IMPACT OF THE FINFISH FISHERY IN THE SOUTH SHETLAND ISLANDS/ANTARCTIC PENINSULA REGION

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Abstract

Besides krill, finfish is at present the only living resource commercially exploited in the Southern Ocean. Following seals and baleen whales prior to the 1970s, demersal fish stocks were depleted off the South Shetland Islands by intensive industrial fishing during the late 1970s to early 1980s, being the notothenioid species Champsocephalus gunnari and Notothenia rossii the main target species and Gobionotothen gibberifrons mainly taken as by-catch. The impact of the offshore fishery also reached the juvenile stocks of the last two species in inshore waters. More than three decades after the end of the fishery, the inshore population of N. rossii is still in the process of recovery while that of G. gibberifrons remains in low condition. Not surprinsingly, the stock of Notothenia coriiceps, a species with similar ecological habits nearshore that was not fished commercially, increased. Since 1982, the Antarctic marine resources have been managed by CCAMLR. Presently (2015), the commercial fishery in the Atlantic sector is restricted mainly to the patagonian toothfish Dissostichus eleginoides and in less intensity to C. gunnari, around South Georgia, Shag Rocks, and in small proportion the South Sandwich Islands. The South Orkney Islands and South Shetland Islands/Antarctic Peninsula areas have remained closed to any finfishing since 1990. Since then, a high number of nations have entered into the fishery in all circumantarctic areas, mainly attracted by the high commercial value of the two Dissostichus species, the second, the Antarctic toothfish D. mawsoni. The diminution of certain fish populations appears to have affected other components of the food web. The decrease in the abundance in inshore waters of the South Shetland Islands of G. gibberifrons and N. rossii, which were probably two former important fish preys of the Antarctic Shag Phalacrocorax bransfieldensis, may have influenced to some extent a declining trend in the number of breeding pairs observed in the 1990s at two colonies at Nelson Island, in that archipelago. Conversely, in the shallow water communities of the lower Scotia Arc, N. coriiceps is at present by far, in terms of abundance and biomass, the most successful species, and is an important prey of shags.

Keywords

Fishery depletion, Notothenioidei, Antarctic ecosystem, Inshore fish

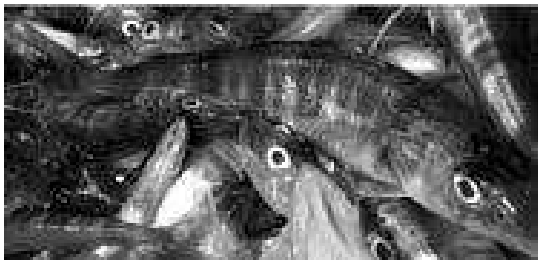
Commercial exploitation

The Antarctic fish fauna is unique in being dominated in terms of diversity (45%) and biomass (95%) by an endemic coastal demersal group, the suborder Notothenioidei, which includes six families and can be found as deep as 1200-1500 m. There is a lower diversity of Antarctic fish species on the continental shelves (139 spp.) in comparison with other cold-water seas (> 350 spp. in the North Atlantic). However, although the diversity of the notothenioids is limited compared with the large size of the ecosystem, there is no other fish group in the world with such diversification and dominance in a continental shelf habitat (Eastman 1995).

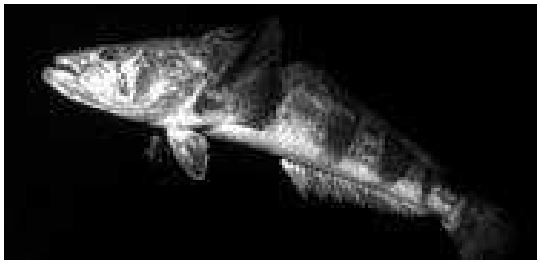
Besides krill, finfish is at present the only living resource industrially exploited in the Southern Ocean. The commercial exploitation of finfish started at the end of the 1960s, just as decades of sealing and whaling were ending. The fishery was developed basically in offshore waters around South Georgia, South Orkney and South Shetland Islands in the Atlantic sector, and around Kerguelen Islands in the Indian sector. Later on, mainly in the 1990s, the fishery expanded to the Ross Sea in the Pacific sector.

The Antarctic notothenioids are characterized by slow growth and low fecundity, which make them particularly susceptible to overexploitation (Kock 1992). In the seasonal Pack Ice Zone of the Southern Ocean and the islands north of it the species diversity and biomass of fish, chiefly notothenioid species, are greater from 100 to 300 m in depth (Tiedtke and Kock 1989).

Notothenia rossii



Champsocephalus gunnari



Disssostichus spp.

Fig. 1. *Main Antarctic fish species exploited in the commercial fishery.*

Thus, commercial vessels operated mostly in the depth range mentioned and down to 450 m using bottom trawls. The fishery has been of a multispecies kind, being the marbled rockcod Notothenia rossii and the mackerel icefish Champsocephalus gunnari the main target species *(Fig. 1)*, of which a maximum of 400,000 and 125,000 tons, respectively, were caught in the 1970/71 season around South Georgia (Kock 1992), after which, not surprisingly, these stocks collapsed. A considerable by-catch of other species has also been taken, at least in bottom trawls. In the Atlantic and Indic sectors historically, up to the end of the 1980s, the countries responsible for the bulk of the commercial catches were the former Soviet Union (about 80%), Poland, the former German Democratic Republic, France (EEZ Kerguelen) and Bulgaria *(Fig. 2*). Since then, from the 1990s up

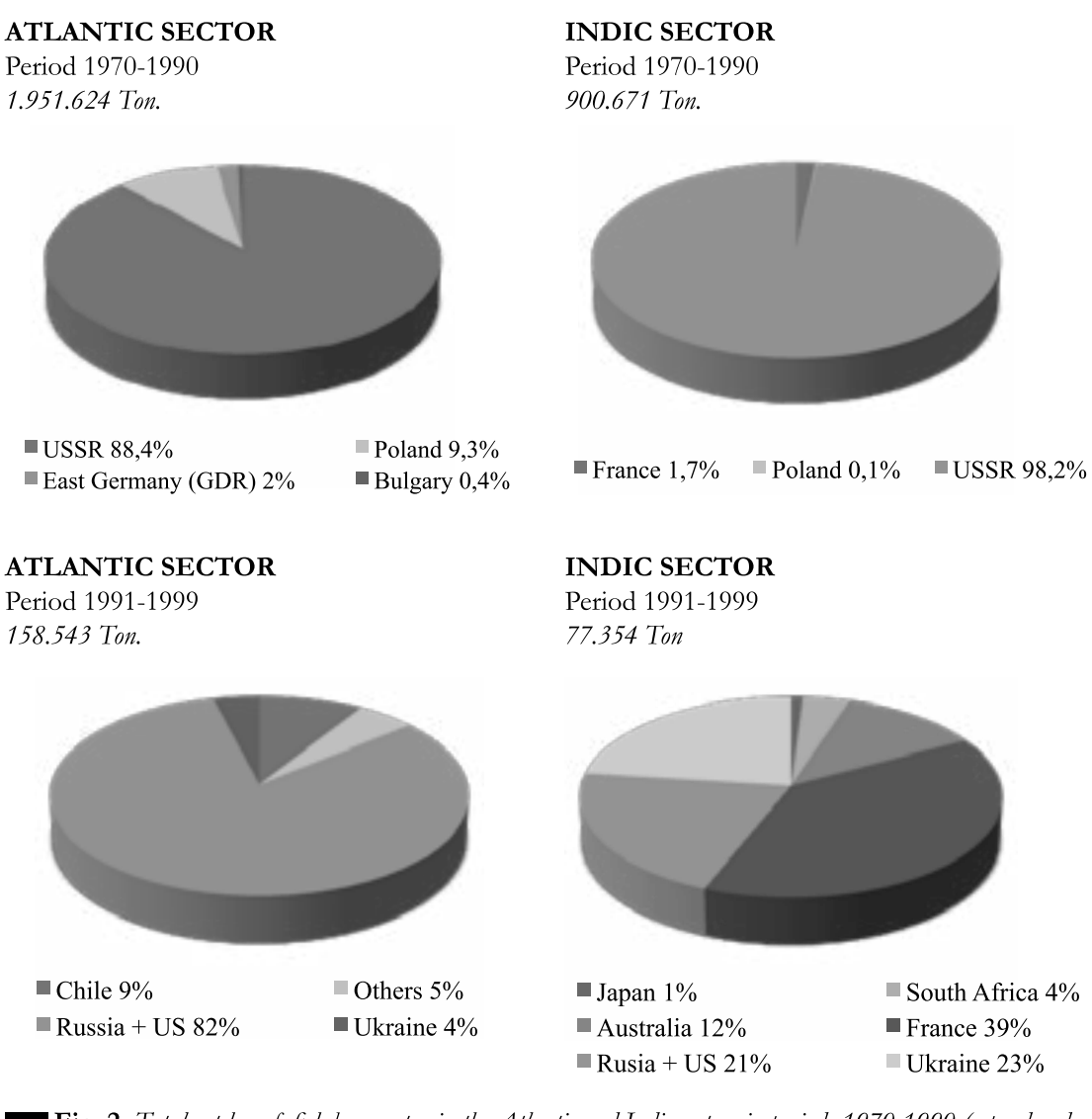


Fig. 2. *Total catches of fish by country in the Atlantic and Indic sectors in periods 1970-1990 (reproduced from Kock 1992) and 1991-1999.*

ATLANTIC SECTOR
31.917 Ton.

C. gunnari 11.951
Granadiers 813
Others 193
D. eleginoides 18.960

INDIC SECTOR
55.794 Ton.

C. gunnari 2.929
Granadiers 4395
Others 13
D. eleginoides 42.620
Rays 2.431
D. mawsoni 3.406

PACIFIC SECTOR
17.290 Ton.

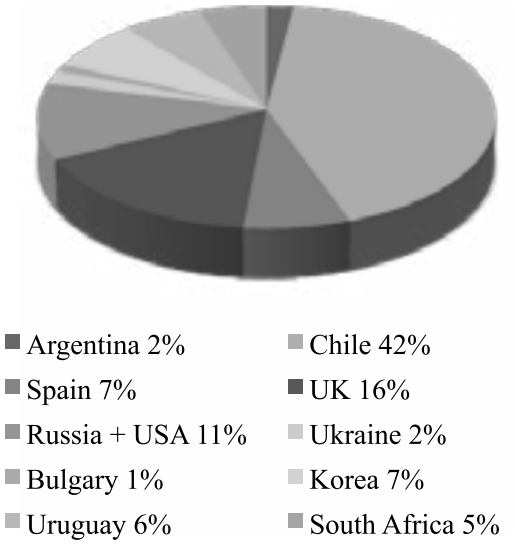
Granadiers 1.378
Others 131
Rays 135
D. mawsoni 15.646

Fig. 3. *Catches of species by area in period 2004-2008 showing the evolution of the fishery to the Pacific sector in the last decades.*

to the present time, a considerably high number of nations have entered into the fishery in all circumantarctic areas, mainly interested in the commercial exploitation of the two Dissostichus species, the patagonian toothfish D. eleginoides and the Antarctic toothfish D. mawsoni *(Figs. 3 and 4)* . In 1984 the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) introduced the first conservation measures (around South Georgia) and since then, the fishery has become progressively more restricted due to the implementation of a series of additional measures (Kock 1992).

Commercial fishing in the South Shetland Islands/western Antarctic Peninsula started in 1978/79. Since then, a total of 87,139 tons of finfish were caught until 1989/90 (Kock 1992) *(Fig. 5)*. Heavy fishing was carried out on the northern coasts of the northennmost island, Elephant Island, in

ATLANTIC SECTOR
50.093 Ton.



INDIC SECTOR
95.199 Ton.

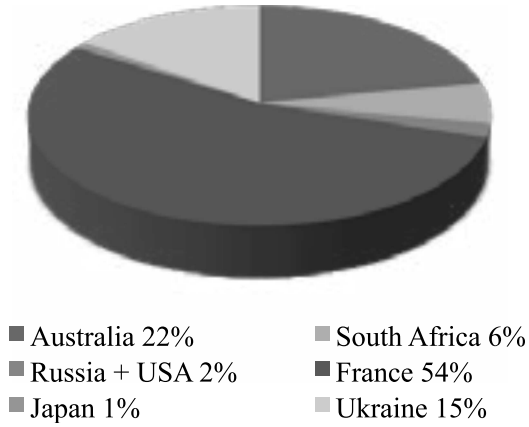


Fig. 4. *Catches of Dissostichus eleginoides in the Atlantic and Indic sectors in period 1991-2003 denoting the participation of new countries in the commercial fishery.*

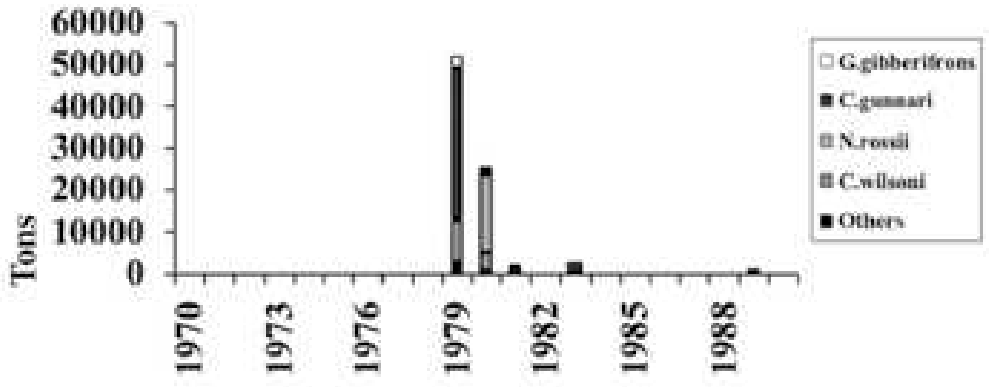


Fig. 5. *Catches by species in the South Shetland Islands/Antarctic Peninsula in period 1978-1990 (reproduced from Kock 1992).*

the period 1977-1980, but catches from the north of Livingston and King George/25 de Mayo Islands and from Joinville-D'Urville Islands in the tip of the Antarctic Peninsula have been also reported (CCAMLR 1986). Champsocephalus gunnari and N. rossii were the main targeted species, constituting 47.5% and 22.1% of the total catch, whereas the humped rockcod Gobionotothen gibberifrons was to some extent also taken in a directed fishery and as by-catch (4200 t) (Kock 1992). As a consequence of the fishing operations in the Atlantic sector of the Southern Ocean the stocks of many species were seriously depleted. For example, until 1992, the stock size of N. rossii at South Georgia was estimated to be less than 5% of the original stock size in 1969.

At the present time (2015), the fishery in the Atlantic sector is restricted to two species around South Georgia, Shag Rocks, and in small proportion the South Sandwich Islands. The main target species is the toothfish D.eleginoides, for which a TAC (Total Allowable Catch) was set in 1990/91 for the first time and the amounts taken in the last 20 years were in the range of 2400-7900 tons. To emphasize the importance of this fishery in the Southern Ocean, the TACs of Dissostichus species established and completed from 1997 to the present time ranged between 10000 and 17000 tons, including the Atlantic, Indic and Pacific sectors. This resource has been caught with long-lines by ships of several countries (Fig. 4). In the Atlantic sector, a small fishery (TAC=1000 t) was re-opened for the ice fish C. gunnari (semipelagic trawls) in the 1995/96 season, after a ban of one year. Since then, annual TACs between 1,548 and 4,600 tons have been established, although in the last five seasons the actual catches were substantially lower the upper limit of this range (i.e. in 2009/10-2010/11, less than 10 t). The South Orkney Islands and South Shetland Islands/Antarctic Peninsula areas (FAO Statistical Subareas 48.2 and 48.1, respectively) have remained closed to any finfishing since the 1990/91 season (CCAMLR 1990).

Other Antarctic marine resources that have been commercialized are krill Euphausia superba, spider-crab Paralomis spinosissima and squid Martialia hyadesi, but it is believed that the direct impact of these fisheries on the ecosystem has been much less than that of the finfish fishery.

Since the beginning of the krill fishery in 1970 until present day, some 7 million tons in the Atlantic sector have been caught (area 48), using pelagic trawls (mid-water) and pumping methods. However, this crustacean is not at risk of overexploitation, due to the fact that from the 4 million annual tons of permitted capture, only about 150 million tons have actually been extracted. The problem of this fishery is that changes within it can affect various predators dependent on krill, such as birds and mammals. For example, it is known that in years of krill scarcity, the reproductive success of predator colonies has been affected. CCAMLR established a trigger level of 620,000 tons for area 48, as an additional preventive measure. Currently, in addition to ignoring the total biomass of krill in the Southern Ocean, it is not known what percentage of this biomass can be fished without threatening the health of the populations dependent on this resource. In the first two decades of the fishery, the major fishing nations were Japan, the former Soviet Union and Ukraine, but just as it occurred with the exploitation of fish, there are actually many more countries involved (Fig. 6).

Of the crab population, 932 tons have been extracted in the area of the South Georgia Islands between 1992-2003, using traps. The principal fishing country was the United States (Fig. 7). Of the squid population, only 210 tons in the Atlantic sector were extracted between 1988-2002, using

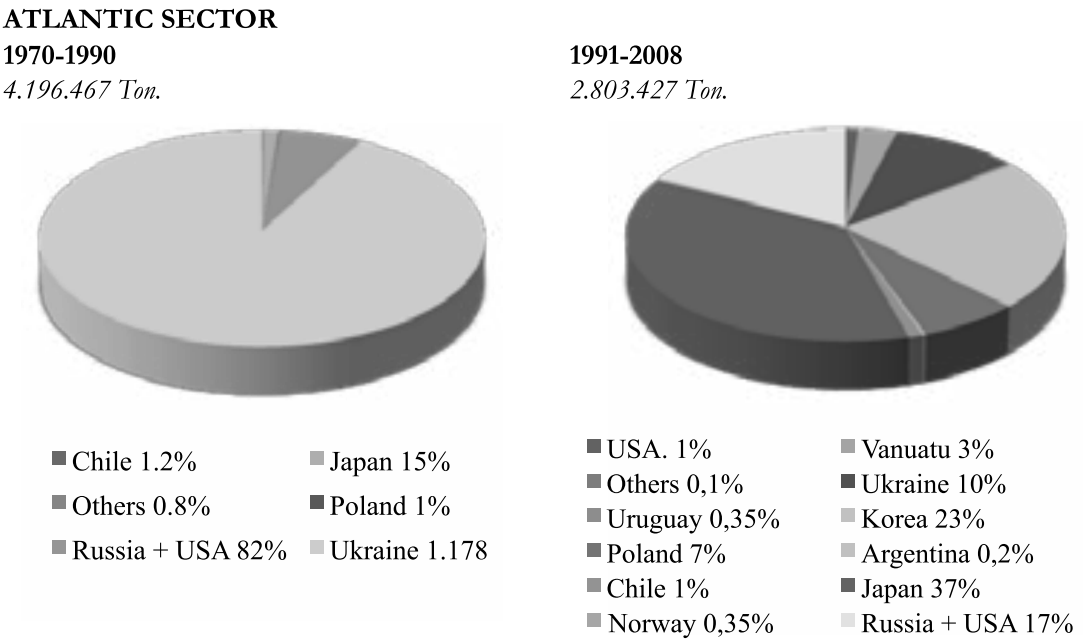


Fig. 6. *Total catches of krill in the Atlantic sector in two periods, denoting the incorporation of new countries in the commercial fishery in the last two decades.*

jiggers. The fishing countries were the Republic of Korea, Poland and, to a lesser extent, the United Kingdom (Fig. 7).

One of the problems of the commercial finfish fishery in Antarctica, in addition to overexploitation, is the lack of compliance or transgressions of the conservation measures adopted by CCAMLR and above all, the existence of illegal fishing that is difficult to control. It is estimated that for the entire Convention Area, the annual catch volume of illegal fishing has been, at least until the last decade, equivalent to the volume of fish obtained legally each year.

Impact of the offshore fishery on inshore fish and dependent species

Young specimens of N. rossii and G. gibberifrons, though exploited offshore, also inhabit nearshore waters; major changes in the offshore (reproductive) stock may be reflected in the inshore populations through recruitment processes. This phenomenon was studied in sites of the South Shetland Islands over a total period of three decades from 1983 mainly at Potter Cove, King George Island/Isla 25 de Mayo and also at Harmony Cove, Nelson Island and Moon Bay, Livingston Island, with samples obtained by trammel nets (Barrera-Oro et al. 2000, Marschoff et al. 2012). Associated with these species, the black rockcod Notothenia coriiceps is a species that was not commercially fished but has ecological habits in the fjords similar to the exploited species (Fig. 8). In summary, these three demersal notothenioids spend at least part of their life cycles in inshore waters (<120 m deep) and also occur in offshore waters at depths down to 200-550 m (Barrera-Oro 2002).

ATLANTIC SECTOR

Squid 1988-2010
210 Ton.

Crab 1992-2010
973 Ton.

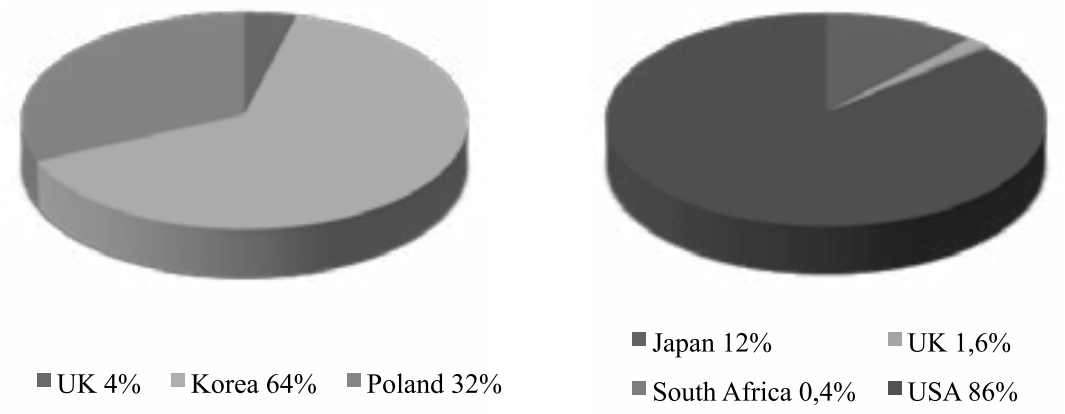


Fig. 7. *Total catches of squid Martialia hyadesi and crab Paralomis spinosissima by country in the periods of these commercial fisheries in the Atlantic sector.*

Other conventional gear used to catch demersal fish for research purposes in inshore, shallow waters at depths down to 110-120 m (littoral, coves, shallow fjords), have been small trawlers (less common), hooks and lines and traps. Trawling has been scarcely used due to the lack of appropriate bottoms. Trammel/gill nets have shown to be the best gear, their advantages are capture of a higher quantity of fish in a short time, no damage to benthos, negligible by-catch of benthic organisms and easy operation from rubber boats. As it is a passive sampling device, catches depend solely on fish activity which is assumed to reflect population size. Therefore, changes in population size are expected to be reflected by proportional changes in catches. In the period 1983-1990, a sharp decline in the abundance of juvenile N. rossii and G. gibberifrons was found, whereas the stock of N. coriiceps remained stable. This paralleled what was happening to the overall stock of the first two species; subsequent sampling to 2007 showed that the inshore populations of the exploited species remained in poor condition, whereas to date, the relative abundance of N. rossii is in the process of recovery but is still far of the levels observed in the early 1980s, while that of G. gibberifrons remains low (Kock 1992, Barrera-Oro et al. 2000, Marschoff et al. 2012). This decrease is consistent with historical information from offshore bottom trawl surveys (Jones et al. 2003, Kock et al. 2007) and was attributed to a reduction in recruitment due to the decline of the offshore populations, subsequent to overfishing in the late 1970s and early 1980s.

Monitoring of pre-recruit fish by means of trammel nets was previously applied in the Morbihan Gulf, Kerguelen Islands, Indic sector (Duhamel 1990). It was reported a reduction in juvenile N. rossii inshore catches as being caused by the depletion of the offshore reproductive stock due to the operation of the commercial fishery. Further monitoring showed a continuous recovery of the juvenile stock from 1984 to 1988, after the closure of the fishery, unlike the long delay in the

NOTOTHENIA CORIICEPS

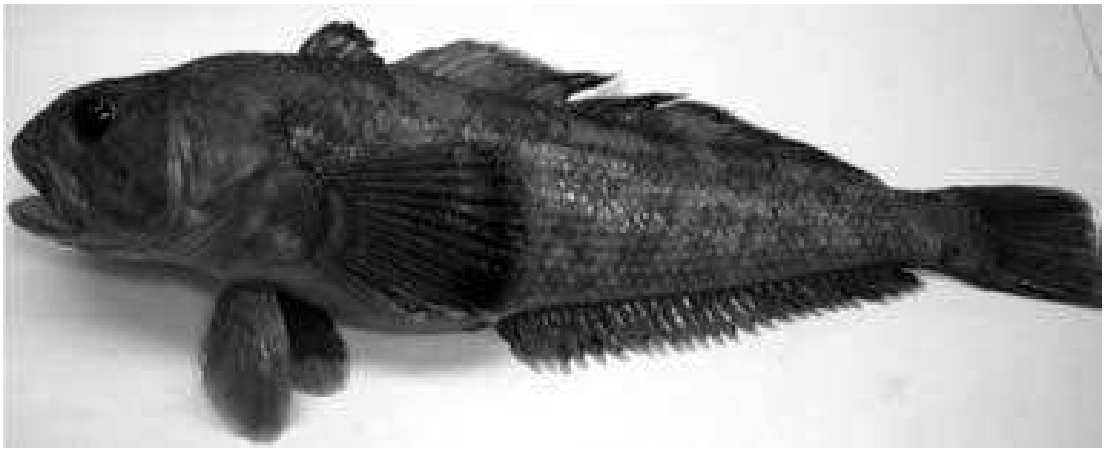


Fig. 8. *Notothenia coriiceps, the dominant fish species in inshore waters of the Southern Scotia Arc and western Antarctic Peninsula.*

beginning of this process observed in the South Shetland Islands.

The diminution of certain fish populations appears to have affected other components of the food web. It is well known that prey availability influences the foraging strategy, breeding output and population parameters of their predators (Montevecchi 1993). In Antarctic inshore waters shags (Phalacrocorax sp., Fig. 9) occupy the trophic niche of main predators of demersal fish and play an important ecological role as regulators of populations of particular fish prey that have marked site fidelity (Casaux and Barrera-Oro 2006). Shags feed heavily on notothenioids nearshore, as indicated by otoliths in the pellets that they cast daily, whereas benthic organisms such as polychaetes, gastropods, bivalves, cephalopods and crustaceans are known to be secondary diet components (Fig. 9).

Not surprisingly, among the prey species caught with nets inshore at the South Shetlands, only N. rossii and G. gibberifrons have been absent or scarcely represented in shag's pellets. Moreover, at the onset of the 1980s in waters around the South Orkney Islands, a fishing ground also affected by the commercial fishery, N. rossii was a frequent prey of shags (Shaw 1984), but one decade after, this fish species was not represented in the diet of this bird in that area (Casaux et al. 1997). In the South Shetlands, the absence of otoliths from the two exploited species contrasts with the high occurrence of those from N. coriiceps. These results are consistent with the high incidence of G. gibberifrons in the diet of shags and in trammel-net catches at the Danco Coast, western Antarctic Peninsula, reflecting higher availability of this fish in an area remote from the main historical fishing grounds of the South Shetland Islands (Elephant Island and north of Livingston/King George Islands) and the Antarctic Peninsula (Joinville-D'Urville Islands) (Casaux et al. 2002, Casaux and Barrera-Oro 2006).

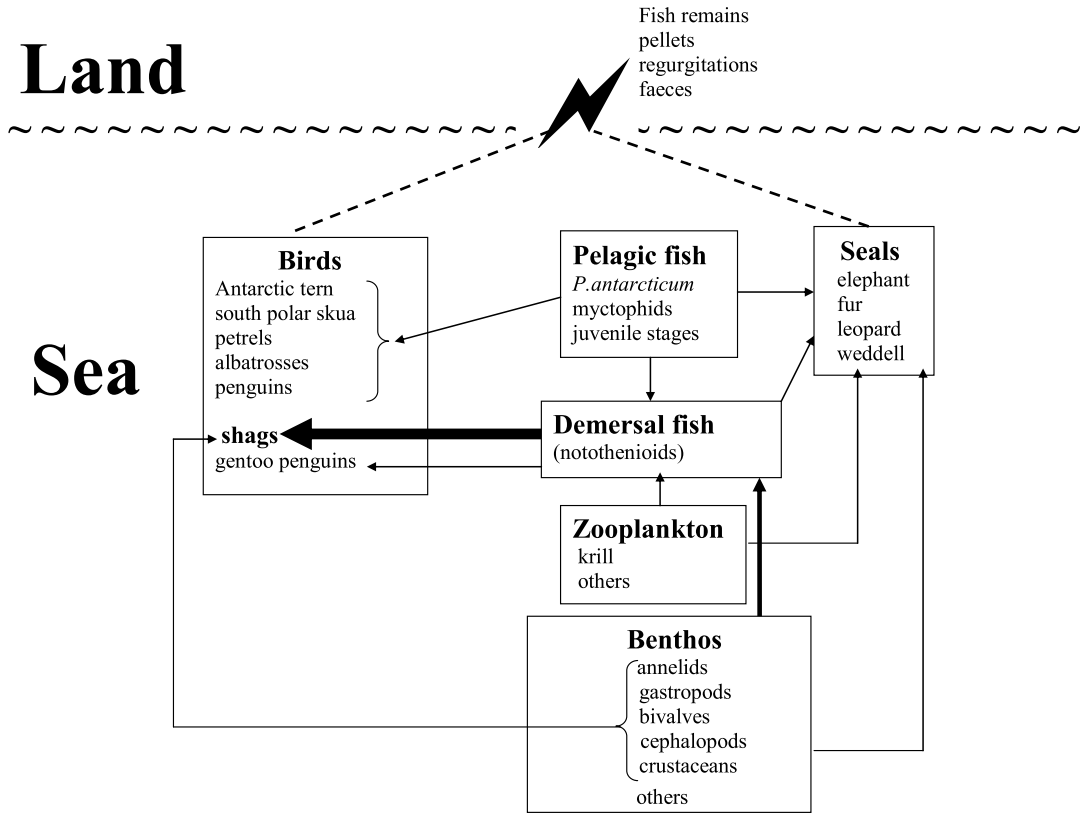


Fig. 9. *Diagram indicating the position of shags and other high predators in the Antarctic marine food web (taken from Casaux and Barrera-Oro 2006).*

A steady declining trend in the number of breeding pairs of shags was reported for several colonies in the southern Scotia Arc region (summarized in Ainley and Blight 2009). In addition, at Marion Island, in the sub-Antarctic Indian Ocean, a decrease in colony size of Crozet shags Palacrocorax marionensis has been similarly reported as being caused by an altered availability of food, which was reflected by a changed dominance in nototheniid prey in the diet (Crawford et al. 2003). Industrial fishing for demersal species was heavy in these waters as well (Kock 1992). This phenomenon in the South Shetland Islands was studied at two colonies of the Antarctic Shag Phalacrocorax bransfieldensis located in Duthoit Point and Harmony Point, in Nelson Island, from a long term data series of 23 years (Casaux and Barrera-Oro 2012). The reported decrease in the abundance in inshore waters of the South Shetland Islands of G. gibberifrons and N. rossii, which were probably two former important fish preys of the Antarctic Shag, may have influenced to some extent the declining trend in the number of breeding pairs of this bird, observed in the colonies studied in that archipelago. These findings also reflect the sensitivity of shags' reproductive and behavioral parameters to changes in fish populations.

The above examples show that substantive changes in one level of the food web can be traced

to changes in other components, supporting the hypothesis of Ainley and Blight (2009) that the structure of the Antarctic marine ecosystem has entered its current state due not just to changed climate, weather and sea ice, but equally to extractions of seals and whales (as suggested by many researchers) as well as of fish in the 1970-80s.

Impact of inshore catches on local populations

It is to be noted that the fishing vessels did not operate in inshore waters because of the many uncharted, subsea rocks present and also because no large exploitable fish concentrations occur in such zones. However, the abundance of fish in fjords and bays has been exploited by man for local consumption. Historical information indicates that before industrial exploitation in the onset of the 20th century at South Georgia the quantities of N. rossii in nearshore waters were so large that many thousands of fish were caught for consumption at various whaling stations (compiled in Kock 1992).

In the South Shetland Islands and western Antarctic Peninsula N. coriiceps is a neritic species of interesting size for local human consumption. This nototheniid is the dominant fish in number and biomass in nearshore waters of the Scotia Sea, including the western Antarctic Peninsula (Barrera-Oro 2002). It has proliferated markedly in the last three decades, parallelly with the decrease in the N. rossii and G. gibberifrons populations, this last process caused by the commercial exploitation. As the three species have similar ecological habits in fjords and bays, it is probable that during this period N. coriiceps encountered progressively less interspecific competition and consequently expanded its trophic and habitat niches. The status of the inshore populations of the formerly commercially important N. rossii and G. gibberifrons is still limited, as it was reflected in sampling data obtained from nets and shags. Besides, mostly the juvenile stages of these two species would be taken inshore, which might affect their recruitment offshore. The Scotia Sea ice fish Chaenocephalus aceratus is large in size, but it is relatively abundant only below 90-100 m depth.

It was experimentally demonstrated that the meat of N. coriiceps is good for human consumption, basically due to its high proteic and mineral value, low content of fluor and lipids and good conservation quality (Casaux et al. 1995). Notothenia coriiceps, from the catches taken by scientific programms, has been, in fact, consumed at the Argentine permanent scientific station "Carlini" (formely "Jubany"), placed in the shore of Potter Cove, in King George Island/ Isla 25 de Mayo. Although this species was intensively taken year round (around 400 kg) at Potter Cove mostly between 1983 and 1989 for scientific purposes, a great proportion of the specimens was also regularly eaten by the station members (about 12 and 70 people in winter and summer, respectively). The population of N. coriiceps within the cove, far from being reduced, increased in that period. A strong site fidelity is known for the species (Barrera-Oro and Casaux 1996, North 1996) and intense sampling for research has produced local effects only (Casaux and Barrera-Oro 2002). In the South Shetland Islands/Antarctic Peninsula at least 33 scientific/logistic stations or shelters which belong to 15 nations are settled (76% in the South Shetland Islands) and 15 of them are open permanently. It is likely that mainly N. coriiceps have been used in some of these bases for local consumption as well.

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