supplement at www.int-res.com/articles/suppl/n014p091_supp.pdf

Country	Location	Fishery type	Previous estimate	Current estimate	Reason for change
Angola	S Angola, Benguela current, S Atlantic	P	NA	245	6
Argentina	Patagonian shelf	D	1160	[58]	3
Australia	S and E Australia	D	NA	10	7
Australia	E Australia	P	NA	[209]	7
Australia	W Australia	P	NA	[30]	7
Brazil	SW Atlantic Ocean	P	6656	[2061]	1,5
Brazil	Itaipava	P	NA	[Max. 9107]	6
Brazil	SW Atlantic	D	4214	0	4,5
Canada	Gulf of St. Lawrence	D	NA	[70–327]	6
Canada	Atlantic	D	NA	500	6
Canada	Scotia Shelf, Grand Banks	P	NA	1400	6
Canada	Pacific	D	NA	54	7
Canada	Pacific	D	NA	72	6
CCAMLR	Convention Area (excl. sub-areas listed below)	D	14050	0	1,3
CCAMLR	Sub-areas 58.6 and 58.7 (Crozet & Prince Edward Islands)	D	10583[a]	131	1,3
CCAMLR	Sub-areas 58.5.1 and 58.5.2 (Kerguelen and HIMI)	D	43597[a]	1224	1,3
Chile	NW Patagonian region, S Chile, S Pacific Ocean	D	NA	[54]	7
Chile	NW Patagonian region, S Chile, S Pacific Ocean	D	NA	437	7
Chile	S Chile, S Pacific	D	NA	0	7
Chile	FAO Area 87	P	NA	517–923	7
China	E Pacific Ocean	P	NA	[866]	6
China	Indian Ocean	P	NA	[0]	6
China	W Pacific Ocean	P	NA	[0]	6
Chinese Taipei	Atlantic Ocean	P	NA	936	6
Chinese Taipei	Pacific Ocean	P	2945	1660	5
Chinese Taipei	Indian Ocean	P	NA	1512	6
Japan	Mainly south of 20ºS	P	[17242]	[6299]	3,5
Japan	North Pacific Ocean	P	14540	14540	–
Korea	East Pacific Ocean (IATTC waters)	P	NA	[727]	6
Korea	Indian Ocean, south of 20° S	P	NA	[97]	6
Korea	Atlantic Ocean	P	NA	[67]	6
Mediterranean	Maltese waters	D	NA	1220	6
Mediterranean	Mediterranean	P	NA	[259]	6
Namibia	Benguela current, S Atlantic	D	NA	20,200	6
Namibia	Benguela current, S Atlantic	P	NA	206	6
New Zealand	NE and SW EEZ predominantly	P	NA	715	7
New Zealand	Campbell Plateau, Chatham Rise	D	4958	1122	1,8
Peru	Ilo, Callao, Salaverry	P	3990	190	5
Peru	12–18° S Pacific Ocean	D	NA	NA	6
Russia	W Bering Sea, E Kamchatcka (Pacific)	D	NA	[6334]	6
Russia	Sea of Okhotsk	D	NA	[288]	6
South Africa	Benguela current, S Atlantic Ocean	D	NA	225	6
South Africa	Indian Ocean (Asian fleet)	P	[17427]	141	1,3,5
South Africa	Atlantic Ocean (Asian fleet)	P	as above	35	1,3,5
South Africa	S Atlantic, Indian Ocean (Domestic fleet)	P	[354]	[299]	1
Spain	East Pacific Ocean (IATTC waters)	P	NA	[260]	6
Spain	West Pacific Ocean (WCPFC waters)	P	NA	[141]	6
Spain	SW Indian Ocean	P	NA	[37]	6
Spain	S Atlantic	P	NA	[258]	6
Spain	W Mediterranean	P	NA	[413]	6
Spain	Columbretes Islands, Mediterranean	D,P	NA	[1743]	6
Spain	Gran Sol, SW Ireland	D	NA	56307	6
UK	Falkland Islands (Islas Malvinas)	D	40	[16]	1,3
UK	South Georgia	D	66[a]	0	1,2,3
UK	Tristan da Cunha, UKOT	P	NA	[164]	6
UK	Tristan da Cunha, UKOT	D	NA	[86]	6

(Continued on next page)

Table 2 (continued)

Country	Location	Fishery type	Previous estimate	Current estimate	Reason for change
Uruguay	S Atlantic	P	[6000]	[498]	3,5
USA	Alaska (groundfish)	D	16800	5138	1,5
USA	Alaska (rockfish)	D	as above	[78]	1,5
USA	NW Atlantic, Gulf of Mexico, Caribbean	P	NA	230	6
USA	Hawaii (tuna)	P	3268	125	1,5
USA	Hawaii (swordfish)	P	as above	69	1,5
IUU	South of 30°S	P	NA	[4533]	6

[a]Estimate comprised of Nel & Taylor (2003) entries for the regions regulated and unregulated (i.e. IUU fisheries) combined

eries listed above, driven both by the use of mitigation measures, changing fishing practices and reduction of fishing effort (Table 2). All of these fisheries overlap with albatross distributions, indicating potentially important reductions in the numbers of albatrosses being caught. However, for some species there remains the possibility that part of any decrease actually reflects diminished populations available to interact with longline fisheries, following a decade or more of unsustainable levels of bycatch. In other words, the proportion of a population being killed as bycatch may remain the same, despite reductions in the total numbers of birds being killed.

Emerging bycatch problems

Progress made towards seabird bycatch reduction in the fisheries listed above is tempered by new information concerning significant bycatch in other fleets. New bycatch data account for ca. 90 730 birds killed each year, all of which was previously unknown and/or unaccounted for in the review by Nel & Taylor (2003), and include the following.

Spanish demersal longline fishery (Gran Sol, North Atlantic). The highest estimated average annual mortality of seabirds in any fishery exists in the Spanish demersal longline fishery operating on Gran Sol, North-East Atlantic (ca. 56 000 birds yr^{-1}), based on data collected in 2006 to 2007. The majority of birds caught in this fishery are great shearwaters, a species not currently believed to have a declining global population (though few, if any, relevant data exist). Nevertheless, the sheer scale of the numbers caught is cause for concern. Further study is required to verify that the bycatch rate is routinely of this magnitude.

Namibian fleets. Seabird bycatch in Namibia did not feature in previous reviews due to an absence of data. The limited information now available points to large numbers of birds being caught by the demersal fleet. Petersen (2008) reported a potential bycatch estimate of ca. 20200 birds yr^{-1}. While the majority of this bycatch is thought to be petrels, albatrosses contribute ca. 600 ind. yr^{-1} to the total, which includes the Critically Endangered Tristan albatross.

Russian Far East demersal longline fishery. Seabird bycatch data from the Russian industrial demersal fleets operating in the Kamchatka region and the Sea of Okhotsk have only become available in recent years. Artyukhin et al. (2006) estimated that ca. 10 000 seabirds were killed in the fishery in 2003 and ca. 2745 seabirds in 2004, resulting in an annual average of ca. 6500 birds killed per year. Species caught include northern fulmar, slaty-backed gull *Larus schistisagus* and short-tailed shearwater *Puffinus tenuirostris*. No mitigation measures were reported in use, and bycatch rates varied considerably, both spatially and temporally. This variation may stem from low levels of observer coverage (3% of total effort in 2003), but could also relate to inter-annual variations in the distributions of seabirds and fishing effort.

Continuing data gaps

Globally, there remain many longline fisheries with insufficient data to assess seabird bycatch. Major data gaps remain for artisanal fleets, such as those in the Mediterranean, West Africa and Northwest Pacific, and many industrial fleets. Some of the main data gaps, for those fleets that have high spatial overlap with vulnerable seabird species, are summarised below.

North-East Atlantic demersal longline fleets. The large uncertainty over seabird (mainly northern fulmar) bycatch levels associated with Norwegian, Icelandic and Faroese demersal fleets in the North Atlantic reflects the fact that the bycatch estimates for all 3 fisheries are based on data collected from the Norwegian fleet over a decade ago. With upper range estimates of annual bycatch nearing 140 000 birds for the 3

fleets combined, it is essential that these fleets be adequately assessed for current bycatch rates, and for true impacts on the relevant seabird populations in the North Atlantic to be characterised. No estimates are currently available for demersal fleets from Greenland or the Barents Sea.

Asian distant water pelagic longline fleets. Significant uncertainty over longline-related seabird bycatch continues in relation to the large Asian distant water pelagic fleets. Data were available from Chinese Taipei fleets fishing in the Atlantic, Indian and Pacific Oceans, but few data were available for the Japanese fleet outside those reported to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT); few data are also available from the Korean and Chinese fleets (see the Supplement).

Mediterranean fleets. Cooper et al. (2003) highlighted the lack of seabird bycatch data available for the Mediterranean. The only rigorous scientific investigations to date have come from Spanish waters in the western Mediterranean (e.g. García-Barcelona et al. 2009). Elsewhere, there are thousands of vessels, mostly artisanal, fishing within the region, yet very little is known of their impacts on seabirds or other vulnerable species. The limited data available indicate that several species of shearwater, namely Balearic *Puffinus mauretanicus*, Yelkouan *P. yelkouan* and Cory's *Calonectris diomedea*, are caught in numbers that may prove to be unsustainable for the potential source populations concerned (Igual et al. 2009). The European Commission has recently taken steps towards an EU Plan of Action-Seabirds to reduce the incidental catch of seabirds in longline and other fisheries, which may stimulate further study of Mediterranean and other poorly documented fisheries within European waters, and may also recommend measures to curb the impact of distant water fleets registered to European states.

Humboldt Current fleets. The Humboldt Current is a particularly important over-wintering ground for several species of albatross that breed in New Zealand, as well as being a key part of the foraging range of the Critically Endangered waved albatross *Phoebastria irrorata* and of several other globally threatened species of *Procellaria* petrels from New Zealand and South Georgia. Bycatch and directed take (intentional hunting) are known to occur in this region, but few data are available to quantify the scale of the problem (Pro Delphinus 2006, Ayala et al. 2008).

IUU fisheries bycatch. Catch rates associated with IUU activity are inherently difficult to assess. Estimates for seabird bycatch in IUU longline fisheries in this review are only for latitudes south of 30° S (MRAG 2005). Although most threatened albatross and *Procellaria* petrel species occur south of 30° S, the potential that significant levels of seabird bycatch continue to occur in IUU fisheries north of this latitude cannot be discounted while such substantial data gaps remain.

Future challenges to improving bycatch estimates

Our review highlights 2 key issues that must be addressed before global estimates of seabird bycatch can be further improved: the lack of observer programs in certain key fleets and/or inadequate spatial and temporal coverage by onboard observer programs; and the need for standardisation in seabird bycatch data collection and reporting.

Increasing coverage by onboard observer programs. A significant number of longline fisheries remain for which no, or very limited, seabird bycatch data are available. Within those fleets, the number of hauled hooks observed is frequently <1% of total fishing effort, and such data as are collected commonly have inadequate spatial and/or temporal coverage of the fleet. To accurately monitor rates of seabird bycatch, observation of ≥20% or more of the hooks may be required (Ashford 2002, Lawson 2006), though in many cases having representative coverage of >5% would be a significant improvement. Sampling strategies must ensure that the observed hooks are spatially and temporally representative of the fishery.

Data collection, analysis and reporting standards. Inconsistencies in the formats of data reported currently hamper our ability to compare seabird bycatch rates between fisheries or over time. Best practice methods for collecting bycatch data have been elaborated (e.g. Dietrich et al. 2007), and establishment of agreed minimum standards for collecting and reporting bycatch data is vital to assist future assessment and mitigation efforts on the catch of non-target species (not just of seabirds), and to ensure transparency for all stakeholders. Based on this review, to allow comparison, reporting should include, at a minimum:

(1) The number of hauled hooks observed per year within the fleet and the proportion of total fishing effort that this represents;
(2) Information on the spatial and temporal distribution of observer effort within the fishery;
(3) The number of birds observed caught (including species identification and status, i.e. dead or alive) and a bycatch rate per thousand hooks;
(4) An estimate of total seabird bycatch along with a stated methodology as to how figures were derived.

CONCLUSIONS

We estimate that at least 160 000 birds (with an upper range of 320 000 birds) are killed each year in global longline fisheries. However, for almost all cur-

rent estimates, the absolute levels of seabird bycatch will be substantially higher (by as much as 50%) due to birds killed being unobserved or under-reported. Taking this and other identified data gaps into account, the true global level is likely to be substantially higher.

For those fleets for which seabird bycatch data have been reported, the fisheries with the highest levels of seabird mortality are the demersal fleets of Spain, Namibia, Norway, Iceland, Faroe Islands, Russia and Alaska, the distant water pelagic fleets of Japan and (potentially) the artisanal pelagic fleets in Brazil. The data reliability score for all of the aforementioned fisheries was 'Poor' (with the exception of the Alaskan demersal groundfish fleet, which was 'Medium'), indicating the need for further data as well as implementation of effective mitigation. While demersal fleets have some of the highest levels of bycatch, many pelagic fleets are also important due to the proportion of vulnerable albatrosses and *Procellaria* petrel species caught. Data gaps remain for a number of fleets (especially in the North Atlantic, Mediterranean and Pacific), and these urgently need to be addressed.

As most bycatch estimates, especially at regional and global scales, have considerable associated uncertainties, largely because of persistent fundamental deficiencies in data collecting and reporting, we cannot conclusively determine whether overall levels of seabird bycatch have increased or decreased in recent years. Nevertheless, there are a number of fisheries in which the overall level of estimated seabird bycatch has decreased significantly over the last decade. The single largest reported reduction is of ca. 67 000 birds yr^{-1} in CCAMLR fisheries. Major reductions have also been reported in USA, South Africa and New Zealand fisheries, mainly stemming from the implementation of effective mitigation measures. Reductions are also thought to have occurred in the Japanese southern bluefin tuna fleet and pelagic fleets operating off Uruguay and Brazil, mainly due to reduced fishing effort and some implementation of mitigation measures. These fleets have historically caught large numbers of vulnerable albatross populations, indicating likely important reductions in the number of albatrosses being caught. However, this may still be insufficient to redress population declines if the proportion taken from diminishing populations has not also decreased.

Since Nel & Taylor (2003), emerging bycatch problems have been identified in a number of fleets not previously documented, including the Spanish demersal fishery on Gran Sol (North Atlantic), the Namibian demersal longline fleet, the Russian demersal longline fishery in Kamchatka and the Sea of Okhotsk and (potentially) the artisanal pelagic longline fishery within the Brazilian EEZ. Some of these, such as the Namibian fleet, are also catching high proportions of *Procellaria* petrels and albatrosses. Others in the northern hemisphere are predominantly catching northern fulmars, shearwaters and gulls.

Furthermore, this paper takes no account of bycatch of seabird species (generally of very similar taxonomic composition) associated with trawl or gillnet fisheries, now recognised as contributing substantially to the global bycatch total, particularly in certain regions.

Previous studies have established that bycatch mortality for some seabird species (especially albatrosses and some petrels) is at levels that have potentially serious impacts, and in some cases are clearly unsustainable for known or likely source populations. Numerous seabird species are already globally threatened (sensu Red List Criteria of IUCN 2010), with longline interactions identified as the primary cause of many population declines. Continued bycatch mortality at current levels may well drive them to the brink of extinction.

Key recommendations emerging from this review follow:

(1) All relevant fisheries should implement, to minimum and consistent standards, systematic onboard observer programs to collect and report seabird bycatch information and should make such data available to all stakeholders in a timely and comprehensive fashion. There is an urgent need to collect bycatch data in those fisheries for which data are lacking or current data reliability is deemed 'Poor' (the latter includes 9 of the top 10 fleets identified in this review as having the highest levels of seabird bycatch globally). Regional fisheries management organisations have a key role to play in establishing such standards, notably by implementing the new FAO Best Practice Technical Guidelines for International Plan of Action-Seabirds (FAO 2008). Independently verifiable reduction in seabird bycatch should become one of the indicators of compliance with the UN Code of Conduct for Responsible Fisheries.

(2) Demersal fleets, particularly those in the Atlantic, account for some of the highest levels of current seabird bycatch. Considerable experience in other demersal fisheries indicates that such bycatch can be quickly and substantially reduced (at minimal cost to the fisheries concerned) to levels that pose a negligible threat to populations. The mandatory use of best-practice mitigation measures for the fisheries involved, using only measures of proven efficacy, should urgently be implemented in these fisheries.

(3) Seabird bycatch in a number of pelagic fleets is particularly significant due to the proportion of threatened albatrosses and *Procellaria* petrels being caught. This review has demonstrated substantial reductions in bycatch in some key pelagic fisheries.

Nevertheless, mitigation measures for pelagic fisheries are less well established than those for demersal fleets: some research is underway and more is needed to improve the design of measures such as line weighting and streamers lines. Additional research is needed to facilitate uptake of mitigation measures in these fisheries and to monitor the effectiveness of implementation with a view to adaptive management.

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Global seabird bycatch in longline fisheries

Orea R. J. Anderson[1,*], Cleo J. Small[1], John P. Croxall[2], Euan K. Dunn[1], Benedict J. Sullivan[1], Oliver Yates[3], Andrew Black[1,4]

[1]**BirdLife International Global Seabird Programme, Royal Society for the Protection of Birds, Sandy, Bedfordshire, SG19 2DL, UK**

[2]**BirdLife International Global Seabird Programme, BirdLife International, Wellbrook Court, Girton Road, Cambridge, CB3 0NA, UK**

[3]**BirdLife International Global Seabird Programme, Casilla 145, La Serena, Chile**

[4]***Present address:*** **Fisheries Department, Falkland Islands Government, PO Box 598, Stanley, FIQ 1ZZ, Falkland Islands**

*Email: orea.anderson@rspb.org.uk

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Supplement. Background data on seabird bycatch estimates for individual longline fleets

Supplemental text. Information on the methods used to calculate the seabird bycatch estimates for longline fisheries reported in Table 1 of the main text.

Angola

The estimate of seabird bycatch within Angolan pelagic longline fisheries (245 birds yr^{-1}) is derived from applying the bycatch per unit effort (BPUE) of similar fisheries in Namibia (0.07 birds per 1000 hooks) to an estimate of longline effort in Angolan waters from 2000 to 2004 (3500000 hooks yr^{-1}) and is therefore assigned a 'Poor' metric of data reliability, as it was not obtained directly from the fishery. Observer data for the Namibian BPUE come from 2004 and 2006 (Petersen et al. 2007).

Argentina

Seabird bycatch data for the demersal longline fishery for Patagonian toothfish *Dissostichus eleginoides* and kingclip *Genypterus blacodes* are from 1999 to 2001, and cover 17% of the total sets that year (Favero et al. 2003). In the 1990s, 12 vessels operated with an annual effort of ca. 29 million hooks yr^{-1} (Favero et al. 2003), but this has markedly decreased since then: effort of the current single demersal longline vessel is estimated as ca. 1440000 hooks yr^{-1} (E. Frere pers. comm.). Data reliability is given as 'Medium', reflecting the observer coverage rate for 1999 to 2001.

The artisanal fishery for hake *Merluccius* spp. was not included in Table 1 of the main text, since data indicate that seabird bycatch in the fishery within the restricted area of the San Matias Gulf is at or close to 0 (Gandini & Gonzalez 2005). However, there are no data from hake fisheries elsewhere along the Argentinean coast.

Australia

South and eastern scalefish and shark fishery

This predominantly demersal fishery operates off the coasts of Tasmania and Victoria, with the main catch species being ling *Genypterus* spp. and blue-eye trevally *Hyperoglyphe antarctica*. Effort increased from ca. 4000000 hooks in 2003 to 9800000 hooks in 2005, and then fell to 8900000 hooks in 2006, and 6700000 in 2007. The Australian Fisheries Management Authority (AFMA) does not anticipate that effort will increase substantially higher than 2005 levels, as catches are now constrained by total allowable catches for target species (Baker & Finley 2008). Since 2002, vessels have been required to have a fisheries observer on board for every fourth trip. Between 2002 and 2005, over 3300000 hooks (13.3% of hooks set) were observed, and the bycatch rate was 0.001 birds per 1000 hooks.

However, all of the 26 birds killed in 2002 to 2005 were caught by 1 vessel which, as a result, had 100% observer coverage and adopted strict mitigation measures (AFMA 2006), including the use of integrated weight line, until the issue was resolved. Baker & Finley (2008) therefore considered it likely that fewer than 10 birds yr^{-1} are currently killed by autoliners operating in this fishery, with a rate below that recorded in 2002 to 2005. Bycatch data are available for 2007, but this covered the summer season, with a level of 5.7% coverage, and did not cover the winter season. Data reliability is given as 'Medium', reflecting the level of observer coverage.

Eastern tuna and billfish fishery (ETBF)

Of the several longline fisheries within Australian waters, the ETBF reports the highest seabird bycatch rates (Baker & Finley 2008). Total fishing effort in 2007 was 8443782 hooks, with observer coverage comprising 5.4% of the total fishery (i.e. 455964 hooks). Mean bycatch rates for 2007 were 0.0248 birds per 1000 hooks (from Lawrence et al. 2008). From this, an estimate of 209 birds yr^{-1} was calculated for the ETBF, with a 'Medium' data reliability metric, reflecting the level of observer coverage.

With regards to mitigation measures, vessels operating as part of the ETBF are required to carry an approved bird-scaring line, which must be used when setting south of 25° S. In this area, they are also required to set hooks at night or use weighted swivels on longlines (Baker & Finley 2008). Other compulsory measures include bans on offal discharge and compulsory use of thawed bait. In 2006, AFMA observers reported a high rate of non-compliance or partial compliance with the mitigation measures, resulting in high catch rates of seabirds by some vessels (Baker & Finley 2008).

Western tuna and billfish fishery (WTBF)

In the WTBF, fishing effort peaked at ca. 6000000 hooks yr^{-1} in 2000 to 2002, before declining markedly to 4000000 hooks in 2003 and 1500000 hooks in 2004, when bycatch rates were reported as 0.02 birds per 1000 hooks (observer coverage was 4% of total effort; Baker & Finley 2008). No albatrosses were observed caught during this period. The relatively low bycatch rate was attributed to the fact that the 4 vessels in the fishery fished at night, targeting broadbill swordfish *Xiphias gladius*.

More recent data collected between April 2003 and June 2006 recorded a seabird interaction rate of 0.055 birds per 1000 hooks (0.032 non-fatal, 0.023 fatal). All birds caught were flesh-footed shearwaters *Puffinus carneipes*, and non-fatal interactions were entanglements that occurred during hauling (AFMA 2007b). In 2007, 10500 hooks were observed in the fishery (equating to an overall observer coverage of 2.4%), and no birds were caught (AFMA 2007a). Baker et al. (2007) concluded that a maximum of 50 birds are killed per year in this fishery, of which very few are likely to be albatrosses. Data reliability is given as 'Poor', reflecting the level of observer coverage of <5%.

All longline vessels operating in the WTBF are now required to carry an approved bird-scaring line, to deploy it when fishing and to set longlines only at night when operating south of 30° S, and to not discharge offal during line setting and hauling (Baker & Finley 2008).

Australian Antarctic fishery

This fishery for Patagonian toothfish falls within the jurisdiction of Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), and bycatch associated it is covered under the CCAMLR entry in Table 1 of the main text.

A single demersal longliner has fished each year at Heard Island and McDonald Islands (HIMI) since 2002 and at Macquarie Island since 2007. Longline fishing at HIMI is carried out from May to October, setting around 1800000 hooks each year. Since 2003, only 3 bird interactions have been recorded, and no birds were killed (AFMA 2007c). In 2007, 171000 hooks were set in the Macquarie Island longline fishery, and no birds were killed (AFMA 2007a). More than 90% of all hooks set in both fisheries have been observed (Baker & Finley 2008). The bycatch rate in both fisheries is therefore within the 0.01 birds per 1000 hooks specified by the Threat Abatement Plan (TAP) as a performance indicator for these fisheries.

Longline vessels are required to use integrated weight line, paired streamer lines, blue snoods, Brickle curtains and seasonal closures to avoid seabirds attending baits (AFMA 2007b). At Macquarie Island, other compulsory measures include a requirement to set all hooks at night. A ban on offal discharge is applied to all Australian vessels fishing in Antarctic waters (Baker & Finley 2008).

Brazil

Industrial pelagic longline fishery

Bugoni et al. (2008a) reported that the Brazilian pelagic longline fishery consists of 2 distinct fleets, the leased fleet and the domestic fleet. The leased fleet is comprised of foreign-operated medium to large vessels (30 to 50 m) with longlines of 40 to 55 miles (64 to 88 km) long. This fleet is mainly based out of north-eastern Brazilian ports targeting swordfish and tuna. The domestic fleet is comprised of smaller vessels (15 to 28 m) and an operational capacity limited to 1 mo at sea, unlike the leased fleet, which can fish for several months at a time. The domestic fleet also differs as it catches large quantities of sharks (Bugoni et al. 2008a). Onboard observers collected data from 63 cruises made by the Brazilian domestic fleet between January 2001 and November 2007 (made up of 656 sets and 788446 hooks observed). A total bycatch estimate for the fleet of 2061 birds yr^{-1} was obtained from the average bycatch rate (0.229 birds per 1000 hooks) multiplied by the total fishing effort (i.e. 9000000 hooks in 2006) reported by Bugoni et al. (2008a). Ranges were also calculated from the minimum and maximum bycatch rates reported, excluding 2001, which had a bycatch rate of 0.00 birds per 1000 hooks, as this would have resulted in a bycatch total of 0 birds. Having replaced the lowest bycatch rate with the second lowest (i.e. 0.036 birds per 1000 hooks) and using the highest bycatch rate observed across the study period to calculate the upper range (i.e. 0.542 birds per 1000 hooks), a total range of 324 to 4878 birds yr^{-1} was obtained. These estimates do not take account of the heterogeneous nature of fishing effort throughout the area of application, as seabird bycatch rates were not available at sufficiently fine-scale spatial resolution for such extrapolations to be possible. Hence, bycatch estimates for this fleet should be treated with caution, and should be used only as a rough guide to the scale of the bycatch problem within the fishery. Given that the observed effort, when averaged across 2001 to 2007 data collection period, comprises only 1.25% of total effort (based on ca. 9000000 hooks set in 2006); the data reliability metric was defined as 'Poor'.

Artisanal pelagic longline fishery – Itaipava, southern Brazil

Data on seabird bycatch, and even fishing effort, in this large artisanal fleet are very sparse. Bugoni et al. (2008b) reported 497 vessels operating in the fleet as a whole. Within the fishery, 7 fishing techniques are used: (1) fast trolling, (2) slow trolling for bigeye tuna *Thunnus obesus*, (3) handlining, (4) surface longlining for dolphinfish *Coryphaena hippurus*, (5) pelagic longline for broadbill swordfish, (6) bottom dropline and (7) pole-and-line with live bait. Crucially, it is not currently known what proportion of time each vessel spends using a particular technique, as all techniques can be used interchangeably on the vessels. While the dolphinfish fishery does operate within a roughly defined season (November to December in southern Brazil in waters of 200 m depth, and from October to February off Rio de Janeiro and Espirito Santo coasts; Bugoni et al. 2008b), this is not the case for the other fishing methods operating within the fleet. Lastly, it is not known what proportion of the fleet is in operation at any one time, with reports of boats frequently laid up at all times of year (C. Marques pers. comm.). Hence, while some data are available on bycatch rates for the different fishing methods in this fleet, it remains impossible to calculate a likely average bycatch figure for the Itaipava fleet at this time. Due to the low levels of observer coverage, the data reliability metric was set as 'Poor'.

From 2001 to 2006, 178 fishing days were observed across the fleet (40717 hooks observed in total) between 18 and 35° S. Of the 7 fishing techniques observed, bycatch was reported on vessels using the following methods: slow trolling for bigeye tuna (39 days observed, 16 birds caught, 0.41 ± 0.68 birds d^{-1}, range 0–2), handlining (41 days observed, 25 birds caught, 0.61 ± 1.45 birds d^{-1}, range 0–7), and surface longlining for dolphinfish (40 days observed, 40717 hooks, 6 birds caught, 0.15 ± 0.58 birds d^{-1}, range 0–3). No bycatch was reported when the other 4 fishing techniques were used (1, 5, 6 and 7), with 140 days observed across these remaining fishing techniques.

We extrapolated an estimate of the maximum number of birds caught in the surface longline fishery for dolphinfish, as this was the only fishery for which an approximate number of hooks set per day could be calculated. The extrapolation was based on a bycatch rate of 0.15 birds d^{-1} (rather than the absolute upper range estimate of 3 birds d^{-1}) because the extrapolated total from the absolute upper range applied universally was deemed too large to be realistic. Bugoni et al. (2008b) reported 40 days and 40717 hooks observed in the Itaipava fleet when this method was being used (i.e. ca. 1018 hooks d^{-1}). As the fishery operates across a roughly demarcated period (i.e. a maximum of 4 mo spanning November to February), we estimated ca. 120 fishing days in the fishery per year. We have also assumed that all 497 boats fished used this technique throughout the entire period (again the validity of this assumption cannot be ascertained with any certainty). In recognition of the unlikelihood of this scenario, we set this number as the maximum potential number of birds caught in the fishery. Due to the paucity of available information, no attempt was made in Table 1 of the main text to estimate an average total number of birds caught.

Canada

Gulf of St. Lawrence fishery

The longline fishery operating in the Gulf of St. Lawrence has on-board observer data from 2001 for 976 sets, which was estimated to represent 5 to 10% of the total fishing effort (DFO Canada 2007). From this we extrapolated a range of fishing effort of 10000 to 20000 sets yr^{-1}. Seabird bycatch consisted of 8 kg of unidentified gull and 3 kg of herring gull *Larus argentatus*, or an estimated 0.0036 to 0.0108 birds per 1000 hooks, assuming 1000 to 3100 hooks per set. This corresponds to an estimate of 0.011 birds killed per set or 107 to 214 birds killed per year, depending on whether the 976 sets observed represented either 5% or 10% of total fishing effort. BPUE per 1000 hooks was extrapolated from the range in BPUE referred to above, by averaging the 2 estimates (0.0036 to 0.0108 BPUE). Given the levels of observer coverage reported, a data reliability score of 'Medium' was identified.

Scotia Shelf and Grand Banks demersal longline fishery

The demersal longline fishery operating in Canadian Atlantic waters has an observed bycatch rate of 0.016 birds per 1000 hooks over a 14 yr period between 1986 and 1999 (Cooper et al. 2000, cited by DFO Canada 2007). The report estimated ca. 500 birds caught each year. The Canadian Department of Fisheries and Oceans reported 3 to 10% of the fishery observed from 1999 onwards (DFO Canada 2007), but these data have not yet been analysed. Analyses of these data will provide more up to date bycatch data for this fishery. Given the levels of observer coverage reported, a data reliability score of 'Medium' was identified.

Scotia Shelf and Grand Banks pelagic longline fishery

The Canadian pelagic longline fleet in the North Atlantic reported a bycatch rate of 0.032 birds per 1000 hooks between 1986 and 1999. DFO Canada (2007) reported 3 to 10% of the fishery observed during this period, but did not specify what the total fishing effort of the fleet was at that time. Between these years, all fishing effort took place along the outer slope of the Scotia Shelf and the southwest slope of the Grand Banks. The fishery was estimated to kill 1400 birds yr^{-1}. Given the levels of observer coverage reported, a data reliability score of 'Medium' was identified.

Pacific demersal longline fishery – Pacific halibut

The International Pacific Halibut Commission (IPHC) regulates the fishery for Pacific halibut *Hippoglossus stenolepis* in British Columbian waters between 15 March and 15 November each year. Average total fishing effort within the IPHC area for 1999 to 2002 was 7515000 hooks (Smith & Morgan 2005). Observer coverage steadily increased since the observer programme began in 1999, and is now usually around 18% as of 2002 (Smith & Morgan 2005). However, for the period 1999 to 2002, which is the span of bycatch data available, average observer coverage was 8.1%. A bycatch rate of 0.0071 birds per 1000 hooks was reported, resulting in an average estimate of 54 birds killed per year. As the level of observer coverage varied significantly between 1999 and 2002 (1.6 to 18.6%), a data reliability score of 'Medium' was given.

Pacific demersal longline fishery – rockfish

The rockfish (*Sebastes* spp.) fishery in British Columbia comprises a commercial fleet and a chartered fleet that fish around seamounts. Fishing effort (reported as a 4 yr average between 1999 and 2002) was 3912000 hooks for the commercial fleet and 234000 for the charter fleet, amounting to an average total effort of 4146000 hooks yr^{-1}. Bycatch rates were collected during the same period and were largely similar between the 2 fleets (0.0181 and 0.0241 birds per 1000 hooks, for commercial and charter fleets, respectively). Moreover, Smith & Morgan (2005) reported a total bycatch estimate for both fleets combined of 72 birds. From this, we were able to extrapolate an average BPUE for the period across both rockfish fleets, based on their relative fishing effort. Average BPUE was determined to be 0.017 birds per 1000 hooks. Total observer coverage was reported as 2.6% for the commercial fleet and 71.1% for the charter fleet. Based on relative total fishing effort and total numbers of hooks observed across both fleets (100240 and 145000 hooks, for the respective fleets) it was possible to extrapolated a 4 yr average level of observer coverage of 5.9% across both fleets. This led to a data reliability score for the rockfish fishery of 'Medium' based on the combined levels of observer coverage.

CCAMLR

Longline fisheries operating in the Convention Area (except French EEZ)

The latest data available for the longline demersal fishery operating in the CCAMLR Convention Area, which predominantly fishes for toothfish (*Dissostichus* spp.), indicate that seabird incidental mortality is currently close to 0. In 2007 to 2008, 30333900 hooks were set, of which 13028700 hooks (43%) were observed. From this observed effort, no seabirds were reported killed, although 21 birds were reported as being caught and released uninjured throughout the Convention Area that year. As CCAMLR does not include the catching and release of uninjured birds in the total seabird mortality estimates, we have maintained the estimated bycatch rate for this area at 0 (CCAMLR 2008). As the level of observer coverage in 2007 to 2008 was 43%, a data reliability score of 'Good' was obtained.

Longline fisheries operating in the French EEZ (Subarea 58.6 and Division 58.5.1)

Bycatch data for longline fisheries operating in the French EEZ has been well documented in recent years; for further information see Cherel et al. (1996), Weimerskirch et al. (2000) and Delord et al. (2005, 2010). However, the most recent estimates come from published figures in CCAMLR reports, and so these are the figures highlighted below. Nevertheless, it is interesting to note that there has been a significant reduction in BPUE since early estimates began (e.g. 1994 reports of 1.00 to 0.15 birds per 1000 hooks, depending on whether day-setting or night-setting with deck-lights turned off, taken from Cherel et al. 1996) to those of current levels (see below). Total extrapolated seabird mortalities resulting from longline fishing in the Convention Area in 2007 to 2008 were ca. 1355 petrels (91% white-chinned petrels *Procellaria aequinoctialis*, 7% grey petrels *P. cinerea* and 2% giant petrels *Macronectes* spp.; CCAMLR 2008). All estimated mortalities were from within the French EEZs, with 131 seabirds estimated killed in sub-area 58.6 and 1244 in division 58.5.1. The fishing effort for each of these areas was 4524240 and 21134790 hooks, respectively. The reported bycatch rate for sub-area 58.6 was reported to be 0.0305 birds per 1000 hooks, while in division 58.5.1 it was 0.0585 birds per 1000 hooks. The total observed fishing effort in each area amounted to 24.6% of the total fishing effort in each area. As the level of observer coverage for the region was >20%, a data reliability metric of 'Good' was obtained.

Illegal, unregulated and unreported (IUU) fisheries in CCAMLR

CCAMLR did not attempt to estimate seabird bycatch for IUU activities for 2007 to 2008. The vast majority of IUU effort identified to be occurring in the Convention Area was gillnet fishing, for which no reliable bycatch estimates are currently available (CCAMLR 2008).

Chile

Artisanal demersal longline fishery – hake Merluccius spp.

Moreno et al. (2006) reported bycatch and fishing effort data from the fishery between 1999 and 2002, although bycatch rates and effort were not always available for the same year. Total fishing effort in 1999 was ca. 900000 hooks, with a bycatch rate of 0.03 birds per 1000 hooks (330632 hooks observed; Moreno et al. 2006). However, Moreno et al. (2006) noted that fishing effort increased to ca. 1800000 hooks after 2002. An estimated annual total bycatch of seabirds was therefore extrapolated based on 1999 BPUE data and 2002 fishing effort data, to give an estimated number of birds caught for 2002 of 54 birds, including 9 albatrosses (all black-browed albatrosses *Thalassarche melanophrys*) and 29 petrels (mostly white-chinned petrels and some giant petrels). Given that the observed effort comprised a third of total effort in 1999, a data reliability score of 'Good' was assigned.

Artisanal demersal longline fishery – Patagonian toothfish

Moreno et al. (2006) also examined seabird bycatch in the artisanal longline Patagonian toothfish fishery operating within the Chilean EEZ. This fishery comprises 15 to 18 m long vessels that are able to operate at sea for 1 mo periods. In 2002, the total fishing effort for this fleet was reported to be 19570000 hooks (± 1890000 hooks). The bycatch rate was 0.047 birds per 1000 hooks, calculated from 88280 hooks observed between May and November 2002. Moreno et al. (2006) estimated total seabird bycatch for 2002 to be 437 birds. This provides more than a simple extrapolation from total effort, as it takes into account monthly patterns in fishing effort and bycatch rates. Given that observed effort comprised only 0.45% of total effort in 2002, a data reliability score of 'Poor' was assigned.

Industrial demersal longline fishery – hake Merluccius spp.

The Chilean industrial demersal longline fishery for hake reportedly set 19000000 hooks in 2003 (Moreno et al. 2006). No data are currently available on seabird bycatch rates. It is not known whether the rates observed in the artisanal demersal longline fleet (see above) are applicable here, and hence this fishery was not included in Table 1 of the main text.

Industrial demersal longline fishery – Patagonian toothfish

The Chilean industrial longline fleet for Patagonian toothfish operates south of 47° S in the south-western Pacific Ocean near Cape Horn (Moreno et al. 2008). Total fishing effort between September and December 2006 was 4137000 hooks, across a fleet of 11 vessels (industrial factory vessels >45 m length). Of the total effort, 1508500 hooks were observed (36.5%). In the same year, the fishery switched to using the 'cachalotera' (Chilean longline) system, which involves using nets to protect the hooks from depredation by killer whales *Orcinus orca*. The use of this system reduced seabird bycatch from an estimated 1588 birds caught in 2002 and 448 birds in 2004 (after tori lines were introduced), to 0 (Moreno et al. 2008). Hence, the bycatch rate in this fleet is now estimated to be 0.00 birds per 1000 hooks. Given that the observed effort comprised 36.5% in 2006, a data reliability score of 'Good' was assigned.

Industrial pelagic longline fishery – broadbill swordfish

Chile has both artisanal and industrial pelagic fisheries targeting swordfish. In 2007, there were 4 industrial vessels and 8 artisanal vessels with a combined fishing effort of 2500000 hooks yr^{-1}, representing over 1118 sets in 46 trips (Moreno et al. 2007). Based on 2007 observer data of 90000 hooks (ca. 3.6% of the total effort), Moreno et al. (2007) estimated 517 to 923 birds killed per year in this fishery, which equates to a bycatch rate of 0.21 to 0.37 birds per 1000 hooks, with an average bycatch rate of 0.29 birds per 1000 hooks. Albatrosses represented 79% of all birds hooked, with petrels making up the remaining 21%. Wandering albatrosses *Diomedea exulans* were the species most frequently caught. The fleet has a National Observer Programme, which commenced in 2001 and is operated by the Instituto de Fomento Pesquero (IFOP). Since 2008, the IFOP observer programme has collected data on seabird bycatch rates and achieved 100% observer coverage across the Chilean industrial pelagic longline fleet. However, data from this period are not yet available (O. Yates pers. obs.). Given that observed effort comprised only 3.6% of total effort in 2007, a data reliability score of 'Poor' was assigned.

China

Industrial pelagic longline fishery – East Pacific Ocean

China commenced its observer programme in the Eastern Pacific Ocean in 2003. Data were collected from July to November 2003 in an area between 03–17°S and 96–146°W (Dai et al. 2006). This fishery operates under the management of the Inter-American Tropical Tuna Commission (IATTC). Six seabirds were caught incidentally among 304390 hooks observed on 110 fishing days. This equates to a seabird bycatch rate of 0.02 birds per 1000 hooks. Chinese fishing effort in the IATTC area in 2003 was 43289000 hooks (IATTC 2007). Based on these data, a total bycatch estimate of 866 birds yr^{-1} was extrapolated. Given that the observed effort comprised only 0.7% of total effort (i.e. <5% coverage), a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – Indian Ocean

No bycatch data were publicly available for the Chinese Indian Ocean tuna and swordfish fleet. However, effort data were available from Xu et al. (2007). They reported total fishing effort of 35285000 hooks in 2006, which was an increase in effort from 2004 and 2005. Although we have no direct data on seabird bycatch in this fleet, we felt it was necessary to at least partially account for some bycatch, due to the scale of the fishery. We examined bycatch rates in a similar fishery over a similar period however (i.e. the Chinese Taipei fleet from 2002 to 2006). However, the Chinese Taipei fleet only observed bycatch south of 25°S. Maps of fishing effort from Xu et al. (2007) show that all fishing effort for the Chinese fleet occurred north of 25°S. For this reason, we have assumed a total bycatch figure for 2006 of 0 birds, based on the current geographic distribution of the Chinese fleet. However, it should be noted that the fleet could incur seabird bycatch should this distribution shift. Given that no observer data were available for the Chinese fleet in the Indian Ocean, a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – West Pacific Ocean

Fishing effort for the Chinese fleet pelagic longline fleet operating in the West Pacific Ocean was 26103000 hooks in 2001 and concentrated between 15°N and 20°S (Lawson 2007). Dai et al. (2008) reported observer data collected between 27 May and 9 July 2008. The total hooks observed were 96070, across 34 sets. Among the observed sets, no incidents of seabird bycatch were reported. Observer data from the Chinese Taipei fleet operating in a roughly similar area also documented 0 seabird bycatch (Huang 2009). Should the Chinese fleet move northwards, bycatch rates could increase substantially, as the majority of seabird bycatch recorded in the Chinese Taipei fleet was caught north of 30°N (Huang 2009). Given that observed effort (from 2008) equated to 0.37% of total effort in 2001, a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – Atlantic Ocean

Between 2002 and 2006, the average fishing effort of the Chinese pelagic fleet was 27970000 hooks yr^{-1} (ICCAT 2008). All effort occurred above 20° S, hence bycatch of Procellariiformes is likely to be limited. Dai et al. (2008) also noted that the majority of Chinese fishing effort in the Atlantic is restricted to between 15° N and 15° S. However, it is necessary to obtain direct evidence from observers on Chinese pelagic longline vessels operating in the Atlantic before the levels of seabird bycatch in this fleet can be adequately estimated. No entry was made for this fleet in Table 1 of the main text.

Chinese Taipei

Industrial pelagic longline fishery – Atlantic Ocean

Observer data on seabird bycatch were collected from 2002 to 2006 on 35 trips, 25 on bigeye tuna vessels and 10 on albacore *Thunnus alalunga* vessels (Huang et al. 2008a). A total of 4755 observer days were reported, consisting of 15602000 hooks from 2002 to 2006. The observed fishing effort was predominantly in tropical areas, with only minimal coverage in the Mediterranean and the area between 30–40° S and 45–55° W in the south Atlantic (Huang et al. 2008a). Huang et al. (2008a) reported average total fishing effort of 112909000 hooks for 2002 to 2006 for the entire Atlantic and Mediterranean (the area managed by the International Commission for the Conservation of Atlantic Tuna, ICCAT), with a range of 59799000 to 160643000 hooks yr^{-1}. From observer data, they reported an average seabird bycatch of 0.0075 birds per 1000 hooks for 2002 to 2006, with a range of 0 to 0.2266 birds per 1000 hooks; the variation betwee 5° × 5° grid squares accounted for most of the disparity in ranges. Huang et al. (2008a) estimated a total seabird bycatch figure of 936 birds yr^{-1}, with a range of 634 to 1364, which appeared to account for spatial and temporal variation in bycatch rates, although the details of this are not presented. Huang et al. (2008a) reported a level of 5.33% observer coverage, based on the total numbers of hooks observed between 2002 and 2006, resulting in a data reliability score of 'Medium'.

Industrial pelagic longline fishery – Pacific Ocean

Data for this fleet comes from Huang et al. (2008b). The fleet operates in eastern, central and western Pacific regions, with an average fishing effort of 118206000 hooks yr^{-1} between 2002 and 2006. Huang et al. (2008b) reported seabird bycatch rates to be highest in the areas between 30–45° N and 160° W–160° E. Chinese Taipei commenced its observer program in 2002, and 5348000 hooks were observed between 2002 and 2006, with observer coverage increasing from 0.75% in 2002 to 8.55% in 2006. Huang et al. (2008b) estimated an average of 1660 birds killed per year, with a range of 544 to 2628, and an average bycatch rate of 0.045 birds per 1000 hooks (range 0 to 0.65 birds per 1000 hooks). Since observer coverage was on average 3.5% per year, a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – Indian Ocean

Chinese Taipei was one of the first to launch an observer program within the Indian Ocean longline fleets for tuna. There were 23 observer trips conducted between 2002 and 2006, and 6407000 hooks were observed, representing average observer coverage of 1.8%. These data produced an average bycatch rate of 0.048 birds per 1000 hooks, which varied from 0 to 0.22 birds per 1000 hooks in different 5° × 5° grid squares (Huang et al. 2008c). Seabird bycatch rates were highest between 30–45° S and 25° W–35° E and between 25–35° S and 65–95° E. In 2002 to 2006, fishing effort by the fleet ranged from 197793000 to 281473000 hooks yr^{-1}, with an average of 253412000 hooks. Based on these data, Huang et al. (2008c) estimated 1512 birds killed per year, based on variable temporal and spatial bycatch rates, seabird distributions and fishing activities, with a range of 332 to 3763 yr^{-1} (Huang et al. 2008c).

Faroe Islands

As no observer data were available for this fleet, bycatch rates were extrapolated from those of the Norwegian autoline fleet (0.02 birds per 1000 hooks; taken from Dunn & Steel 2001). Total fishing effort for the Faroese fleet was reported to be 153106000 hooks from September 1997 to August 1998 (J. Reinert pers. comm., cited in Dunn & Steel 2001). Dunn & Steel (2001) concluded that this fleet, in particular 19 large autoliners, is responsible for killing several thousand fulmars each year. By assuming a bycatch rate of 0.02 birds per 1000 hooks, we obtained an estimated total of ca. 3062 birds caught per year alongside an upper range estimate of ca. 10000 birds yr^{-1} to represent the several thousand fulmar deaths mentioned by Dunn & Steel (2001). Dunn & Steel (2001) listed northern fulmar *Fulmarus glacialis* as the main species taken as bycatch, with seabird mortality varying considerably between seasons and areas.

Clearly, the estimates for the Faroese fleet should be treated with caution given the lack of first-hand observer data, the potential for variation in fishing effort, paucity of information on mitigation measures and their application, and the heterogeneous nature of bycatch rates on which these extrapolations have been based. New information is required to arrive at a more reliable estimate of the bycatch problem. However, our extrapolations are roughly comparable to those of others, including 5000 to 25000 fulmars annually on longlines in Faroese waters (B. Olsen pers. comm.). Indeed, even if the lower estimates prove to be closer to the true state of bycatch, these are still considerable numbers of birds being taken each year. Due to the lack of direct observer data for this fleet, a data reliability metric of 'Poor' was assigned.

Iceland

As with the Faroe Islands, no observer data were available for this fleet, so bycatch rates were assumed to be similar to those of the Norwegian autoline fleet (0.02 birds per 1000 hooks). Effort data were reported for 2007 as 367000000 hooks (ICES 2009). This resulted in an estimated total seabird bycatch of ca. 7340 birds yr^{-1}. The only direct data on seabird bycatch available for the fleet come from ringing returns. Recoveries have included 15 great skuas *Stercorarius skua* and 5 northern fulmars (A. Petersen cited by Dunn & Steel 2001). However, it has been estimated that the Icelandic fleet annually kills thousands to tens of thousands of fulmars (A. Petersen cited by Dunn & Steel 2001). From this, we

extrapolated a crude upper range estimate of ca. 20000 birds yr^{-1}. Again, the estimates for this fleet should be treated with caution, given the lack of first-hand observer data, the potential for variation in fishing effort, the paucity of information on mitigation measures and their application, and the heterogeneous nature of bycatch rates on which these extrapolations have been based. Due to the magnitude of the numbers discussed, and the potential effect these numbers have on the overall estimates of seabird bycatch globally, it is vital that new data are collected from the fishery. Due to the lack of direct observer data for this fleet, a data reliability metric of 'Poor' was assigned.

Japan

The data used in this review are based on those reported by Japan to the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) *Thunnus maccoyii* (Minami et al. 2009) and an estimate of bycatch by Japanese fleets in the North Pacific by Crowder & Myers (2001). Data gaps remain for other Japanese fleets, both in relation to bycatch rates and fishing effort data. Overall fishing effort for the Japanese distant water pelagic fleet is difficult to ascertain as there is spatial overlap between fishing effort reported to the CCSBT and that reported to the 4 other tuna commissions (ICCAT, IATTC, Indian Ocean Tuna Commission [IOTC], and Western and Central Pacific Fisheries Commission [WCPFC]).

Industrial pelagic longline fishery – southern bluefin tuna

Estimates of annual seabird bycatch for the Japanese southern bluefin tuna longline fishery for 2006 to 2007 come from data collected by the Real Time Monitoring Programme (RTMP; Minami et al. 2009). In 2006, an estimated 8746 birds were caught, whereas in 2007, the total was 3852 birds yr^{-1}, giving an average bycatch rate over the 2 yr of 0.23 birds per 1000 hooks, with an extrapolated average total fishing effort of 26361073 hooks yr^{-1} (with ca. 6% of hooks observed; Minami et al. 2009). Thus, the extrapolated average total bycatch was 6299 birds yr^{-1}. The lower and upper 95% confidence intervals (CIs) over the 2 yr were 1163 and 14182 birds yr^{-1} (Minami et al. 2009). A data reliability metric of 'Medium' was assigned to this fishery, based on the level of observer coverage. However, it was noted that bycatch rates were extremely variable between 2006 and 2007, indicating a high potential for error in estimates of average total seabird mortality.

Industrial pelagic longline fishery – North Pacific

A large Japanese pelagic distant water fleet is active in the North Pacific. Effort reported by WCPFC (2009) was 91 million hooks in 2006 to 2007, with 71679000 hooks yr^{-1} reported to IATTC (IATTC 2007). However, no seabird bycatch estimates have been reported to either regional fisheries management organisation (data reported have been the results of mitigation trials). Crowder & Myers (2001) estimated bycatch of Laysan *Phoebastria immutabilis* and black-footed *P. nigripes* albatrosses based on bycatch rates from the US fleet, and using estimates of fishing effort based on catch data. They estimated an average of 14540 birds caught yr^{-1} (made up of 7200 Laysan and 7340 black-footed albatrosses). Given that this estimate is ca. 10 yr old, and is based on extrapolation, there is a clear need for data from this fleet. Due to a lack of direct observer data for this fleet, a data reliability metric of 'Poor' was assigned.

Korea

Industrial pelagic longline fishery – Eastern Pacific Ocean (IATTC waters)

Korea developed an observer program in its distant-water fleet in 2002. Thus far, it has predominantly focused on purse seine vessels fishing in WCPFC waters; however, 1 observer was deployed on a longline vessel fishing in the East Pacific (between 5°42'–11°23' S and 123°39'–146°43' W; Moon et al. 2005). Between December 2004 and January 2005, 51533 hooks were observed, representing ca. 0.14% of the fishery (calculated as a percentage of average effort from 2004 to 2005, i.e. 36345000 hooks, as reported by IATTC 2007). A bycatch rate was calculated based on the number of birds caught compared to the total number of hooks observed (0.02 birds per 1000 hooks), which equated to a total seabird bycatch estimate of 727 birds yr^{-1} (see Table 2 in the main text). As only 1 bird (an albatross) was caught during the observer study, this extrapolation is uncertain. However, it should be noted that this bycatch rate is comparable to other longline fleets operating in IATTC waters (e.g. Chinese Taipei). As only 0.14% of the fishery was observed, a data reliability metric of 'Poor' was assigned.

Industrial pelagic longline fishery – Atlantic Ocean (ICCAT waters)

No known seabird bycatch data have been reported for the Korean Atlantic pelagic longline fleet. Therefore, we extrapolated data from a similar fishery. Chinese Taipei data on bycatch from 2002 to 2006 reported nearly all seabird bycatch occurring south of 30° S. The average bycatch rate from 2002 to 2006 was ca. 0.10 birds per 1000 hooks (Huang et al. 2008a). In the same period, the average Korean total fishing effort south of 30° S was 670000 hooks yr^{-1}, resulting in an estimate of ca. 67 birds yr^{-1} caught in this fishery. Due to a lack of direct observer data for this fleet, a data reliability metric of 'Poor' was assigned.

Industrial pelagic longline fishery – Western Pacific Ocean (WCPFC waters)

Korea's longline fishery in the Western Pacific is highly concentrated in tropical latitudes between 15° N and 15° S (Kim et al. 2010a), an area which does not overlap with Pacific albatross populations. Korea has developed an observer programme in its distant-water fleet since 2002, and data were reported from an observer onboard longline vessels in the tropical Western Pacific in 2008 and 2009 (An et al. 2009, Kim et al. 2010b). Approximately 250000 hooks were observed over the 2 yr, concentrated in a relatively small area to the east of Papua New Guinea (range 12° N–5° S and 171° E–171° W). Since the area observed was small, additional observer data will increase knowledge of likely seabird bycatch rates. Taiwan observer data from the tropical area recorded low (but not 0) bycatch. Given that other fleets (e.g. Taiwan) operating across the wider WCPFC region report varying levels of seabird bycatch (although often quite

minimal), and given the spatial extent of the observer coverage in the Korean observer programme mentioned above, we omitted this entry from Table 1 in the main text, as it was not sufficiently comprehensive enough to demonstrate an absence of seabird bycatch in WCPFC waters across the Korean pelagic longline fleet.

Industrial pelagic longline fishery – Indian Ocean (IOTC waters)

No seabird bycatch data are available for the Korean pelagic longline fleet in the Indian Ocean. However, fishing effort data are available from the IOTC database (IOTC unpubl. data), and bycatch rate data from the distant water Chinese Taipei fleet (Huang et al. 2008c) could be considered roughly comparable. Using the graph presented by Huang et al. (2008c), we extracted BPUE per latitude band (2002 to 2006 data), and then used the IOTC effort database (IOTC unpubl. data) to extract both Korean and Chinese Taipei fishing effort by latitude band for 2002 to 2006. This method gave an estimate for Chinese Taipei of 1312 birds killed per year, roughly comparable to the figure reported by Huang et al. (2008c) of 1512 birds killed per year, indicating that this method of estimating might be roughly justifiable. Applying the Korean effort data to the Taiwan bycatch rate data gave an estimate of 97 birds killed per year by the Korean fleet in the Indian Ocean, and an extrapolated average BPUE of 0.038 birds per 1000 hooks. The data reliability score was classed as 'Poor', since no observer data are available directly from the Korean fleet.

Mediterranean

Extensive pelagic and demersal longline fisheries exist in the Mediterranean. However, while they are known to catch seabirds, their true impact remains unknown: data on seabird bycatch is sparse, and fishing effort data for individual fleets are difficult to obtain. The most comprehensive dataset comes from a study on Spanish vessels in the Valencia region, which indicated that large numbers of Cory's *Calonectris diomedea* and Balearic shearwaters *Puffinus mauretanicus* are caught in these fisheries (García-Barcelona et al. 2009).

Maltese demersal longline fishery

While there are no on-board observers in this fishery, interviews with fishermen were undertaken in 2007, when 146 full-time and part-time fishermen were interviewed (10% of the population). Information on seabird bycatch was collected as part of these interviews (Dimech et al. 2008). The number of birds reported caught ranged from 0 to 50 yr^{-1}, with an average of 1.41 birds per demersal fisherman per year. Dimech et al. (2008) estimated total annual mortality of 1237 birds for the Maltese fleet. As this is not based on direct on-board observations, this estimate should be treated with caution. Nevertheless, this rate of bycatch indicates that potentially up to 8.5 to 10% of the breeding population of Cory's shearwater in the Maltese Islands could be caught as bycatch each year. As data for this fishery were collected by fisher interviews, instead of observer data, a data reliability metric of 'Poor' was assigned.

Industrial pelagic longline fishery – tuna and swordfish

Fishing effort for pelagic tuna and swordfish fleets in the Mediterranean amounted to an average of 19489389 hooks yr^{-1} between 2002 and 2006, excluding the Spanish pelagic longline fleet (covered under 'Spain') (ICCAT 2008). Countries that contribute fishing effort (in hooks yr^{-1}) to this total include: Chinese Taipei (396810), Cyprus (1572608), Greece (9874357), Japan (2164688), Korea (25023) and others (5375903). Bycatch data are extremely limited among the various fleets that operate in ICCAT waters. However, bycatch rates recorded in the Spanish Western Mediterranean fleet between 1999 and 2000 (on average 0.0133 birds per 1000 hooks, and range of 0.002 to 0.023 birds per 1000 hooks, taken from Valeiras & Caminas 2003), result in an estimate of 259 birds yr^{-1} (range 40 to 448). Clearly, it is important to emphasise that there are considerable problems with applying a single bycatch rate across different fleets. In addition, such figures do not account for the potentially high rates of bycatch that may occur around key breeding colonies, nor the potential for large incidents of bycatch occurring periodically as fisheries encounter rafting seabirds. Given that no observer data were available for this fleet, and extrapolated bycatch rates arose from similar fleets in the region, a data reliability score of 'Poor' was assigned.

Namibia

Industrial demersal longline fishery – hake Merluccius spp.

Petersen (2008) reported that the Namibian demersal longline fishery set ca. 120 million hooks (or 6700 sets) yr^{-1}, with effort remaining broadly constant between 2000 and 2003. Interviews were conducted among the fishing industry in Walvis Bay in 2004 and 2006. Additional bycatch data were available from on-board observers on 4 trips in November 2006. We used these data as they were thought to be more reliable. Throughout the period, 456000 hooks were observed (21 sets). Based on the estimated annual fishing effort of 120 million hooks, this equates to ca. 0.38% of total effort. Hence, a data reliability metric of 'Poor' was assigned. White-chinned petrels were the dominant species caught (95%), followed by Atlantic yellow-nosed albatross *Thalassarche chlororhynchos* (3%) and Cape gannet *Morus capensis* (2%). The total bycatch rate obtained (from 66 birds caught) was 0.145 birds per 1000 hooks. Petersen (2008) estimated total seabird bycatch for the fishery in 2006 to be 20200 birds yr^{-1}. We extrapolated total petrel bycatch of ca. 19190 birds and albatross bycatch of ca. 606 birds yr^{-1}. However, bycatch estimates are highly variable for the fleet, and Petersen et al. (2007) provided a total estimate of 30650 birds yr^{-1}. We included that figure in our review to provide an upper range on the estimated total bycatch for this fishery.

Industrial pelagic longline fishery

Fishing effort data exist for 2002 to 2004 and range from 2.5 to 3.5 million hooks (average 2.9 million hooks, comprised of 1620 sets; Petersen et al. 2007). The fishery occurs mainly within the Namibian EEZ but also in the high seas beyond. Observer data were collected from October to November 2004 onboard a large pelagic longline vessel targeting tuna, swordfish and sharks (Petersen et al. 2007). During 38 days of fishing, 7 birds were caught equating to a

bycatch rate of 0.6 birds per 1000 hooks. A second trip in June 2006 caught 3 birds (0.1 birds per 1000 hooks) with 30770 hooks observed (ca. 1% of total fishing effort). Petersen et al. (2007) concluded that since fishing effort averaged 2.9 million hooks yr^{-1} and seabird bycatch rates (accounting for spatial variation and observer effort) averaged ca. 0.07 birds per 1000 hooks, ca. 206 birds were caught per year in the fishery at this time. Various bycatch rates and observer effort were quoted throughout this work, hence only those extrapolated figures quoted by Petersen et al. (2007), i.e. total numbers of birds caught, are shown in Table 1 of the main text. Based on the levels of observer coverage in this fleet (i.e. <5%) a data reliability metric of 'Poor' was assigned.

New Zealand

Chartered mixed pelagic fishery

Abraham & Thompson (2009) reported an estimated total seabird bycatch for 2006 to 2007 of 715 birds (range 567 to 883). This was based on an observed capture of 187 birds. The total estimated bycatch rate for the domestic, charter and Australian fleets combined was 0.196 birds per 1000 hooks. The total effort for all pelagic fleets combined in 2006 to 2007 was 3719232 hooks, of which 955919 hooks were observed, i.e. 25.7% (Abraham & Thompson 2009). The estimated composition of seabird bycatch in the pelagic fleet for this year was 478 albatrosses, 233 petrels and 4 shearwaters (Abraham & Thompson 2009). Given the high levels of observer coverage (i.e. >20%), a data reliability score of 'Good' was assigned.

Chartered mixed demersal fishery

In 2006 to 2007, New Zealand's demersal longline fisheries were inadequately observed, with only 6.1% observer coverage (Abraham & Thompson 2009). From 60 observed captures, a total seabird bycatch of 1122 individuals (range 579 to 1777) was estimated, with a bycatch rate of 0.026 birds per 1000 hooks. The total combined number of hooks set by the demersal fisheries in 2006 to 2007 was 38164851 hooks, with 2344205 hooks observed. The estimated composition of seabird bycatch in the chartered mixed demersal fleet for this year was 791 birds of various species, 330 petrels, and 1 shearwater (Abraham & Thompson 2009). Based on a level of observer coverage of between 5 and 20%, a data reliability score of 'Medium' was assigned to this fleet.

Norway

Industrial demersal fishery

Data on seabird bycatch in the Norwegian industrial demersal autoline fishery were taken from Dunn & Steel (2001). This study collated data from several studies on seabird bycatch in the fishery, notably those of S. Løkkeborg. Dunn & Steel (2001) reported estimated average bycatch rates of 0.02 birds per 1000 hooks in the winter and 0.023 birds per 1000 hooks in the summer. Total fishing effort in 1996 was 476 million hooks (comprised of 61 autoline vessels), with 71% occurring in the winter and 29% in the summer. This led to an estimate of 9934 birds caught per year. The autoline fleet is now reported to have reduced to ca. 40 vessels in 2007 (S. Løkkeborg pers. comm.), and the effort estimates have therefore been adjusted to reflect this, assuming that the distribution between effort in winter and summer is unchanged. Using the bycatch rates reported per season, this resulted in an estimated total bycatch of 4432 birds yr^{-1} during the winter and 2032 birds yr^{-1} during the summer.

However, Dunn & Steel (2001) also referred to much higher bycatch rates being reported in this fishery, and estimated that 50000 to 100000 birds yr^{-1} are killed in the Norwegian, Faroese and Icelandic fleets combined. The high variability in bycatch rates is likely to relate to the variable use of mitigation measures among this fleet. The time of year also has an effect on bycatch rates. In the summer, Løkkeborg (2003) reported bycatch rates ranging from 0.013 birds per 1000 hooks, when tori lines were used as a mitigation measure (obtained from an average of 3 cruises), to 1.12 birds per 1000 hooks, when no mitigation measures were used (obtained from an average of the same 3 cruises). Because there are no data on the proportional use of mitigation measures (or type used), we applied the upper and lower estimates of bycatch to the most recently reported information on total fishing effort for the fleet, resulting in an estimated range of 2216 to 8865 birds caught during the winter, and 1177 to 101380 birds caught during the summer. The estimates provided here should be treated with caution and revised in light of any new information that becomes available.

In addition to the autoline vessels addressed above, Dunn & Steel (2001) estimated a further 10000 birds killed per year in a substantial fleet of smaller longline vessels, for which few data were available. No data were available for this fleet on either fishing effort or seabird bycatch rates, so seabird bycatch cannot be quantified. However, it can be assumed that it represents a potentially significant addition to the levels calculated for the autoline fleet, which must therefore be regarded as a conservative estimate of the total impact by Norwegian vessels. Due to the lack of observer coverage in recent years and the age of the bycatch data available, a data reliability score of 'Poor' was assigned to this fleet.

Peru

Artisanal pelagic longline fishery

Pro Delphinus (2006) reported data collected by observers from the ports of Ilo, Callao and Salaverry in southern, central and northern Peru, respectively. Surveys were conducted between May 2005 and April 2006 on 72 artisanal fishing trips. Throughout that period, 354222 hooks were observed. They reported a bycatch rate of 0.0028 birds per 1000 hooks, although this figure was calculated based on only 1 individual bird caught in all observed trips. El Instituto del Mar del Perú (IMARPE) estimated that 11316 artisanal longline fishing trips were conducted in 2002 (IMARPE unpublished data). Using the Pro Delphinus database, which contains details on 173 artisanal longline fishing trips from 7 ports from 2003 to 2006), Pro Delphinus determined an average of 6.5 sets $trip^{-1}$, and an average of 860 hooks set^{-1}. Assuming that fishing practices in 2002 were similar to 2003 to 2005, they therefore estimated that 63.25 million hooks were set in 2002, yielding an estimated bycatch of 190 birds caught in 2002 (Pro Delphinus 2006). However, it should be

noted that this study is unlikely to have accounted for all artisanal longline fishing effort throughout Peru because of the diversity of fishing ports from which these activities occur. Moreover, previous interviews with fishermen indicated that 2370 to 5610 albatrosses may be caught in these fisheries each year (Jahncke et al. 2001). We chose to omit references relating to fishermen questionnaires from global bycatch estimates because these figures were deemed less reliable than those of onboard independent observers. However, it should be recognised that the level of bycatch in the Peruvian artisanal longline fishery could be far higher than that reflected by the Pro Delphinus study. Due to the low levels of observer coverage (i.e. <5%) and the potential to have underestimated effort for the fleet, a data reliability score of 'Poor' was assigned.

Industrial demersal longline fishery – Patagonian toothfish

Very few data are available for the Peruvian demersal longline fishery for Patagonian toothfish. The fleet was reported to consist of 13 vessels in 2003, an increase from 6 in 1996 to 1999 (Goya & Cardenas 2003). Effort data for the years 1996 to 1999 were reported to be 1409354 hooks (Goya & Cardenas 2003). By extrapolation, we estimated the total effort for 2003 as 1017868 hooks. However, Goya & Cardenas (2003) made no assessment of seabird mortality, but noted that matters are hindered by the industrial (and more regulated) fleet comprising only 1% of total vessels operating throughout Peru. With sparse data available for this fishery, both in terms of effort and bycatch rates, a data reliability metric of 'Poor' was assigned.

Russia

Data from this fishery, which operates in the Russian Far East, come from Artyukhin et al. (2006). The peak fishing season is May to August, with a predominant catch of cod and Pacific halibut. Historically, there is believed to have been considerable foreign vessel activity, but by 2004, only a few medium-sized demersal vessels from North Korea operated in the region. By 2006, the bulk of the vessels were Russian, most of which use the autoline system produced by Mustad. The fishery is divided into 4 zones: West Bering Sea zone (61.01), East Kamchatka zone (61.02), North-Kurils zone (61.03), and Sea of Okhotsk zone (61.05). See Artyukhin et al. (2006) for further details.

Industrial demersal longline fishery – West Bering Sea and East Kamchatka

Observer data were collected from 2003 to 2004 and recorded 343 dead seabirds in 2003 and 108 in 2004 in the 2 zones combined, corresponding to a bycatch rate of 0.132 birds per 1000 hooks in 2003 and 0.051 birds per 1000 hooks in 2004. Artyukhin et al. (2006) extrapolated this to an overall estimate of 9883 and 2745 birds killed in 2003 and 2004, respectively, for the 2 areas combined. Figures in Table 1 of the main text represent averages of 2003 and 2004 data: an average total fishing effort of 69225000 hooks yr^{-1}, an average bycatch rate of 0.0915 birds per 1000 hooks, and an average of 6314 birds killed yr^{-1}.

Northern fulmars comprised 65.1% and 27.8% of the total birds killed in 2003 and 2004, respectively. Other species caught included slaty-backed gull *Larus schistisagus*, short-tailed shearwater *Puffinus tenuirostris*, Siberian gull *L. heuglini* and 1 Laysan albatross. Artyukhin et al. (2006) suggested that the differences in bycatch rate and species composition between the 2 years may have resulted from observations being more off-shore in 2003, and closer to shore in 2004, and may alsohave been influenced by stormy weather in 2004.

Industrial demersal longline fishery – Sea of Okhotsk

Data collected in 2004 to 2005 resulted in 12 birds observed to be caught on 1.1 million hooks observed, producing a bycatch rate of 0.011 birds per 1000 hooks. Northern fulmars comprised 66.7% of the birds killed. Total fishing effort was in 2004 was 26219000 hooks (compared to 69151000 hooks in 2003). Based on bycatch rate data from 2004 to 2005 and effort data from 2004, we extrapolated an estimate of 288 birds killed in the Sea of Okhotsk fishery in 2004. We used effort data solely from 2004 for the extrapolation, due to the substantial drop in effort from 2003. However, this figure will be an underestimate if 2003 effort data are more representative of the fishery. Artyukhin et al. (2006) also indicated that this may be an underestimate as most observations occurred during winter (i.e. from October to January and April), while many seabirds (mainly Procellariiformes) gather on the West Kamchatka shelf area in late August to September, indicating the need for further research on seabird mortality at this time of year.

South Africa

Industrial demersal longline fleet (domestic) - hake

Data on the South African demersal fleet come from Petersen (2008). This fishery operates throughout the Benguela upwelling system and mainly fishes for hake *Merluccius capensis* and *M. paradoxus*. Effort and bycatch data were collected from 2000 to 2006. Fourteen million hooks were observed throughout the study period (ca. 6.8% of total fishing effort), and 107 birds were caught (0.0075 birds per 1000 hooks), of which 41 were dead (0.0029 birds per 1000 hooks). We have reported the rates in relation to seabirds caught, as this provides the most consistency with the other studies examined in this review. Petersen (2008) reported a total estimated number of seabirds caught per annum for this fishery of 225 (range 220 to 245), calculated from an average total fishing effort for the fleet of 30 million hooks (range 15.2 to 43.6 million hooks). Petersen (2008) also reported a decrease in catch rate from 0.033 birds per 1000 hooks in 2000 to 0.001 birds per 1000 hooks in 2006. There was no observed seasonal trend in bycatch rates. White-chinned petrels were the most commonly caught (36%), and albatrosses comprised 5% of the total caught. As levels of observer coverage fell between 5 and 20%, a data reliability score of 'Medium' was assigned.

Industrial pelagic longline fleet (foreign-flagged vessels) – Indian Ocean

The most recent data available come from P. Ryan (unpublished). The foreign-flagged fleet, which operates under license in the South African pelagic longline fishery for tuna (*Thunnus* spp.) and broadbill swordfish, is required to have 100% observer coverage throughout the fleet. Foreign-flagged vessels were responsible for almost 74% of all fishing effort in the South African fishery during 2007 and 2008. Of the 20 foreign-flagged vessels operating in the fishery during 2007 and 2008, 19 operated in the IOTC area. Total fishing effort was 2670000 hooks in 2007 and 2846000 hooks in 2008. Nine species of seabird were observed killed across the 2 years. White-chinned petrels were the most frequently killed (69%), followed by shy albatrosses *Thalassarche cauta* (21%), Indian yellow-nosed albatrosses *T. carteri* (4%) and black-browed albatrosses (4%). There was no change in the ratio of albatrosses to petrels killed between the 2 years. The bycatch rate in the IOTC area decreased 5-fold from 2007 (0.30 birds per 1000 hooks) to 2008 (0.05 birds per 1000 hooks). In this report, we have focused on the bycatch rate in the most recent year of study (2008) in order to provide the most up-to-date picture of bycatch in this fleet. The total number of birds observed caught (and total bycatch because of the 100% observer coverage in this fleet) was 141 in 2008. The reduction in the second year was attributed largely to a cap on the number of birds that could be caught by an individual vessel (25) before it was forced by the regulations to return to port for examination of the mitigation measures it was using (P. Ryan unpublished data). As observer coverage is 100% in this fishery, a data reliability score of 'Good' was assigned.

Industrial pelagic longline fleet (foreign-flagged vessels) – Atlantic Ocean

The most recent data available for this fleet come from Ryan et al. (2009). The foreign-flagged fleet, which operates under license in the South African pelagic longline fishery for tuna and swordfish, is required to have 100% observer coverage throughout the fleet. In 2007, foreign vessels killed at least 223 birds on 687000 hooks (0.33 birds per 1000 hooks). In 2008, with the cap of 25 birds per vessel introduced, this rate dropped to 0.103 birds per 1000 hooks and a total seabird bycatch of 35 birds, of which 28 were albatrosses and 6 were petrels. No shearwaters were taken. Bycatch rates were higher than those in the Indian Ocean, although this may have been the result of higher bird numbers along the shelf edge in the Atlantic area (Ryan et al. 2009). Using data from 2007 and 2008, shy albatrosses were the most frequently caught species (39%, averaged over the 2 yr reported), followed by white-chinned petrels (23%), black-browed albatrosses (19%), cape gannets (11%), Indian yellow-nosed albatrosses (9%) and Atlantic yellow-nosed albatrosses (5%). The introduction of a cap on the numbers of birds caught as bycatch in 2008 appears to have had a substantial influence on the reduction of bycatch rates. However, anecdotal evidence would suggest that the relaxing of this regulation in 2009 resulted in the numbers of birds increasing once again, and hence the figures here should be treated with caution. The observer program active in this fleet means that new information will soon become available to monitor longer-term patterns. As observer coverage is 100% in this fishery, a data reliability score of 'Good' was assigned.

Industrial pelagic longline fleet (domestic)

The South African domestic pelagic fleet also fishes in both the Atlantic and Indian Oceans, but targets predominantly swordfish, with bycatch of tuna and shark (S. Petersen pers. comm.). This fleet set 10.2 million hooks from 1998 to 2005, with an average of 1.3 million hooks yr^{-1} (Petersen 2008). Fishing effort was noted to peak in 2002 at 2.6 million hooks, then decrease to 0.8 million in 2005. South African vessels tended to fish on South Africa's west coast and off Richards Bay on the east coast (Petersen 2008). Average bycatch rates for the fleet were reported to be 0.23 birds per 1000 hooks (0.22 birds per 1000 hooks in winter and 0.24 birds per 1000 hooks in summer). This results in an extrapolated total bycatch figure of 299 birds yr^{-1}. However, if the ranges in effort and bycatch rates are applied, a range in estimates of 176 to 624 birds yr^{-1} is obtained. One million hooks were observed over the period (827 sets), equating to an average of 9.8% hooks observed throughout 1998 to 2005. Albatrosses comprised 30.3% of all bycatch, petrels comprised 69.3% and shearwaters 0.3% (Petersen 2008). Based on the levels of observer coverage, a data reliability score of 'Medium' was assigned.

Spain

Industrial pelagic longline fishery – East Pacific Ocean (IATTC area)

Spanish industrial longline vessels in the East Pacific predominantly fish for swordfish, and operate under the management of IATTC. Mejuto et al. (2007a) reported an interaction (and mortality) rate of 0.04 birds per 1000 hooks, based on 2.153 million hooks observed in 1990 and 1998 to 2005 (observer effort per year not given) across the entire Pacific region. Mejuto & Garcia-Cortes (2005) reported fishing effort data for 2002 and 2003, with an average of 6496008 hooks yr^{-1} (the data cover the entire Pacific, but maps show that effort occurred exclusively within the IATTC area). Fishing effort for this fleet expanded westward considerably in 2004 and 2005 (see Mejuto et al. 2007b). Using the seabird bycatch rate of 0.04 birds per 1000 hooks, combined with an average of fishing effort data for 2002 and 2003, we calculated that ca. 260 birds are killed annually through interactions with the Spanish industrial longline fleet operating in the East Pacific. As observed effort would appear to fall below 5% per year (based on an average of total observed between 1998 and 2005), a data reliability score of 'Poor' was assigned to this fleet.

Industrial pelagic longline fishery – West Pacific Ocean (WCPFC area)

Spanish industrial longline vessels in the West Pacific Ocean predominantly target swordfish and operate under the management of the WCPFC. Data on bycatch rates come from Mejuto et al. (2007a), with a rate of 0.032 birds per 1000 hooks, based on data from 1990 to 2005 and 1129000 hooks observed. Recent effort data indicate 17 vessels active in the fishery in 2008, setting 1000 to 1400 hooks set^{-1}, but total fishing effort was not given (WCPFC 2009). Catch data for the Spanish fleet in 2005 was 3009 t (Lawson 2007), while Mejuto et al. (2007b) reported that catch per unit effort (CPUE) in 2005 was 0.6815 t per 1000 hooks. From this it was possible to estimate a total fishing effort of ca. 4415260 hooks in

2005. Based on this extrapolated figure for total fishing effort in 2005, we estimated ca. 141 birds killed annually in this fishery. Clearly, this figure should be revised in light of new estimates of total fishing effort, especially given that 8 vessels were recorded as operating in 2005, versus the 17 thought to be operating in 2008. As observed effort was not reported on an annual basis, we can only estimate that observer coverage was less than 5% per year. Based on this assessment, a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – south-west Indian Ocean

The only available data on seabird bycatch comes from experimental cruises in 2005 on 2 surface longline vessels in the southwestern Indian Ocean (Ariz et al. 2006). Observations took place between 25–35° S and 30–50° E, with 531916 hooks observed (across 539 sets). Only 3 seabirds were observed caught (2 albatrosses and 1 petrel) and occurred in only 2 d (16 and 17 Oct 2005) in Area 5. This equates to a bycatch rate of 0.0056 birds per 1000 hooks, much lower than rates observed by South African observers on vessels in similar areas. Extrapolating this rate to the fleet as a whole (6546607 hooks set in 2006), gives an estimate of 37 birds caught in 2006. However, it must be noted that the experimental cruises were testing the effect of differing fishing methods on sea turtle bycatch, including different hook designs and use of coloured bait, which could reduce seabird bycatch rates. Hence, the bycatch rate may well be an underestimate. Moreover, the level of observer coverage for 2005 was ca. 8% of total effort (i.e. within the 5 to 20% range), resulting in a data reliability score of 'Medium'.

Industrial pelagic longline fishery – South Atlantic

While bycatch data are available for Spanish pelagic longline vessels fishing in the Atlantic Ocean (Mejuto et al. 2007c), these data were collected between 47.5° N and 22.5° S, not south of 20° S, the area in which effort would overlap with the distribution of albatrosses and petrels, and the area in which data from Brazil, Chinese Taipei and others indicate that seabird bycatch is likely to occur at significant levels. In addition, the Spanish bycatch data were collected from experimental cruises that were testing bait and hook type, factors that are likely to have affected seabird bycatch rates. For these reasons, we did not use this source in our estimations for seabird bycatch in the Spanish Atlantic pelagic longline fishery. Instead, we extrapolated a total bycatch estimate using Spanish effort data south of 30° S, which in 2002 to 2006, was ca. 2580000 hooks yr^{-1} (ICCAT 2008), and bycatch rate data from the Chinese Taipei fleet south of 30° S (i.e. 0.10 birds per 1000 hooks, Huang et al. 2008a). This resulted in an estimated 258 birds killed per year. However, crucially this does not address bycatch that may be occurring between 20 and 30° S, which may be the critical area for high rates of bycatch because of the high seabird density in this area at certain times of the year (e.g. the breeding season). As observer data were not available for the area for which bycatch estimates were extrapolated, a data reliability score of 'Poor' was assigned.

Industrial pelagic longline fishery – Western Mediterranean

Bycatch rates recorded in Spanish demersal and pelagic fleets operating around the Columbretes Islands are higher than those recorded in other areas of the Mediterranean, likely due to the breeding colonies on the islands. We therefore treated the area around the Columbretes Islands separately (see below).

From January 2000 to December 2008, onboard observers were stationed on 58 Spanish longliners targeting swordfish, bluefin tuna and albacore in the Western Mediterranean. García-Barcelona et al. (2009) reported 4786466 hooks observed over 2278 sets. This equates to ca. 5% observer coverage, if averaged over the 9 yr of the observer programme. An average total bycatch rate of 0.038 birds per 1000 hooks was observed (annual range from 2000 to 2008 was 0.003 to 0.091 birds per 1000 hooks), with Cory's shearwater and yellow-legged gull *Larus michahellis* being the species most frequently caught. Between 2000 and 2008, average fishing effort for the Spanish pelagic longline fleet for the entire Mediterranean was 13164660 hooks yr^{-1} (IEO unpubl. data). Removing effort around the Columbretes Islands (2.3 million hooks yr^{-1}) gives an average of 10864660 hooks. From this we extrapolated an average total bycatch estimate of 413 birds (range 33 to 989 birds), of which 152 were estimated to be Cory's shearwaters, based on an estimated bycatch rate of 0.014 birds per 1000 hooks (García-Barcelona et al. 2009). Based on a 5% level of observer coverage per year, a data reliability metric of 'Medium' was assigned.

Columbretes Islands longline fishery – demersal & pelagic

Seabird mortality around the Columbretes Islands was studied by observers in 1998 to 1999. Both pelagic and demersal longline vessels operate in the region, fishing for swordfish, hake and bream, respectively. The fleet is composed of small vessels setting lines manually. Based on 88812 hooks observed, seabird bycatch rates were between 0.16 and 0.69 birds per 1000 hooks, with an estimated total bycatch of ca. 656 to 2829 birds killed per year, based on total fishing effort of 2.3 million hooks set in the pelagic fishery, and 1.8 million set in the demersal fishery (Belda & Sanchez 2001). Total fishery effort can therefore be calculated as ca. 4.1 million hooks, resulting in an estimate of total observer effort per year of 2.2%. Cory's shearwater was the dominant species caught (37%), followed by Audouin's gull *Larus audouinii* (8%). Based on these rates, Belda & Sanchez (2001) calculated that about 437 to 1867 Cory's shearwaters were being killed annually around the Columbretes Islands. We extrapolated an average annual bycatch rate of 0.425 birds per 1000 hooks and an annual total estimate of 1743 birds. Based on the approximate level of observer coverage (i.e. <5%), a data reliability score of 'Poor' was assigned to this fishery.

Northeast Atlantic Gran Sol hake fishery

In 2006 to 2007, 3 surveys were undertaken over the seasonal spread of the fishery, which operates for ca. 165 d yr^{-1} targeting mainly hake and black bream (P. Arcos [SEO/BirdLife] pers. comm.). There are ca. 35 Galician demersal longline vessels in the fleet and ca. 16 vessels operating at any one time (P. Arcos [SEO/BirdLife] pers. comm.). BirdLife International (2009) collated data on bycatch in the Gran Sol fishery from A. Barros, who conducted the majority of surveys. A bycatch rate of 1.008 birds per 1000 hooks was reported, with total estimated mortality of ca. 56307 birds yr^{-1}.

Total fishing effort (55860119 hooks yr^{-1}) was extrapolated from 238025 hooks observed, which equates to ca. 0.4% of the fishery observed. Total seabird mortality was estimated based on bycatch rates when full deck lighting was in use (as is the current norm in this fishery). On days when the observer asked for deck lighting to be switched off as an experiment, bycatch was virtually eliminated (BirdLife International 2009). Given the low levels of observer coverage in this fleet, a data reliability score of 'Poor' was assigned.

United Kingdom

Falkland Islands (Islas Malvinas) demersal longline fleet – Patagonian toothfish

Since 2002, the 2 vessels licensed to fish for Patagonian toothfish in the waters around the Falkland Islands have been required to take dedicated seabird observers. The requirement to follow a suite of mitigation measures and the compliance monitoring of the observers has resulted in very low levels of seabird bycatch (Crofts 2006). The target of 0.002 birds per 1000 hooks was achieved in 2006, a year ahead of the schedule set in the National Plan of Action (NPOA)-Seabirds. Falklands Conservation provided unpublished data from 2005 to 2006, reporting a bycatch rate of 0.002 birds per 1000 hooks, based on observations of 1693585 hooks (18.1% of the total annual effort of 9355201 hooks), resulting in an estimated total bycatch for the fleet of 16 birds yr^{-1} (S. Crofts pers. comm.). Latest figures for 2007 to 2008 indicate that no seabirds were killed within the EEZ, although 1 bird (a giant petrel) was reported killed by a Falkland Islands registered longliner on the high seas outside the EEZ (S. Crofts pers. comm.). Given that the level of observer coverage falls between 5 and 20%, a data reliability score of 'Medium' was assigned to this fishery.

South Georgia demersal longline fishery – Patagonian toothfish

This fishery is subject to a closure each year during the seabird breeding season. Vessels are also required to use a comprehensive suite of mitigation measures to reduce seabird bycatch, and there is 100% coverage by onboard observers. From 2006 onwards, no birds have been reported caught in the fishery (Croxall 2008). In 2008, total fishing effort was 16155379 hooks. As observer coverage is 100% in this fleet, a data reliability score of 'Good' was assigned.

Tristan da Cunha pelagic longline fishery – tuna and swordfish

Data for the pelagic longline fishery active around Tristan da Cunha are very limited, despite the important albatross and seabird colonies located there. Cuthbert et al. (2005) modelled annual seabird mortality and estimated that 471 to 554 Tristan albatross *Diomedea dabbenena* were killed per year, of which 32% of the interactions were likely to be occurring within the Tristan EEZ. From this we extrapolated a total seabird bycatch estimate for the Tristan EEZ of 151 to 177 birds. As bycatch estimates in this fishery were modelled, rather than being derived from direct observer data, a data reliability score of 'Poor' was assigned.

Tristan da Cunha demersal longline fishery – blue-eye trevalla

Data from the Tristan da Cuhna Government provide fishing effort and seabird bycatch data for the demersal longline fleet, which predominantly fishes for blue-eye trevally *Hyperoglyphe antarctica.* Total fishing effort from 1996 to 2008 was 7270021 hooks (N. Glass unpublished data). Assuming that the period 2005 to 2008 is representative of the current fishery, we used an average annual fishing effort of 907454 hooks from 2005 to 2008. For the majority of trips from 1996 to 2008, there was 100% observer coverage and 687 birds reported caught. From the observer data, we extrapolated an average annual bycatch rate of 0.09 birds per 1000 hooks (across 1996 to 2008). When applied to the 2005 to 2008 effort data, this results in an estimate of 86 birds killed per year. The records indicate that only 1 Tristan albatross was caught in the fishery throughout the period. The bulk of seabird mortality occurred on a few isolated trips, where up to 279 great shearwaters *Puffinus gravis* were caught on a single trip. These trips mainly occurred in the months of January to May. Given that observer coverage was 100% in this fleet, a data reliability score of 'Good' was assigned.

Uruguay

Industrial pelagic longline fishery – South Atlantic

Total fishing effort in 2006 for the Uruguayan industrial pelagic longline fleet was obtained from ICCAT records. ICCAT Task II data reported 1186243 hooks set in 2006. Bycatch data are available from the Uruguayan Observers Program, which observed 657722 hooks over 29 trips between 1998 and 2004 (Jimenez et al. 2009), with an average bycatch rate of 0.42 birds per 1000 hooks (range 0.11 to 2.48 birds per 1000 hooks), although there was considerable variability across areas and seasons, and between years (average rate of 0.11 birds per 1000 hooks in 2004 and 2.48 birds per 1000 hooks in 2002). A further study reported data from 1998 to 2006, with an average bycatch rate of 0.26 birds per 1000 hooks (from 2242026 hooks observed) (Jimenez & Domingo 2007). However, as Jimenez et al. (2009) provided the most recent published data, we used this source. Based on their data, we extrapolated a total bycatch figure of 498 birds (range 130 to 2942 birds) in 2006. Jimenez et al. (2009) also reported bycatch composition: albatrosses (82.8%), petrels (16.4%) and shearwaters (0.8%). From the average total bycatch, we calculated that ca. 412 albatrosses, 82 petrels and 4 shearwaters were caught in 2006. This fleet reports one of the highest proportions of albatrosses within its bycatch totals, and is thought to be of critical importance with respect to the declines of wandering albatross populations on South Georgia. As observer data were only reported by period (1998 to 2004), rather than by year, we estimated annual observer coverage to be ca. 9.2% (based on total effort figures for 2006). This led to a data reliability score of 'Medium'.

Industrial demersal longline fishery – hake

No data are currently available on seabird bycatch rates or total fishing effort for this fleet. It is not known whether seabird bycatch rates observed in the Chilean artisanal demersal longline fleet (see above) would be applicable to this fleet and therefore no extrapolation was attempted.

USA

Demersal longline fishery – All groundfish excluding Pacific halibut (Alaska)

In 2002, vessels began voluntary use of tori lines, and requirements for tori lines were implemented in 2004. NOAA (2006a) and Fitzgerald et al. (2008) reported an annual average seabird bycatch of 5138 birds in 2002 to 2006, compared to an average rate of 16507 birds killed per year between 1993 and 2000, i.e. a reduction of 68.9%. Seabird bycatch was relatively stable throughout 2002 to 2006. Since 2004, more than 95% of sets checked by observers had 1 or more tori lines deployed. Tori lines have been especially effective in reducing the bycatch of albatrosses (1051 albatrosses estimated killed per year between 1993 and 2000 compared to 185 albatrosses estimated killed per year in 2002 to 2006, taken from Fitzgerald et al. 2008).

The effort data shown in Table 1 of the main text are from 2006, and the number of birds estimated killed per year is based on the average 2002 to 2006 bycatch rate and 2006 effort data. This is because average fishing effort for 2002 to 2006 is not available in NOAA (2006a) or Fitzgerald et al. (2008). Estimated bycatch composition in 2006 was ca. 191 albatrosses, 1455 petrels (all of which were northern fulmars) and 429 shearwaters. As bycatch figures were only given in the above sources as total mortality estimates, it was not possible to discern specific levels of observer coverage. However, reference is made to an objective of 5% minimum observer coverage in the fleet, indicating that the data reliability would be likely to fall within the 'Medium' category. NOAA (2006b) also reported levels of observer coverage for 1993 to 2004. If we use 2004 levels, as most comparable to the period of bycatch and effort data, observer coverage was 17.2%. The average observer coverage from 2000 to 2004 was 19.3%. In either case, the level of observer coverage indicates a likely data reliability score of 'Medium'.

Demersal longline fishery – Pacific halibut (Alaska)

Observers are not required on groundfish vessels less than 60 feet (e.g. most of the sablefish fleet) or halibut vessels of any size (except for a few rare circumstances; Dietrich & Fitzgerald 2010). This makes it difficult to estimate seabird bycatch in the halibut fleet operating off Alaska. However, the fishery does have estimates of total effort. Unpublished data from the IPHC report hooks set from 2004 to 2010, and distinguish between effort reported to IPHC in the commercial halibut fishery, the directed halibut fishery and in miscellaneous fisheries (IPHC unpubl. data). Observer data from the Pacific halibut fishery operating off British Columbia reported an estimated bycatch rate of 0.0071 between 1999 and 2002 (Smith & Morgan 2005). We extrapolated an average annual total effort for the Alaskan halibut fishery of 35580316 hooks yr^{-1} (2004 to 2010), and estimated total mortality as 253 birds yr^{-1}.

Demersal longline fishery – West coast USA

The groundfish trawl fishery comprises the majority of west coast demersal activity, with nearshore fixed-gear vessels targeting sablefish forming the rest. The latter fleet operates from northern Oregon to southern California. Observer data are collected by the West Coast Groundfish Observer Program (Heery et al. 2010). In this report, data were provided by individual species, requiring extrapolations to obtain total seabird mortality estimates for the fishery. Data were reported from 2002 to 2008, with observer coverage varying between 21 and 52% of trips during these years. The main species caught was black-footed albatross. We extrapolated a total bycatch estimate per year of 78 birds, based on black-footed albatross estimates for 2004 to 2008 (Heery et al. 2010). This species appeared to be the only species caught in any significant number in the fixed gear fishery during this period, although other species were caught in the demersal trawl fleet operating in the same area. Given that observer coverage was reported to be >20% per year between 2002 and 2008, this fishery falls within the 'Good' data reliability category.

Pelagic longline fishery – NW Atlantic, Gulf of Mexico, Caribbean

The pelagic longline fleet targets swordfish and various tuna and shark species in the Gulf of Mexico, Caribbean Sea and North Atlantic Ocean. The US Pelagic Observer Programme aims to cover 5% of the fleet, through a random sample of permitted vessels each year, and observed 6400 pelagic longline sets from 1992 to 2004 (or 4375000 hooks) during which 113 birds were caught, with an overall average bycatch rate of 0.027 birds per 1000 hooks (Hata 2006). However, when total hooks observed were averaged over the 12 yr period, observer coverage was only ca. 4.5%. Rounding this value up (i.e. to 5%), a data reliability metric of 'Medium' was assigned to the fleet. Seabird bycatch occurred in all years except 1996.

Hata (2006) estimated average annual seabird bycatch to be ca. 230 birds yr^{-1} (range 139 to 333 birds yr^{-1}), based on data from 1992 to 2004. These estimates were based on the assumption that hook types used throughout the fishery were used in equal proportion to those observed, and that capture rates remained the same. The range in bycatch rates varied considerably by region (0.036 to 0.105 birds per 1000 hooks), and by season. The highest bycatch rates occurred in July to September. It should be noted that annual estimates as high as 4445 were reported for 1990. For the purposes of this review, however, we listed the typical ranges from 1987 to 2004 as being more representative of the likely bycatch annually. Comprehensive species-specific data were not available; however, great shearwaters *Puffinus gravis* were reported killed in highest numbers (95% of total bycatch), followed by gulls (65%) and northern gannets *Morus bassanus* (14%).

Pelagic longline fishery – Hawaiian Islands tuna and swordfish

Some of the most comprehensive observer coverage, and therefore seabird bycatch data, originates from the Hawaiian pelagic longline fisheries that operate predominantly in waters between 3–37° N and 132–173° W (tuna vessels), and between 12–43° N and 127–178° W (swordfish vessels). Vessels targeting broadbill swordfish (shallow-set) are required by US law to have 100% observer coverage. Those vessels targeting tuna (deep-set) are required to have at least 20% observer coverage overall. Within this, vessels which operate north of 23° N are only required to have 5% observer coverage, but the true coverage often exceeds this and is typically ca. 20% (32.1% in 2005). Because both shallow and deep-set fisheries have >20% observer coverage, the data reliability metric for this fishery was identified as 'Good'.

In Table 1 of the main text, 2005 data are used rather than 2006 data, since the fishery was curtailed in 2006 following bycatch of loggerhead turtles. Following the adoption of mandatory mitigation measures, seabird bycatch declined from ca. 2300 albatrosses yr^{-1} in the late 1990s to fewer than 200 in 2005 (Clemens 2006). In 2005, the total estimate take of albatrosses was 125 in the tuna fishery (ca. 0.004 birds per 1000 hooks) and 69 albatrosses in the swordfish fishery (ca. 0.04 birds per 1000 hooks; Clemens 2006). Effort data for 2005 was 33.6 million hooks set for tuna and 1.3 million hooks set for swordfish (Rivera 2008). Species composition data were available for both of these fisheries, with 82 black-footed albatrosses and 43 Laysan albatrosses estimated killed in 2005 in the tuna fishery, and 62 Laysan and 7 black-footed albatrosses killed in 2005 in the swordfish fishery (Clemens 2006).

Pelagic longline fishery – West coast USA

This fleet fishes for swordfish in the East Pacific Ocean, a fishery that is overseen by the IATTC. National Marine Fisheries Service (NMFS) observers monitored this fishery from 2001 to 2004 and reported 72 black-footed albatrosses and 7 Laysan albatrosses caught (Rivera et al. 2006). This equated to a bycatch rate of 0.23 birds per 1000 hooks (L. Enriquez, cited by Rivera et al. 2006). However, from 2005 this fishery reduced to 1 vessel and switched to deep-set tuna fishing. While the fishery maintains 100% observer coverage, no data on fishing effort are available due to confidentiality. Hence, it is not possible to obtain a total bycatch estimate for this fishery at the current time (L. Enriquez pers. comm.). Nevertheless, given that the observer coverage is reported to be 100%, a data reliability score of 'Good' was assigned.

IUU fisheries

Due to the nature of IUU fishing, it is very difficult to estimate bycatch in these fleets with any degree of accuracy. The Marine Resources and Assessment Group (MRAG) highlighted several problems when attempting to quantify seabird bycatch in IUU fisheries: (1) the lack of accurate knowledge on the extent of IUU longlining in high seas waters relative to legitimate longlining, (2) the lack of data on seabird bycatch generally, even in the non-IUU fleet, and (3) the assumption that IUU vessels do not use any mitigation measures to prevent seabird bycatch may not be true, but we have no means of ascertaining whether this is the case (MRAG 2005).

Nevertheless, MRAG (2005) were able to estimate of seabird bycatch for IUU longline fishing activities in tuna and swordfish fisheries in the high seas south of 30° S. MRAG estimated levels of IUU activity occurring in 3 of the tuna RFMOs south of 30° S (10% of total effort south of 30° S in the IOTC, 1% in the ICCAT, and 10 to 33% in the CCSBT). Fishing effort data were then multiplied by an estimated bycatch rate for 2001 to 2002, based on data from the Japanese southern bluefin tuna fleet. This resulted in a total estimate of 2739 to 6326 birds caught per year by IUU activities in tuna and swordfish fleets south of 30° S (MRAG 2005). Estimates for the Pacific tuna commissions IATTC and WCPFC were covered within the CCSBT estimates. The MRAG report also includes data for CCAMLR, but in this review we dealt with this separately (see CCAMLR). Clearly, given the complete lack of observer coverage in IUU fisheries, data reliability is nil and so a score of 'Poor' was assigned to all IUU fisheries.

Table S1. Further information on how overall data reliability scores (DRS, see Table 1 of the main text for details) were arrived at. DRS criteria, 1: age of bycatch data, 2: source, 3: accuracy (see the Methods section in the main text). Criterion 3 was further divided into 3 sub-categories, 3i: quantity of observer coverage, 3ii: quality of observer coverage, 3iii: variability of bycatch rates. Figures in square brackets are extrapolated from other data. Fishery type, D: demersal, P: pelagic. DRS code: P: Poor, M: Medium, G: Good. BPUE: birds per unit effort (birds per 1000 hooks), NA: not applicable

Country	**Location**	**Fishery type**	**Bycatch data period**	**Observed fishing effort** (Hooks or %)	**Estimated BPUE**	**Range of estimated annual seabird bycatch rate** (birds per 1000 hooks)	**Age of bycatch data** (1986-94 = P, 1995-99 = M, 2000-09 = G)	**Source of bycatch data** (All bycatch data from elsewhere = P, partial data from elsewhere = M, no data from elsewhere = G)	**Quantity of observer coverage** (<5% =P, 5-20% = M, >20% = G)	**Quality of observer coverage** (Poor spatial & temporal cover = P, poor spatial or temporal cover = M, high relative spatial & temporal cover = G)	**Variation in bycatch** (High spatial & temporal var. = P, high spatial or temporal var. = M, low spatial & temporal var. = G)	**Overall data reliability matrix**
Angola	S Angola, Benguela current, S Atlantic	P	2004, 2006	0	[0.07]		G	P	P	P	P	P
Argentina	Patagonian shelf	D	1999-2001		0.04		G	G	M	M	NA	M
Australia	S & E Australia	D	2002-2005	270166	[0.001]		G	G	M	M	NA	M
Australia	E Australia	P	2007	455964	0.0248	0.0146-0.0383	G	G	M	G	G	G
Australia	W Australia	P	2004	200000	0.02		G	G	P	M	NA	M
Brazil	SW Atlantic	P	2001-2007	788446	0.229	0.036-0.542	G	M	M	M	P	M
Brazil	Itaipava	P	2001-2006	40717	0.15	0-3	G	G	P	P	P	P
Canada	Gulf of St. Lawrence	D	2001	5-10%	unknown	0.0036-0.0108	G	G	M	G	M	M
Canada	Atlantic	D	1986-1999	3-10%	0.016		M	G	M	P	NA	M
Canada	Scotia Shelf, Grand Banks	P	1986-1999	3-10%	0.032		M	G	M	P	NA	M
Canada	Pacific	D	1999-2002	8.1%	0.0071		G	G	M	M	NA	M
Canada	Pacific	D	1999-2002	[245240]	[0.017]		G	G	M	M	NA	M
CCAMLR	Convention Area (excl. sub-areas listed below)	D	2007-2008	[43%]	0		G	G	G	G	NA	G
CCAMLR	French EEZ 58.6 (Crozet)	D	2007-2008	24.6%	0.0305		G	G	G	G	NA	G
CCAMLR	French EEZ 58.5.1 (Kerguelen)	D	2007-2008	24.6%	0.0585		G	G	G	G	NA	G

Country	Location	Fishery type	Bycatch data period	Observed fishing effort (Hooks or %)	Estimated BPUE	Range of estimated annual seabird bycatch rate (birds per 1000 hooks)	Age of bycatch data (1986-94 = P, 1995-99 = M, 2000-09 = G)	Source of bycatch data (All bycatch data from elsewhere = P, partial data from elsewhere = M, no data from elsewhere = G)	Quantity of observer coverage (<5% =P, 5-20% = M, >20% = G)	Quality of observer coverage (Poor spatial & temporal cover = P, poor spatial or temporal cover = M, high relative spatial & temporal cover = G)	Variation in bycatch (High spatial & temporal var. = P, high spatial or temporal var. = M, low spatial & temporal var. = G)	Overall data reliability matrix
Chile	NW Patagonia, S Chile, S Pacific	D	1999, 2002	330632	0.03		G	G	G	M	NA	G
Chile	NW Patagonia, S Chile, S Pacific	D	2002	88280	0.047	+/-0.029	G	G	P	P	M	P
Chile	S Chile, S Pacific	D	2006	1508500	0		G	G	G	G	G	G
Chile	FAO Area 87	P	2007	90000	[0.29]	[0.21-0.37]	G	G	P	M	M	M
China	E Pacific Ocean	P	2003	304390	[0.02]		G	G	P	P	NA	P
China	Indian Ocean	P	2002-2006	0	[0.00]		G	P	P	P	NA	P
China	W Pacific Ocean	P	2008	96070	[0.00]		G	P	P	P	NA	P
Chinese Taipei	Atlantic Ocean	P	2002-2006	15602000	0.0075	0-0.2266	G	G	M	M	P	M
Chinese Taipei	Pacific Ocean	P	2002-2006	5348000	0.045	0-0.65	G	G	P	M	M	M
Chinese Taipei	Indian Ocean	P	2002-2006	6407000	0.048	0-0.22	G	G	P	P	P	P
Faroes	N Atlantic	D	1997-1998	0	[0.02]		P	P	P	P	NA	P
Iceland	N Atlantic	D	1996	0	[0.02]		P	P	P	P	NA	P
Japan	Mainly S of 20° S	P	2006-2007	[1607229]	[0.23]		G	G	M	G	NA	M
Japan	N Pacific	P	1994-2000		[0.16]		M	P	P	P	NA	P
Korea	E Pacific Ocean (IATTC waters)	P	2004-2005	51533	[0.02]		G	G	P	P	NA	P
Korea	Atlantic Ocean	P	2002-2006	0	[0.038]		G	P	P	P	NA	P
Korea	Indian Ocean	P	2002-2006	0	[0.10]		G	P	P	P	NA	P
Mediterranean	Maltese waters	D	2006	146 fishers	1.41 fisher^{-1} yr^{-1}		G	G	P	P	NA	P
Mediterranean	W Mediterranean	P	1999-2000	0	[0.0133]	[0.002-0.023]	G	P	P	P	NA	P

Country	Location	Fishery type	Bycatch data period	Observed fishing effort (Hooks or %)	Estimated BPUE	Range of estimated annual seabird bycatch rate (birds per 1000 hooks)	Age of bycatch data (1986-94 = P, 1995-99 = M, 2000-09 = G)	Source of bycatch data (All bycatch data from elsewhere = P, partial data from elsewhere = M, no data from elsewhere = G)	Quantity of observer coverage (<5% =P, 5-20% = M, >20% = G)	Quality of observer coverage (Poor spatial & temporal cover = P, poor spatial or temporal cover = M, high relative spatial & temporal cover = G)	Variation in bycatch (High spatial & temporal var. = P, high spatial or temporal var. = M, low spatial & temporal var. = G)	Overall data reliability matrix
Namibia	Benguela current, S Atlantic	D	2006	456000	[0.145]	0.002-0.138, 0.01-0.65	G	G	P	P	P	P
Namibia	Benguela current, S Atlantic	P	2004, 2006	30770	0.07	0.05-0.6	G	G	P	M	P	P
New Zealand	NE and SW EEZ predominantly	P	2006-2007	955519	0.196	0.13-1.87	G	G	G	G	P	G
New Zealand	Campbell Plateau, Chatham Rise	D	2006-2007	2344205	0.026	0-0.075	G	G	M	M	M	M
Norway	NE Atlantic	D	1996-1999	760000	0.02	0.01-0.04	M	G	P	P	M	P
Norway	NE Atlantic	D	1996-1999	[126700]	0.023	0.013-1.12	M	G	P	P	P	P
Peru	Ilo, Callao, Salaverry	P	2005-2006	354222	0.0028		G	G	P	P	NA	P
Peru	12-18° S	D			Unknown		M	P	P	P	NA	P
Russia	W Bering Sea, E Kamchatka	D	2003-2004	2700000	[0.0915]		G	G	P	M	NA	P
Russia	Sea of Okhotsk (Pacific)	D	2004-2005	1100000	0.011		G	G	P	M	NA	P
South Africa	Benguela Current, S Atlantic	D	2000-2006	6.8%	0.0075	0.0012-0.0329	G	G	M	M	M	M
South Africa	Indian Ocean (Asian fleet)	P	2008	2846000	0.05		G	G	G	G	G	G
South Africa	Atlantic Ocean (Asian fleet)	P	2008	341000	0.103		G	G	G	G	G	G
South Africa	S Atlantic, Indian Ocean (domestic fleet)	P	1998-2005	9.8%	0.23	0.22-0.24	G	G	M	M	G	M
Spain	E Pacific Ocean (IATTC waters)	P	1990, 1998-2005	2153000	0.04		G	G	P	M	NA	P
Spain	W Pacific Ocean (WCPFC waters)	P	1990-2005	1129000	0.032		G	G	P	M	NA	P
Spain	SW Indian Ocean	P	2004-2005	531916	[0.00563]		G	G	M	P	NA	M
Spain	S Atlantic	P	2002-2006	[15602000]	[0.10]		G	P	P	P	NA	P

Country	Location	Fishery type	Bycatch data period	Observed fishing effort (Hooks or %)	Estimated BPUE	Range of estimated annual seabird bycatch rate (birds per 1000 hooks)	Age of bycatch data (1986-94 = P, 1995-99 = M, 2000-09 = G)	Source of bycatch data (All bycatch data from elsewhere = P, partial data from elsewhere = M, no data from elsewhere = G)	Quantity of observer coverage (<5% =P, 5-20% = M, >20% = G)	Quality of observer coverage (Poor spatial & temporal cover = P, poor spatial or temporal cover = M, high relative spatial & temporal cover = G)	Variation in bycatch (High spatial & temporal var. = P, high spatial or temporal var. = M, low spatial & temporal var. = G)	Overall data reliability matrix
Spain	W Mediterranean	P	2000-2008	4786466	0.038	0.003-0.091	G	G	M	M	M	M
Spain	Columbretes Islands, Mediterranean	D & P	1998-1999	[88812]		0.16-0.69	M	G	M	M	P	M
Spain	Gran Sol, SW Ireland	D	2006-2007	238025	1.008		G	G	P	P	NA	P
UK	Falkland Islands (Islas Malvinas)	D	2005-2006	1693585 (18.1%)	0.002	0.0008-0.003 (8)	G	G	M	M	M	M
UK	South Georgia	D	2008	100%	[0.00]		G	G	G	G	NA	G
UK	Tristan da Cunha	P	1990-1998	0	Unknown	[0.00]	M	P	P	P	M	P
UK	Tristan da Cunha	D	1996-2008	100%	[0.09]	0.017-0.020	G	G	G	G	NA	G
Uruguay	S Atlantic	P	1998- 2004	648000	0.42	0.11-2.48	G	G	M	M	P	M
USA	Alaska	D	2002-2006		0.017		G	G	M	M	NA	M
USA	Alaska	D	1999-2002	0	[0.0071]		M	P	P	P	NA	P
USA	Alaska	D	2002-2008	21-52%			G	G	G	G	M	G
USA	NW Atlantic, Gulf of Mexico, Caribbean	P	1992-2004	4375000	0.027	0.036-0.105	G	G	P	M	M	M
USA	Hawaii	P	2005	[8769600]	0.004		G	G	G	G	NA	G
USA	Hawaii	P	2005	[1300000]	0.04		G	G	G	G	NA	G
USA	US West Coast	P	2005	100%	0.23		G	G	G	G	NA	G
IUU	South of 30° S	P	2001-2002				P	P	P	P	NA	P

Table S2. Comparison between current and previous (Nel & Taylor 2003) estimates of numbers of seabirds killed per year in longline fisheries. IPHC: International Pacific Halibut Commission, IATTC: Inter-American Tropical Tuna Commission, ICCAT: International Commission for the Conservation of Atlantic Tuna, IOTC: Indian Ocean Tuna Commission, WCPFC: Western and Central Pacific Fisheries Commission, IUU: illegal, unregulated and unreported longline fishing activity. Fishery types, D: demersal, P: pelagic. Figures in square brackets are extrapolated from other data. For details on sources cited by Nel & Taylor (2003), see their original document. NA: not applicable

Country of fishery	Location	Fishery type	Previous bycatch estimate	Current bycatch estimate	Reason for change	Comments	Current sources	Nel & Taylor (2003) sources
Angola	S Angola, Benguela current, S Atlantic	P	NA	245	New entry	No entry for fishery in Nel & Taylor (2003)	Petersen et al. (2007), Petersen et al. unpubl.	NA
Argentina	Patagonian shelf	D	1160	[58]	Decline in fishing effort		E. Frere pers. comm., P. Gandini unpubl.	Favero et al. (2003)
Australia	S & E Australia	D	NA	10	New data	No estimate in Nel & Taylor (2003)	Baker & Finley (2008)	Reid et al. (2001), C. Robertson pers comm.
Australia	E Australia	P	NA	[209]	New data	No estimate in Nel & Taylor (2003)	Baker & Finley (2008)	Reid et al. (2001), C. Robertson pers comm.
Australia	W Australia	P	NA	[30]	New data	No estimate in Nel & Taylor (2003)	Baker & Finley (2008)	Reid et al. (2001), C. Robertson pers comm.
Brazil	SW Atlantic	P	6656	[2061]	New data/partial voluntary use of mitigation measures		Bugoni et al. (2008a)	Neves (2000), Olmos et al. (2000)
Brazil	Itaipava	P	NA	[max 9107]	New data	No entry for fishery in Nel & Taylor (2003)	Bugoni et al. (2008b)	NA
Brazil	SW Atlantic	D	4214	0	New data/fishery collapse	The demersal fleet suffered total collapse in recent years	E. Frere pers. comm.	Neves (2000), Olmos et al. (2000)
Canada	Gulf of St. Lawrence	D	NA	[70-327]	New data	No entry for fishery in Nel & Taylor (2003)	DFO Canada (2007)	NA
Canada	Atlantic	D	NA	500	New data	No entry for fishery in Nel & Taylor (2003)	Cooper et al. data in DFO Canada (2007)	NA
Canada	Scotia Shelf, Grand Banks	P	NA	1,400	New data	No entry for fishery in Nel & Taylor (2003)	Cooper et al. data in DFO Canada (2007)	NA
Canada	Pacific	D	NA	54	New data	No estimate in Nel & Taylor (2003)	Smith & Morgan (2005)	Morgan et al. (2000), Trager (2000)
Canada	Pacific	D	NA	72	New data	No entry for fishery in Nel & Taylor (2003)	Smith & Morgan (2005)	NA

Country of fishery	Location	Fishery type	Previous bycatch estimate	Current bycatch estimate	Reason for change	Comments	Current sources	Nel & Taylor (2003) sources
CCAMLR	Convention Area	D	14050	0	New data	Prev. estimate based on IUU in CCAMLR (huge reduction since then)	CCAMLR (2008)	CCAMLR (2002)
CCAMLR	French EEZ 58.6 (Crozet)	D	10510	131	New data	Prev. estimate based on IUU in CCAMLR (huge reduction since then), plus 360 from French fleet	CCAMLR (2008)	CCAMLR (2001, 2002), Nel et al. (2002)
CCAMLR	French EEZ 58.5.1 (Kerguelen)	D	43597	1224	New data	Prev. estimate based on IUU in CCAMLR (huge reduction since then), plus 1897 from French fleet	CCAMLR (2008)	CCAMLR (2001, 2002), Nel et al. (2002)
Chile	NW Patagonia, S Chile, S Pacific	D	NA	[54]	New data	No estimate in Nel & Taylor (2003)	Moreno et al. (2006)	Garcia (2000)
Chile	NW Patagonia, S Chile, S Pacific	D	NA	437	New data/reduction in fishing effort	No estimate in Nel & Taylor (2003)	Moreno et al. (2006)	Arata & Moreno (2002), Garcia (2000)
Chile	S Chile, S Pacific	D	NA	0	New data/change in fishing methods	No estimate in Nel & Taylor (2003)	Moreno et al. (2008)	Arata & Moreno (2002), Garcia (2000)
Chile	FAO Area 87	P	NA	517-923	New data	No estimate in Nel & Taylor (2003)	Moreno et al. (2007)	C. Robertson pers comm.
China	E Pacific Ocean	P	NA	[866]	New data	No entry for fishery in Nel & Taylor (2003)	Dai et al. (2006), IATTC (2007)	NA
China	Indian Ocean	P	NA	[0]	New data	No entry for fishery in Nel & Taylor (2003)	Xu et al. (2007), Huang et al. (2008c)	NA
China	W Pacific Ocean	P	NA	[0]	New data	No entry for fishery in Nel & Taylor (2003)	Dai & Zhu (2008)	NA
Chinese Taipei	Atlantic Ocean	P	NA	936	New data	Old S Ocean estimate [1440 birds] similar to Atlantic and Indian Ocean estimates combined	Huang et al. (2008a)	Huang & Day (2000), Hsia (2002)
Chinese Taipei	Pacific Ocean	P	2945	1660	New data	New upper range similar (2030 birds), but old estimate only for N Pacific	Huang et al. (2008b)	Tuck et al. (2003)
Chinese Taipei	Indian Ocean	P	NA	1512	New data	Old S Ocean estimate [1440 birds] similar to Atlantic and Indian Ocean estimates combined	Huang et al. (2008c)	Huang and Day (2000), Hsia (2002)
Japan	Mainly south of 20° S	P	[17242]	[6299]	New data/reduction in fishing effort/reduction in bycatch rate	Note current range in estimate is still high [1163-14182 birds]	Minami et al. (2009)	Uozumi (1997), Tuck et al. (2003)

Country of fishery	Location	Fishery type	Previous bycatch estimate	Current bycatch estimate	Reason for change	Comments	Current sources	Nel & Taylor (2003) sources
Japan	North Pacific	P	14540	14540	No change	Same source used	Crowder & Myers (2001)	Crowder & Myers (2001)
Korea	E. Pacific Ocean (IATTC waters)	P	NA	[727]	New data	No entry for fishery in Nel & Taylor (2003)	IATTC (2007), Moon et al. (2005)	NA
Korea	Indian Ocean, South of 20° S	P	NA	[97]	New data	No entry for fishery in Nel & Taylor (2003)	IOTC unpubl. data, Huang et al. (2008c)	NA
Korea	Atlantic Ocean	P	NA	[67]	New data	No entry for fishery in Nel & Taylor (2003)	ICCAT (2008), Huang et al. (2008a)	NA
Mediterranean	Maltese waters	D	NA	1220	New data	No entry for fishery in Nel & Taylor (2003)	Dimech et al. (2008)	NA
Mediterranean	W Mediterranean	P	NA	[259]	New data	No entry for fishery in Nel & Taylor (2003)	ICCAT (2008), Valeiras & Caminas (2003)	NA
Namibia	Benguela current, S Atlantic	D	NA	20,200	New data	No entry for fishery in Nel & Taylor (2003)	Petersen (2008)	NA
Namibia	Benguela current, S Atlantic	P	NA	206	New data	No entry for fishery in Nel & Taylor (2003)	Petersen et al. (2007, unpubl.)	NA
New Zealand	NE & SW EEZ predominantly	P	NA	715	New data	No estimate in Nel & Taylor (2003)	Abraham & Thompson (2009)	Baird (2001), C. Robertson pers comm.
New Zealand	Campbell Plateau, Chatham Rise	D	4,958	1122	Reduction in bycatch rate/use of mitigation measures	Increased effort, but use of mitigation measures led to decline in bycatch	Abraham & Thompson (2009)	Baird (2001), NZ Dept Cons (2002)
Peru	Ilo, Callao, Salaverry	P	3,990	190	New data		Pro Delphinus (2006), J. Mangel et al. unpubl. data	Jahncke (2001), D. Anderson pers comm.
Peru	12-18° S	D	NA	NA	New data (total fishing effort)	No entry for fishery in Nel & Taylor (2003)	Goya & Cardenas (2004)	NA
Russia	W Bering Sea, E Kamchatka	D	NA	[6334]	New data	No entry for fishery in Nel & Taylor (2003)	Artyukhin et al. (2006)	NA
Russia	Sea of Okhotsk (Pacific)	D	NA	[288]	New data	No entry for fishery in Nel & Taylor (2003)	Artyukhin et al. (2006)	NA
South Africa	Benguela current, S Atlantic	D	NA	225	New data	No entry for fishery in Nel & Taylor (2003)	Petersen (2008)	NA

Country of fishery	Location	Fishery type	Previous bycatch estimate	Current bycatch estimate	Reason for change	Comments	Current sources	Nel & Taylor (2003) sources
South Africa	Indian Ocean (Asian fleet)	P	[17427]	141	Reduction in bycatch rates/reduction in fishing effort	Enforced used of mitigation measures substantially reduced bycatch rates	P. Ryan et al. unpubl. data	Ryan et al. (2002)
South Africa	Atlantic Ocean (Asian fleet)	P	As above	35	Reduction in bycatch rates/reduction in fishing effort	Old estimate combined Asian fleet data in Indian and Atlantic Oceans	Ryan et al. (2009)	Ryan et al. (2002)
South Africa	S Atlantic & Indian O. (domestic fleet)	P	[354]	[299]	Reduction in bycatch rates	Less reduction than Asian fleets. Poss. due to 20% observer coverage versus 100% in Asian fleets	Petersen et al. (2007, unpubl).	Ryan et al. (2002)
Spain	E Pacific Ocean (IATTC waters)	P	NA	[260]	New data	No entry for fishery in Nel & Taylor (2003)	Mejuto & Garcia-Cortes (2005), Mejuto et al. (2007a)	NA
Spain	W Pacific Ocean (WCPFC waters)	P	NA	[141]	New data	No entry for fishery in Nel & Taylor (2003)	Mejuto et al. (2007a,b) Lawson (2007)	NA
Spain	SW Indian Ocean	P	NA	[37]	New data	No entry for fishery in Nel & Taylor (2003)	Ariz et al. (2006), IOTC unpubl. data	NA
Spain	S Atlantic Ocean	P	NA	[258]	New data	No entry for fishery in Nel & Taylor (2003)	ICCAT (2008), Huang et al. (2008a)	NA
Spain	W Mediterranean	P	NA	[413]	New data	No entry for fishery in Nel & Taylor (2003)	García-Barcelona et al. (2009)	NA
Spain	Columbretes I., Mediterranean	D & P	NA	[1743]	New data	No entry for fishery in Nel & Taylor (2003)	Belda & Sanchez (2001)	NA
Spain	Gran Sol, SW Ireland	D	NA	56307	New data	No entry for fishery in Nel & Taylor (2003)	P. Arcos (SEO/BirdLife) pers. comm.	NA
UK	Falkland Islands (Islas Malvinas)	D	40	[16]	New data	Improvements in mitigation measures, reduction in fishing effort	Falklands Conservation unpubl. data	CCAMLR (2002), Moreno et al. (1996)
UK	South Georgia	D	40	0	New data	Improvements in mitigation measures, reduction in fishing effort	CCAMLR (2008)	CCAMLR (2002)
UK	Tristan da Cunha	P	NA	[164]	New data	No entry for fishery in Nel & Taylor (2003)	Cuthbert et al. (2005)	NA
UK	Tristan da Cunha	D	NA	[86]	New data	No entry for fishery in Nel & Taylor (2003)	N. Glass unpubl.	NA

Country of fishery	Location	Fishery type	Previous bycatch estimate	Current bycatch estimate	Reason for change	Comments	Current sources	Nel & Taylor (2003) sources
Uruguay	S Atlantic	P	[6000]	[498]	New data/reduction in fishing effort	Previous fishing effort 20 million hooks, currently 1.2 million hooks	Jimenez et al. (2009), ICCAT (2008)	Stagi (2000), Tuck et al. (2003)
USA	Alaska	D	16800	5138	New data/use of mitigation measures		NOAA (2006a)	Stehn et al. (2001)
USA	Alaska	D	NA	[253]	New data	No entry for fishery in Nel & Taylor (2003)	IPHC (unpubl. data)	NA
USA	Alaska	D	As above	[78]	New data	Old estimate combined with Alaskan groundfish fleet	Heery et al. (2010)	NA
USA	NW Atlantic, Gulf of Mexico, Caribbean	P	NA	230	New data	No entry for fishery in Nel & Taylor (2003)	Hata (2006)	NA
USA	Hawaii	P	3268	125	New data/use of mitigation measures	Old estimate combined whole US N Pacific fleet, excluding US W coast	Rivera et al. (2008)	Tuck et al. (2003)
USA	Hawaii	P	As above	69	New data/use of mitigation measures	Old estimate combined whole US N Pacific fleet, excluding US W coast	Rivera et al. (2008)	Tuck et al. (2003)
USA	US West Coast	P	NA	NA		Bycatch rate estimates, but no total bycatch figure	L. Enriquez pers comm.	Rivera (2002)
IUU	South of 30° S	P	NA	[4,533]	New data	No entry for fishery in Nel & Taylor (2003)	MRAG (2005)	NA

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