

Karl-Hermann Kock · Martin G Purves · Guy Duhamel

## Interactions between Cetacean and Fisheries in the Southern Ocean

Received: 27 April 2005 / Revised: 15 August 2005 / Accepted: 31 August 2005 / Published online: 7 October 2005  
© Springer-Verlag 2005

**Abstract** Soon after longlining on Patagonian toothfish (*Dissostichus eleginoides*) started in the Southern Ocean in the second half of the 1980s, interactions of cetaceans with these fisheries became apparent. The two species primarily involved were orcas (killer whales) (*Orcinus orca*) and male sperm whales (*Physeter macrocephalus*). Both species took substantial number of fish from the line primarily during day light hours. Catch rates of longliners declined to less than 50% when orcas occurred close to longline vessels while the loss to sperm whales was much less obvious. They were seen diving close to the line down to 400 m where they apparently took fish. Their impact on catch rates was much less notable. Sperm whales became frequently entangled in the line and part of the line was lost in a number of cases. Other cetaceans were rarely seen in the vicinity of longline vessels. They became entangled in the line only occasionally and one whale (presumably a minke whale) died.

- Longline fisheries around various sub-Antarctic islands on Patagonian toothfish (*Dissostichus eleginoides*) (CCAMLR Subareas and Divisions 48.3, 58.6, 58.7, 58.5.1, 58.5.2, and 58.4.4),
- Exploratory longline fisheries on Antarctic toothfish (*D. mawsoni*) in parts of the Ross Sea (CCAMLR Subareas 88.1 and 88.2),
- A pelagic trawl fishery on mackerel icefish (*Champsocephalus gunnari*) around South Georgia (CCAMLR Subarea 48.3),
- A bottom trawl fishery on mackerel icefish around Heard and McDonald Islands (CCAMLR Division 58.5.2), and
- A pelagic trawl fishery on krill (*Euphausia superba*) in the western Atlantic Ocean sector (CCAMLR Subareas 48.1, 48.2, and 48.3)

In addition to commercial activities, CCAMLR receives applications for a large number of exploratory longline fisheries in almost all of its Statistical Subareas and Divisions (Fig. 1) and exploratory trawl fisheries in some Subareas and close to the Antarctic continent in the Indian Ocean sector in each year (SC-CAMLR 2004).

The fishery on the two toothfish species is currently the most important in terms of catch value. The fishery on Patagonian toothfish has declined substantially in recent years and a number of stocks in these fisheries are over-exploited mostly due to illegal, unreported and unregulated (IUU) activities in particular in the Indian Ocean sector of the Southern Ocean since the mid-1990s (Duhamel 2003).

Interactions of fisheries in the Southern Ocean occur on a much larger scale with respect to albatrosses and larger petrels than with cetaceans and other marine mammals (e.g. Anon. 2000, 2001, 2002, 2003, 2004; Kock 2001; Purves et al. 2004). Interactions with cetaceans were first reported to CCAMLR from South Georgia in 1994 when scientific observers onboard three fishing vessels described how orcas (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*) were foraging for fish caught on longlines and sometimes became

### Introduction

Fisheries in the Southern Ocean are regulated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). A number of fisheries are currently in use to harvest fish stocks and krill:

---

K.-H. Kock (✉)  
Institut für Seefischerei, Bundesforschungsanstalt für Fischerei,  
Palmaille 9, 22767 Hamburg, Germany  
E-mail: karl-hermann.kock@ish.bfa-fisch.de

M. G Purves  
Capfish, Waterfront, P.O. Box 50035,  
8002 Cape Town, South Africa

G. Duhamel  
Département des milieux et peuplement aquatiques,  
Biodiversité et dynamique des communautés aquatiques USM 403,  
Museum National D'Histoire Naturelle, Case postale 26, 43 rue,  
Cuvier, 75231 Paris, Cedex 05, France

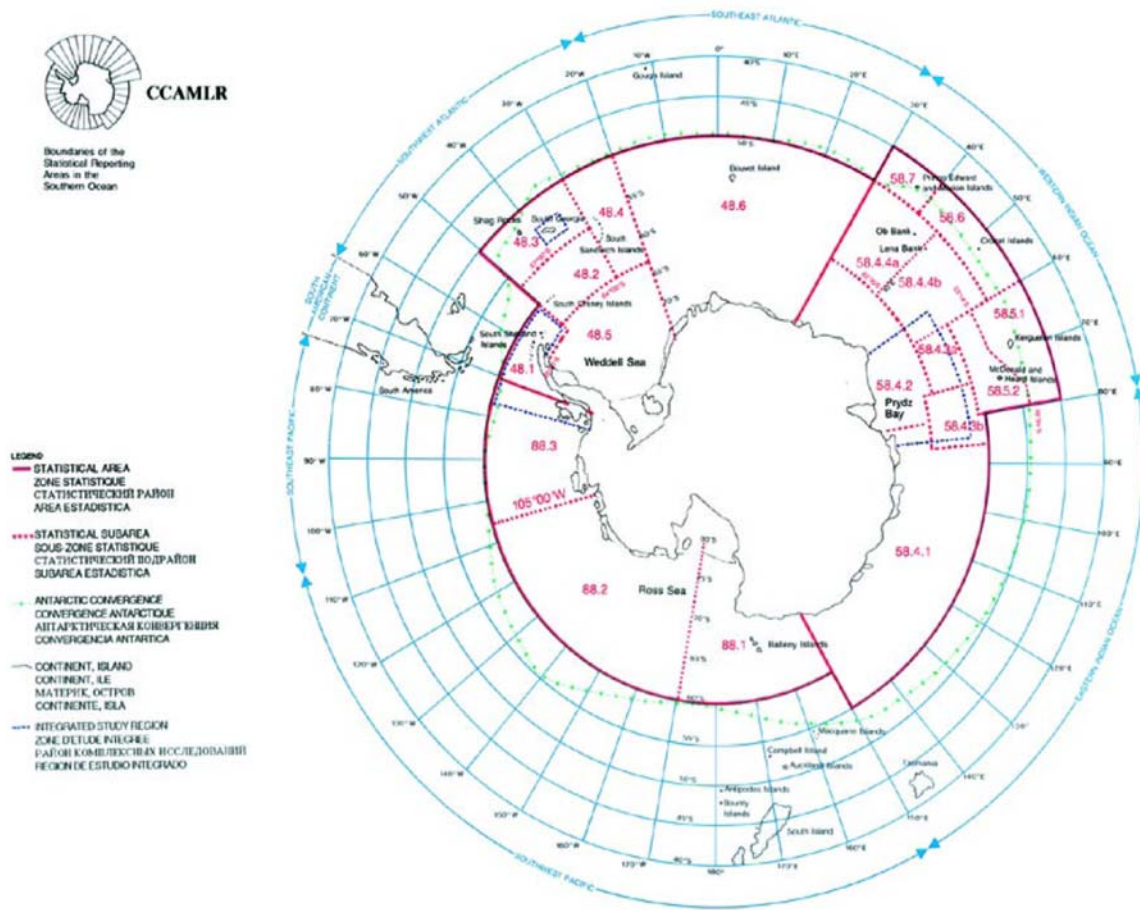


Fig. 1 Map of CCAMLR Statistical areas, Subareas and Divisions (courtesy: David Ramm, CCAMLR secretariat)

entangled in the line and destroyed the line or parts of it (Anon. 1994). Since then, such observations are regularly reported by scientific observers. More systematic observations, such as on the amount of fish taken from the line in proportion to the catch per set, are scarce and largely restricted to South Georgia and to a lesser extent the Prince Edward Islands (e.g. Ashford et al. 1996; Tilney and Purves 1999; Purves et al. 2004).

In this paper, we review the current information on cetacean and fisheries interactions in the Southern Ocean. We have restricted ourselves to considerations of the bottom – set longline fisheries. Pelagic longlining is not conducted in the Southern Ocean. We refer here to CCAMLR Statistical Areas, Subareas and Divisions (Fig. 1) which are different from those statistical areas in use by the International Whaling Commission (IWC) for the Southern Ocean.

### Standardization of observer data from South Georgia and the Prince Edward Islands

Interaction as defined for the purpose of this paper is the presence of cetaceans in the immediate vicinity of fishing vessels (Purves et al. 2004). Observations on interactions

of fishing vessels in the Southern Ocean are collected in a systematic fashion under the auspices of the CCAMLR International Scheme of Scientific Observation (CCAMLR 2005). Observer coverage is 100%, i.e. each vessel during each cruise carries a scientific observer on board (CCAMLR 2005). However, data collection has not been standardized for the fisheries in the different CCAMLR Subareas and Divisions. Observations on cetaceans were predominantly taken during day light hours between nautical twilight in the morning and in the evening. The fishery for Patagonian toothfish is only open after 1 April each year and is closed by CCAMLR when the total allowable catch in a Subarea or Division is reached. Given the inaccessibility of the Ross Sea in winter, the fishery for Antarctic toothfish in Subareas 88.1 and 88.2 is also open during austral summer (CCAMLR 2005).

At South Georgia, the observer protocol was standardized after the 2000 fishing season in that after the start of each of six-hourly hauling observations conducted per day the abundance of cetacean species in the vicinity of the fishing vessel was noted. These hauling observations were selected at random intervals in order to cover as much as possible of the period when lines were being hauled in the course of a day. Observations

were not standardized for the other CCAMLR Subareas and Divisions. Log books of the fishing vessels contained, at most, unsystematic observations on cetaceans in the vicinity of the fishing vessel and were not suitable for analysis here.

Observations were conducted from a fixed position on the deck in the vicinity of where the lines were being hauled. In most cases, the observer was stationed directly above the line hauler on the starboard side of the vessel. The standard survey area was defined as being within a radius of 500 m around the vessel. Weather conditions, such as fog and limited visibility during the night, influenced observations (Purves et al. 2004).

Interactions with fishing operations and the number of damaged fish observed were only recorded at South Georgia in 2001/02. These included observations during which cetaceans were not necessarily interacting with fishing operations but were observed in the vicinity of the vessel. The reason for this was that interactions with fishing gear, in particular those involving sperm whales, were often difficult to identify (Purves et al. 2004).

### Impact of cetaceans on fisheries

Interactions of cetaceans with longline fisheries in the Southern Ocean are numerous though rarely fatal for a cetacean. Interactions of cetaceans with trawl fisheries both on fish and krill have not yet been recorded. Interactions occur mostly with orcas and sperm whales and have been reported at South Georgia (CCAMLR Subarea 48.3), at the Prince Edward Islands (Subareas 58.6 and 58.7), Crozet Islands (Subarea 58.6), Iles Kerguelen (Division 58.5.1) and from Ob and Lena Banks (Division 58.4.4). Interactions are much less common and have been reported much less frequently from other areas and/or with other cetaceans.

What is lacking are estimates of how many cetaceans, both sperm whales and orcas, are involved in interactions with fisheries in individual Subareas or Divisions. An increasing number of photographs of individual whales close to fishing vessels exists from scientific observers in the Southern Ocean which may provide some insight if to what extent individual cetaceans or pods of cetaceans are more often involved in interactions with fisheries than others.

### Longlining and cetaceans

Longlining started at South Georgia in the Atlantic Ocean sector in 1985/86 and around Iles Kerguelen in the Indian Ocean sector in 1991/92. It spread over most of the Southern Ocean in the 1996/97 season and the seasons thereafter (David Ramm, pers. comm.). Only a few years after longlining began at South Georgia, orcas and sperm whales appeared in the vicinity of longline vessels, in particular when the vessels did not move far between sets. Information provided to CCAMLR was mostly restricted to South Georgia, Crozet and the Prince Edward Islands (e.g. Anon. 1996, 1997, 2001, 2002; Kock 2001). No such interactions with longline vessels have been reported for the Ross Sea (Subareas 88.1 and 88.2) fishery despite sightings of orcas from the fishing vessels on most cruises (e.g. SC-CAMLR 2002).

Considerable variation (5–70%) existed in encounters with cetaceans between longline voyages within one season at South Georgia (Table 1; Ashford et al. 1996; Purves et al. 2004). A documented decline in the number of orcas in Subarea 58.6 was considered, at least in part, to be a result of the use of firearms and explosive deterrents by IUU longline vessels (Anon. 2003).

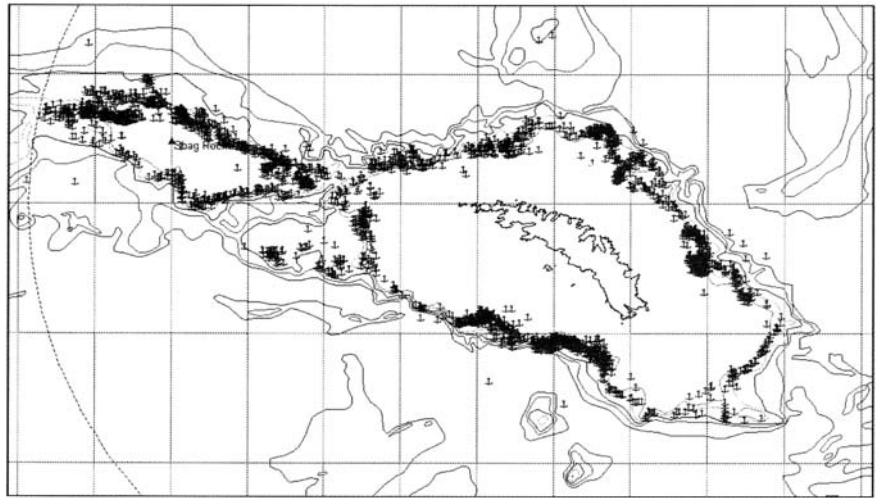
Longlining around South Georgia occurred around all of the island and Shag Rocks, west of the island (Fig. 2). Most interactions occurred during daylight hours from 6:00 to 18:00 h (Table 2). Figure 3 shows the positions where orcas were sighted around South Georgia, Fig. 4 where sperm whales were sighted. There were no particular areas where orcas concentrated while sperm whales seemed to be more numerous north and south of the South Georgia shelf whereas they were less frequently observed to the southwest of the island and south of Shag Rocks (Figs. 3 and 4). It should be noted, however, that such conclusions may be biased by the uneven distribution of fishing effort and that effort was not standardized, for example by the number of whales seen per 100 h or per 100 hauls. Furthermore, all sightings (and not only sightings in good visibility and below a certain sea state) were taken into account.

Sperm whales were often solitary when seen close to fishing vessels but two or three sperm whales were also fairly common (Table 3). Most groups of orcas seen were small and consisted of five or fewer animals but larger pods up to 15 animals were not uncommon (Table 3).

**Table 1** Longline cruises where interaction with sperm whales and killer whales occurred (SC-CAMLR 2001, 2002)

| Subarea                                   | Season | No. of cruises | Sperm whales | Killer whales |
|---|--------|----------------|--------------|---------------|
| South Georgia (Subarea 48.3)              | 1999   | 17             | 1 (5.9%)     | 12 (70.5%)    |
|   | 2000   | 26             | 3 (11.5%)    | 6 (23.1%)     |
|   | 2001   | 15             | 4 (26.7%)    | 5 (33.3%)     |
| Prince Edward Islands' subareas 58.6/58.7 | 1999   | 12             | 4 (33.3%)    | 6 (50.0%)     |
|   | 2000   | 11             | 6 (54.5%)    | 7 (63.6%)     |
|   | 2001   | 3              | 0            | 1 (33.3%)     |

**Fig. 2** Map of South Georgia showing the mid-positions of all the hauls of vessels fishing in the course of 2000, 2001 and 2002 seasons (from Purves et al. 2004)



**Table 2** The times at which interactions occurred with killer whales and sperm whales at South Georgia (Subarea 48.3) during the 2001 and 2002 seasons (from Purves et al. 2004)

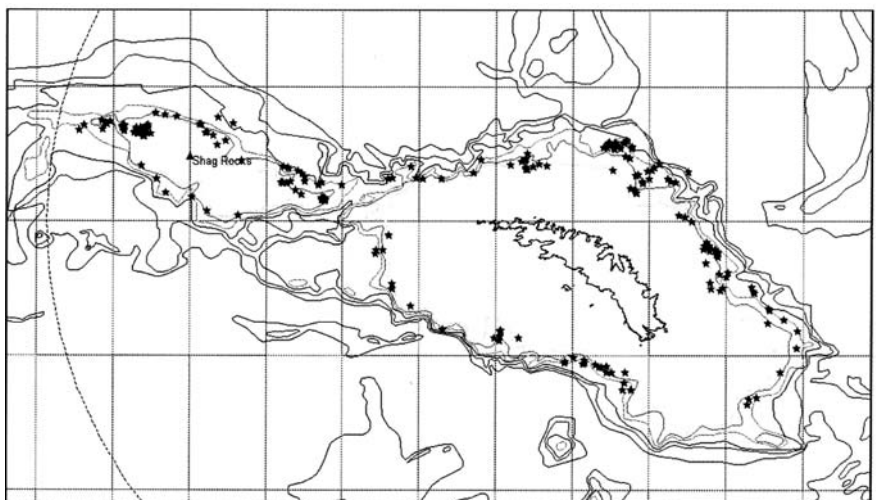
| Period (time of day) | Number of killer whale interactions | % of killer whale interactions | Number of sperm whale interactions | % of sperm whale interactions |
|----------------------|-------------------------------------|--------------------------------|------------------------------------|-------------------------------|
| 00:00–06:00          | 7                                   | 3.4                            | 2                                  | 0.2                           |
| 06:00–12:00          | 68                                  | 32.9                           | 374                                | 43.1                          |
| 12:00–18:00          | 95                                  | 45.9                           | 489                                | 56.4                          |
| 18:00–24:00          | 37                                  | 17.9                           | 2                                  | 0.2                           |
| Total                | 207                                 |                                | 867                                |                               |

Hooks with toothfish lips or jaws were more prevalent when sperm whales were sighted in the vicinity of longline vessels. It is likely that they take fish from the line underwater down to several 100 m deep (Ashford et al. 1996). CCAMLR observers reported, for example, that sperm whales have been observed in the 1999/2000 season around Iles Crozet and Prince Edward Islands where they took up to 80% of the fish from the lines (Kock 2001). However, depredation was less obvious when fish catches were compared for periods when sperm

whales were present to those when they were absent from the neighbourhood of the longline vessel. Catches were not significantly different from hauls without depredation (Table 4) (Purves et al. 2004). Sperm whales became entangled regularly and often caused break in the fishing line (Anon. 2000, 2001, 2002, 2003, 2004).

A considerable loss of fish to orcas was reported in the past 10 years (e.g. Anon. 1996; Kock 2001). Most of the reports are still anecdotal. When comparing the amount of fish caught while orcas were present or absent

**Fig. 3** Map of South Georgia showing positions where killer whales were sighted during hauling of longlines in the course 2000, 2001 and 2002 seasons (from Purves et al. 2004)



**Table 3** The frequency at which specific group sizes of killer whales ( $n = 186$ ) and sperm whales ( $n = 836$ ) were observed at South Georgia (Subarea 48.3) in the 2001 and 2002 seasons (from Purves et al. 2004)

| Killer whales      |                        |                         | Sperm whales       |                        |                         |
|--------------------|------------------------|-------------------------|--------------------|------------------------|-------------------------|
| Group size ( $n$ ) | Number of observations | % of total observations | Group size ( $n$ ) | Number of observations | % of total observations |
| 1                  | 27                     | 13.4                    | 1                  | 361                    | 43.2                    |
| 2–3                | 47                     | 25.3                    | 2                  | 265                    | 31.7                    |
| 4–5                | 25                     | 13.4                    | 3                  | 146                    | 17.5                    |
| 6–8                | 34                     | 18.3                    | 4–5                | 56                     | 6.3                     |
| 9–10               | 20                     | 10.8                    | 6–10               | 7                      | 0.8                     |
| 11–15              | 21                     | 11.3                    | > 10               | 1                      | 0.1                     |
| 16–20              | 12                     | 6.5                     |                    |                        |                         |
| 21–30              | 2                      | 1.1                     |                    |                        |                         |

**Table 4** Catch rates of toothfish at South Georgia in the 2001 season, for hauls during which interaction occurred with killer whales and sperm whales, compared to the catch rate of hauls when no cetacean interaction with fishing operation occurred (from Purves et al. 2004)

|   | CPUE (kg/hook) | CPUE (fish/1,000 hooks) | Number of observations |
|---|----------------|-------------------------|------------------------|
| Killer whale interaction                                    | 0.15           | 21.47                   | 27                     |
| Sperm whale interaction                                     | 0.32           | 51.87                   | 129                    |
| Sperm whale interaction (without southeast Shag Rocks data) | 0.25           | 33.89                   | 74                     |
| No cetacean interaction                                     | 0.29           | 48.86                   | 556                    |
| No cetacean interaction (without southeast Shag Rocks data) | 0.28           | 46.09                   | 491                    |

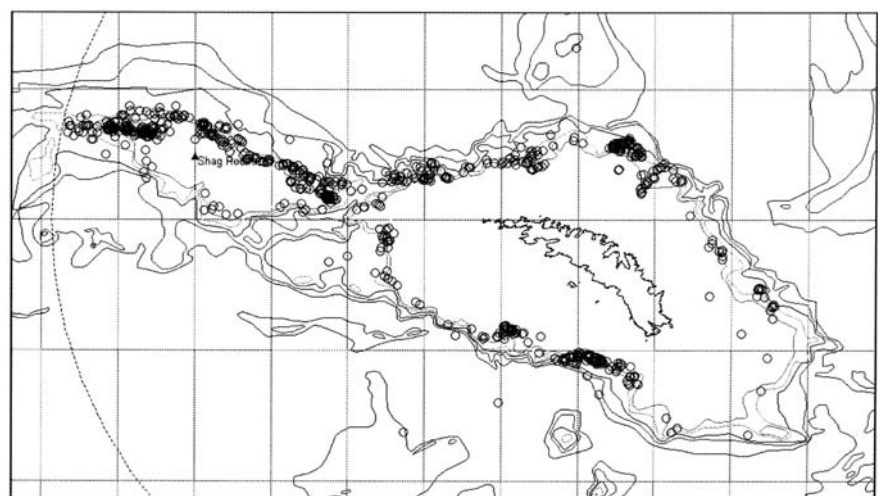
(Table 2) often more than 80–90% of a catch was lost due to depredation. The anecdotal nature of many reports and the fact that solid data are only available from South Georgia for one or two seasons makes it currently too tentative to estimate, how much fish is lost due to depredation in a particular season and a particular Subarea or Division of the Southern Ocean.

### Other cetaceans

A dolphin (species unknown) was seen caught in a longline at South Georgia in 1999, but released alive

(Anon. 1999). Long-fin pilot whales (*Globicephala melas*) have been observed in the vicinity of two hauling operations at Iles Kerguelen in February 1996 (Capdeville 1996). Long-finned pilot whales have been seen driven off by a sperm whale from the vicinity of a longline vessel at South Georgia (Purves et al. 2004).

Minke whales (*Balaenoptera bonaerensis*) were occasionally seen for a short period of time not far from longline vessels in the Ross Sea (Baird 2000). One incidental mortality of a whale was observed in longline fisheries in the Ross Sea in 2004 (CCAMLR Subarea 88.1), possibly a minke whale although its identification has yet to be confirmed. The whale was entangled in the

**Fig. 4** Map of South Georgia showing positions where sperm whales were sighted during hauling of longlines in the course of the 2000, 2001 and 2002 seasons (from Purves et al. 2004)

main line of a longliner (Anon. 2004). One humpback whale, *Megaptera novaeangliae*, in 2003 and an unknown small cetacean in 2001 were tangled in lines in the Ross Sea (CCAMLR Subareas 88.1 and 88.2). They were released alive (Baird 2004).

## Discussion

Male sperm whales migrate into and out of Antarctic waters over an extended period of time (Kasamatsu and Joyce 1995). Females hardly penetrate further south than the subtropical convergence. Male sperm whales have formed a valuable catch in commercial whaling in the Southern Ocean with 3–10,000 whales per year from early 1930s to early 1980s. Sperm whales feed primarily on squid (Kawakami 1980). Sperm whales are also known to feed on Patagonian toothfish in north and south of the Southern Polar Frontal Zone (SPFZ) (Korabelnikov 1959; Solyanik 1963; Yukhov 1972, 1982) though the quantities they take are unknown. Antarctic toothfish have been described being taken by sperm whales as well (Abe and Iwami 1989).

Orcas are abundant in the Southern Ocean. Encounter with orcas increase south of 62°S with a peak south of 66°S and southernmost sightings at 78°S in the Ross Sea. Areas of concentration occurred from 70° to 130°E (Dahlheim 1981). Orcas appear in the Southern Ocean in late November/early December (Mikhalev et al. 1981). Total abundance in the Southern Ocean was 80,000 orcas. Their abundance in the Atlantic and Indian sectors was higher than in the South Pacific (Kasamatsu and Joyce 1995). Their pattern of migration appears to be synchronous with the migratory pattern of minke whales (Kasamatsu and Joyce 1995). By April, most orcas have left the Southern Ocean (Mikhalev et al. 1981). They have been exploited on a small scale (< 100 whales per year) by pelagic whaling fleets from 1954 onwards. It was only in 1979/80 that Soviet whalers took 906 orcas from 60° to 150°W (Dahlheim 1981). Catches of orcas on a similar scale (< 250 whales per year) were also known from other areas of the world ocean before the early 1980s, such as the North Atlantic (Christensen et al. 1982).

Orcas feed on a large range of prey, which includes fish, small cetaceans and pinnipeds north of the SPFZ. Their main prey south of the SPFZ, minke whales, pinnipeds and penguins is closely associated with the pack-ice edge (Budylenko 1981; Mikhalev et al. 1981; Kasamatsu and Joyce 1995). Toothfish are abundant only in deeper water well outside the diving range of orcas. They have been reported to strip fish off the line north of the Southern Ocean, such as tunas and billfish in eastern Australia (Young 1999). Such behaviour had also been reported from the Southern Ocean soon after longline fishing started.

Interactions of cetaceans, in particular orcas and sperm whales, with longline fisheries worldwide are numerous (Northridge 1984, 1991a, b; Northridge and Hofman 1999). They are well documented for most parts

of the world ocean (Yano and Dahlheim 1995; Secchi and Vaske 1998; Visser 2000; Donoghue et al. 2002) including those adjacent to the Southern Ocean, such as on the Patagonian shelf and the waters off Chile (Ashford et al. 1996; Crespo et al. 1997, 2000; Anon. 2000; Donoghue et al. 2002; Gonzales and Olavarria 2002; Hucke-Gaete et al. 2002; Purves et al. 2002; Dans et al. 2003; Hucke-Gaete et al. 2004; Purves et al. 2004).

Interaction with cetaceans in the Southern Ocean is mostly confined to sperm whales and orcas while interaction of longline fisheries with other cetaceans rarely occurs. The main reason is that only bottom set longlines are employed in the Southern Ocean. Pelagic longlining is used only in tropical, subtropical and temperate waters on a large scale to catch tuna and billfish (Donoghue et al. 2002; Secchi et al. 2005). Interactions have been reported to be costly and often disastrous for fishermen when orcas were involved.

There were considerable differences in the encounter of longliners with cetaceans at South Georgia both between longline cruises and years. The high inter-vessel difference in the percentage of sets where cetaceans were present was probably mainly due to differences in fishing grounds around the island and the number of sperm whales and orcas occurring on these grounds at a particular time of the year. Some vessels appear to attract more cetaceans than others. Factors that might play a role are differences in noise levels emitted by the line haulers or the engine of the vessel. Longline operators attempt to make fishing operations less noisy (Purves et al. 2004). It is unclear at present, however, if these measures are effective and subsequently may attract fewer cetaceans.

Areas which are known to be frequented by sperm whales and orcas, such as Shag Rocks to the west of South Georgia, are avoided by longliners. The appearance of fish-oil slicks on the sea surface, together with frenzied seabirds feeding activity over these slicks suggested that orcas were taking hooked Patagonian toothfish. Toothfish heads on the longline following such observations supports this assumption (Tilney and Purves 1999).

Depredation if occurring at a large scale, is also a management concern which stock assessment models for toothfish should ideally take into account (Donoghue et al. 2002; Purves et al. 2004). However, it is still difficult to assess how much toothfish is taken from longlines both with respect to orcas and to sperm whales. Observations which would allow an estimate on how much toothfish is depredated are only available for South Georgia and the Prince Edward Islands for individual cruises within one season. Depredation on average by orcas was more than 50% of the catch. Often 80–90% of the line is plundered. Fishing vessels often leave the ground when orcas are present.

Sperm whales are likely to be attracted to areas with high catch rates of toothfish (Hucke-Gaete et al. 2004). Sperm whales have not been observed directly to take toothfish off the line close to the surface (see also

**Fig. 5** Head of a Patagonian toothfish (*Dissostichus eleginoides*) depredated by a sperm whale at South Georgia (Photo: Michael Unwin)



Northridge 1991a, b). Their frequent diving in the vicinity of lines down to more than 400 m deep and damage to the fishing gear, and the occurrence of toothfish heads, lips and jaws (Figs. 5, 6) seem to indicate that sperm whales strip fish off the line at some depth (Ashford et al. 1996; Purves et al. 2004; M. Unwin, pers. comm.). Observers in the South Georgia fishery did not report seeing sperm whales taking either offal or discarded by-catch (Purves et al. 2004). A comparison of sets with and without sperm whales present close to the line indicates that sperm whales on average take only a few percent of the catch. However, depredation between individual sets may range 0–100%.

Similar observations of only a few percent of toothfish taken off the line have also been obtained off the southern Chilean coast (Hucke-Gaete et al. 2004). In areas where the catch of toothfish was lower, such as in the Prince Edward Islands or the Falkland/Malvinas Islands, depredation of catches by sperm whales can become a significant problem (Purves et al. 2004; M. Unwin, pers. comm.) as it is also known from the longline fishery on sablefish (*Anoploma fimbria*) off Alaska where catch rates were on average 23% lower for sets with evidence of depredation by sperm whales than for sets without evidence of depredation (Straley et al. 2002).

**Fig. 6** Front part of a Patagonian toothfish (*Dissostichus eleginoides*) depredated by a killer whale (Photo Michael Unwin)



Orcas appear to be selective at South Georgia when taking fish off the line. They take only toothfish while they leave by-catch species, such as grenadiers (*Macrourus* spp.) and the morid *Antimora rostrata*. Similar observations have been obtained off New Zealand (Visser 2000) and at the Falkland/Malvinas Islands (Nolan et al. 2000).

There appear to be 'problem' animals among orcas with respect to the depredation events. At South Georgia, there is at least one pod, which is a consistent problem. The pod has been photo-identified and two biopsy samples have been collected. The pod is readily recognizable by the presence of a male with a large v-notch in the trailing edge of the dorsal fin (M. Unwin, pers. comm.). Some sperm whales appear to be interacting more frequently with fishing vessels than others. Some observer reports at South Georgia contain information where the same sperm whale individuals were repeatedly observed interacting with hauling operations. The 'adapted foraging behaviour' of orcas close to longline vessels results in a change away from their natural diet. Current observations indicate prey specialization among orcas (M Unwin, pers. comm.).

Interaction of orcas, sperm whales and other cetaceans with longliners is still difficult to quantify. Orcas and sperm whales were often in attendance simultaneously, diving next to the line during hauling operations (Tilney and Purves 1999). Sperm whales tend to group into tight parallel formation when orcas are present (Hucke-Gaete et al. 2004). Nolan et al. (2000) reported an aggressive interaction between sperm whales and orcas in the Falkland Islands fishing zone over fish captured in the course of longline operations. A number of cases where sperm whales appeared to have been displaced, attacked or even killed by orcas have also been reported from South Georgia and the Prince Edward Islands (Ashford et al. 1996; Tilney and Purves 1999) and elsewhere (Silber et al. 1990; Jefferson et al. 1991; Yano and Dahlheim 1995; Pitman et al. 2001).

Orcas have also been observed attacking humpback whales close to longline vessels at South Georgia. Orcas approached humpback whales and acted aggressively or even attacked them. A large amount of splashing was involved and humpback flukes and pectoral fins were thrown into the air. No blood was seen. The humpbacks were then pursued away from the area. The orcas re-joined the fishing vessel 8 h later (M. Unwin, pers. comm.).

Since more than 10 years interactions between sperm whales and orcas and longline fishing operations are a continuing problem in the Southern Ocean for which there is no obvious solution (SC-CAMLR 1997). The use of acoustic deterrents, for example, may mediate the problem for orcas (Mate and Harvey 1987; Richardson et al. 1995; Jefferson and Curry 1996; Morton and Symonds 2002). Their use with respect to sperm whale, which appear more resistant to acoustic deterrents (André 1997), however, remains doubtful. A summary

of deterring methods in various longline fisheries worldwide has been provided by Donoghue et al. (2002).

There have been remarkably few systematic studies on cetaceans and how they interact with fisheries in the Southern Ocean up to now compared to the large number of studies on longline-seabird interactions (e.g. Kock 2001; SC-CAMLR 2001, 2002, 2003, 2004). Further research is needed in order

- To determine the spatial and temporal pattern of longline-cetacean interactions,
- To address the problems of longline-cetacean depredation,
- To identify identities of animals involved in depredation,
- To standardize observer protocols to ensure the collection of valuable data, and
- To assess and implement mitigation strategies under controlled experimental conditions.

**Acknowledgements** Jan Straley, Pamela Toschik, John Croxall, Eduardo Secchi, Joost Pompert and two anonymous reviewers kindly provided useful comments to the manuscript. Martin Unwin who acted as observer in the longline fishery at South Georgia provided a number of useful observations. We are very grateful to the CCAMLR Data Manager, Dr David Ramm, for providing data on the onset of longlining in the Southern Ocean.

---

## References

- Abe T, Iwami T (1989) Notes on fishes from the stomachs of whales in the Antarctic, II: on *Dissostichus* and *Ceratias*. Proc NIPR Symp Polar Biol 2:78–82
- André M (1997) Sperm whale (*Physeter macrocephalus*) behavioural response after the play back of artificial sounds. Rep Int Whal Commn 47:499–504
- Anonymous (1994) Report of the working group on fish stock assessment, Hobart, Australia, 11–19 October 1994. In: Report of the 13th meeting of the scientific committee, Annex 5, 125–211, CCAMLR, Hobart, Australia
- Anonymous (1996) Report of the working group on fish stock assessment, Hobart, Australia, 7–16 October 1996. In: Report of the 15th meeting of the scientific committee, Annex 4, 303–447, CCAMLR, Hobart, Australia
- Anonymous (1997) Report of the working group on fish stock assessment, Hobart, Australia, 13–22 October 1997. In: Report of the 16th meeting of the scientific committee, Annex 5, 245–425, CCAMLR, Hobart, Australia
- Anonymous (1999) Report of the working group on fish stock assessment, Hobart, Australia, 11–22 October 1999. In: Report of the 18th meeting of the scientific committee, Annex 5, 229–445, CCAMLR, Hobart, Australia
- Anonymous (2000) Report of the working group on fish stock assessment, Hobart, Australia, 9–19 October 2000. In: Report of the 19th meeting of the scientific committee, Annex 5, 283–498, CCAMLR, Hobart, Australia
- Anonymous (2001) Report of the working group on fish stock assessment, Hobart, Australia, 8–19 October 2001. In: Report of the 20th meeting of the scientific committee, Annex 5, 197–558, CCAMLR, Hobart, Australia
- Anonymous (2002) Report of the working group on fish stock assessment, Hobart, Australia, 7–17 October 2002. In: Report of the 21st meeting of the scientific committee, Annex 5, 311–502, CCAMLR, Hobart, Australia



- Anonymous (2003) Report of the working group on fish stock assessment, Hobart, Australia, 13–23 October 2003. In: Report of the 22nd meeting of the scientific committee, Annex 5, 289–547, CCAMLR, Hobart, Australia
- Anonymous (2004) A summary of observations on board longline vessels operating within the CCAMLR convention area. WG-FSA-04/6 Rev. 1 (mimeogr)
- Ashford JP, Rubilar PS, Martin AR (1996) Interactions between cetaceans and longline fishery operations around South Georgia. *Mar Mamm Sci* 12(3):452–457
- Baird SJ (2000) Summary of seabird and marine mammal observations during observed toothfish (*Dissostichus* spp.) longline fishing operations in CCAMLR Subarea 88.1, 1998–2000. WG-FSA-00/56, CCAMLR, Hobart, Australia
- Baird SJ (2004) Summary of the seabird and marine mammal observations during observed toothfish (*Dissostichus* spp.) longline fishing operations in CCAMLR Subareas 88.1 and 88.2. WG-FSA-04/42, CCAMLR, Hobart, Australia
- Budylenko GA (1981) Distribution and some aspects of the biology of killer whales in the South Atlantic. *Rep Int Whal Commn* 31:523–525
- Capdeville D (1996) Impact of marine mammals on longline fisheries around Kerguelen Islands (Division 58.5.1) during the 1995/96 fishing season. WG-FSA-96/12, 6 pp., CCAMLR, Hobart, Australia
- CCAMLR (2005) Scheme of international scientific observation, CCAMLR, Hobart, Australia, 223 pp
- Christensen I, Jønsgård Å, Rørvik CJ (1982) Catch statistics for minke whales (*Balaenoptera acutorostrata*) and killer whales (*Orcinus orca*) caught by Norway in 1980. *Rep Int Whal Commn* 32:487–489
- Crespo EA, Pedraza SN, Dans SL, Alonso MK, Reyes LM, Garcia NA, Coscarella M, Schiavini A (1997) Direct and indirect effects of the high seas fisheries on marine mammal populations in the northern and central Patagonian coast. *J Northw Atl Fish Sci* 22:189–208
- Crespo EA, Alonso MK, Dans SL, Garcia NA, Pedraza SN, Coscarella M, Gonzalez R (2000) Incidental catches of dolphins in mid-water trawls for Argentinean anchovy (*Engraulis anchoita*) off the Argentine shelf. *J Cetacean Res Manage* 2(1):11–16
- Dahlheim ME (1981) A review of the biology and exploitation of killer whales, *Orcinus orca*, with comments on recent sightings from Antarctica. *Rep Int Whal Commn* 31:541–547
- Dans SL, Alonso MK, Pedraza SN, Crespo EA (2003) Incidental catch of dolphins in trawling fisheries off Patagonia, Argentina: can populations persist? *Ecol Appl* 13(3):754–762
- Donoghue M, Reeves RR, Stone G (2002) Report of the workshop on interactions between cetaceans and longline fisheries November 2002. Apia, Samoa, pp. 45
- Duhamel G (2003) La légine, pêche conflictuelle. Pêche légale et braconnage organisé. Cas du secteur indien de l’océan Austral. In: Exploitation et surexploitation des ressources marines vivantes: 177–187. Rapport sur la Science et la Technologie No 17, Académie des Sciences éditions Tec & Doc, Lavoisier, Paris
- Gonzales E, Olavarria C (2002) Interactions between odontocetes and the artisanal fishery for Patagonian toothfish off Chile. In: Donoghue M, Reeves RR, Stone G (eds) Report of the workshop on interactions between cetaceans and longline fisheries November 2002. Apia, Samoa, pp 5–6
- Hucke-Gaete R, Moreno CA, Arata JA (2002) Operational interactions between marine mammals and the Patagonian toothfish (*Dissostichus eleginoides*) fishery off southern Chile. In: Donoghue M, Reeves RR, Stone G (eds) Report of the workshop on interactions between Cetaceans and Longline fisheries November 2002. Apia, Samoa, pp 10–12
- Hucke-Gaete R, Moreno CA, Arata JA (2004) Operational interactions between cetaceans and the Patagonian toothfish (*Dissostichus eleginoides*) industrial fishery off southern Chile. *CCAMLR Sci* 11:127–140
- Jefferson TA, Stacey PJ, Baird RW (1991) A review of killer whale interaction with other marine mammals: predation to co-existence. *Mamm Rev* 21:151–180
- Jefferson TA, Curry BE (1996) Acoustic methods of reducing or eliminating marine mammals—fisheries interactions: do they work? *Ocean Coast Manag* 31(1):41–70
- Kasamatsu F, Joyce GG (1995) Current status of odontocetes in the Antarctic. *Antarct Sci* 7(4):365–379
- Kawakami T (1980) A review of sperm whale food. *Sci Rep Whales Res Inst* 32:199–218
- Kock K-H (2001) The direct influence of fishing and fishery-related activities on non-target species in the Southern Ocean with particular emphasis on longline fishing and its impact on albatrosses and petrels—a review. *Rev Fish Biol Fisheries* 11:31–56
- Korabelnikov LV (1959) The diet of sperm whales in the Antarctic seas. *Priroda* 3:103–104
- Mate BR, Harvey JT (eds) (1987) Acoustic deterrent in marine mammal conflict with fisheries. Workshop Rep. 17–18 February 1986. Newport, Oregon State University, Corvallis, Oregon, 116 pp
- Mikhalev YuA, Ivashin MV, Savusin VP, Zelenaya FE (1981) The distribution and biology of killer whales in the Southern Hemisphere. *Rep Int Whal Commn* 31:551–564
- Morton AB, Symonds HK (2002) Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. *ICES J Mar Sci* 59:71–80
- Nolan CP, Liddle GM, Elliot J (2000) Interactions between killer whales (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*) with longline fishing vessels. *Mar Mamm Sci* 16(3):658–666
- Northridge SP (1984) World review of interactions between marine mammals and fisheries. *FAO Techn. Pap.* 251, 190 pp
- Northridge SP (1991a) An updated world review of interactions between marine mammals and fisheries. *FAO Techn Pap* 251(Suppl):1–58
- Northridge SP (1991b) Driftnet fisheries and their impact on non-target species: a world wide review. *FAO Techn Pap* 320:115
- Northridge SP, Hofman RJ (1999) Marine mammal interactions with fisheries. In: Twiss JR, Reeves RR (eds) Conservation and management of marine mammals, Smithsonian Press Wash, USA, pp 99–119
- Pitman RL, Balance LT, Mesnick SI, Chivers SJ (2001) Killer whale predation on sperm whales: observations and implications. *Mar Mamm Sci* 17(3):494–507
- Purves M, Agnew DJ, Balguerías E, Moreno CA, Watkins B (2002) Killer whales and sperm whale interactions with longline vessels in the Patagonian toothfish fishery at South Georgia. Donoghue M, Reeves RR, Stone G (2002) Report of the workshop on interactions between cetaceans and longline fisheries, November 2002, Apia, Samoa, 6–7
- Purves MG, Agnew DJ, Balguerías E, Moreno CA, Watkins B (2004) Killer whale (*Orcinus orca*) and sperm whale (*Physeter macrocephalus*) interactions with longline vessels in the Patagonian toothfish fishery at South Georgia, South Atlantic. *CCAMLR Sci* 11:111–126
- Richardson WJ, Greene CR, Malme CI, Thomsen DH (1995) Marine mammals and noise. Academic Press, San Diego, XVI, 576 pp
- SC-CAMLR (1997) Report of the 16th meeting of the scientific committee, 27–31 October 1997, Hobart Australia. CCAMLR Hobart Australia, 91 pp
- SC-CAMLR (2001) Report of the 20th meeting of the scientific committee, 22–26 October 2001, Hobart Australia. CCAMLR Hobart Australia, 83 pp
- SC-CAMLR (2002) Report of the 21st meeting of the scientific committee, 21–25 October 2002, Hobart Australia. CCAMLR Hobart Australia, 84 pp
- SC-CAMLR (2003) Report of the 22nd meeting of the scientific committee, 27–31 October 2003, Hobart Australia. CCAMLR Hobart Australia, 98 pp

- SC-CAMLR (2004) Report of the 23rd meeting of the scientific committee, 25–29 October 2004, CCAMLR, Hobart, Australia, 101 pp
- Secchi ER, Vaske T Jr (1998) Killer whale (*Orcinus orca*) sightings and depredation on tuna and swordfish longline catches in southern Brazil. *Aquat Mamm* 24(2):117–122
- Secchi ER, Wang JY, Dalla Rosa L, Yang S-C, Reeves RR (2005) Global review of interactions between cetaceans and longline fisheries: preliminary data. SC/57/BC3, International whaling commission, Cambridge, UK
- Silber GK, Newcomer NW, Perez-Cortes M (1990) Killer whales (*Orcinus orca*) attack and kill a Bryde's whale (*Balaenoptera edeni*). *Can J Zool* 68:1603–1606
- Solyanik GA (1963) An interesting ichthyological find (in Russian). *Inform Byul Sov Antarkt Eksped* 42:62
- Straley J, O'Connell T, Beam G, Mesnick S, Allen A, Mitchell E (2002) Sperm whale depredation in the demersal longline fishery for sablefish in the Gulf of Alaska: research needs and approaches to mitigation. In: Donoghue M, Reeves RR, Stone G (eds) Report of the workshop on interactions between cetaceans and longline fisheries, November 2002. Apia, Samoa, pp 7–8
- Tilney R, Purves MG (1999) The status of integrated fisheries monitoring in South Africa. In: Nolan CP (ed) Proceedings of the international conference on integrated fisheries monitoring, Sydney, Australia, 1–5 February 1999, FAO Rome, 343–356
- Visser IN (2000) Killer whale (*Orcinus orca*) interactions with longline fisheries in New Zealand waters. *Aquat Mamm* 26(3):241–252
- Yano K, Dahlheim ME (1995) Killer whale, *Orcinus orca*, depredation on longline catches of bottom fish in the south-eastern Bering Sea and adjacent waters. *Fish Bull* 93(2): 355–372
- Young JW (1999) Potential for impact of large whales on commercial fishing in the South Pacific Ocean. CSIRO, Report to environment Australia, pp 1–32
- Yukhov VL (1972) The range of fish of the genus *Dissostichus* (Fam Nototheniidae) in the Antarctic waters of the Indian Ocean. *Vopr. Ikhtiol.* 12 (2):384–385. Transl. as *J. Ichthyol.* 12 (2):346–347
- Yukhov VL (1982) The Antarctic toothfish (in Russian). Nauka Moscow, 113 pp