

DECLINE OF ANTARCTIC TOOTHFISH AND ITS PREDATORS IN MCMURDO SOUND AND THE SOUTHERN ROSS SEA, AND RECOMMENDATIONS FOR ITS RESTORATION

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The Antarctic toothfish (*Dissostichus mawsoni*) is a key component of the Ross Sea ecosystem (see Ainley et al. 2006a and references therein). Over the shelf, it is a major predator of other fish, especially silverfish (*Pleuragramma antarcticum*), and in turn is a major prey of Weddell Seals (*Leptonychotes weddellii*) and Killer Whales (*Orcinus orca*). It competes with the seals as well as penguins (*Aptenodytes*, *Pygoscelis*), and perhaps the Killer Whales, for fish prey. In 1996 a fishery for this species began (Fig 1), with humans thus beginning to compete with the natural predators of toothfish; in the past few years annual landings in the industrial catch have reached >3000 tonnes mainly from the Ross Sea slope but from the shelf as well (i.e., CCAMLR SSRUs 88.1G-L; Fig 2). The reported catch has gotten close to the TAC only recently (Dunn & Hanchet 2006a). CPUE of the fishery has varied annually but has generally been increasing at least through 2005 (Dunn & Phillips 2005; Fig 3).

Ross Sea Toothfish Catch as reported to CCAMLR

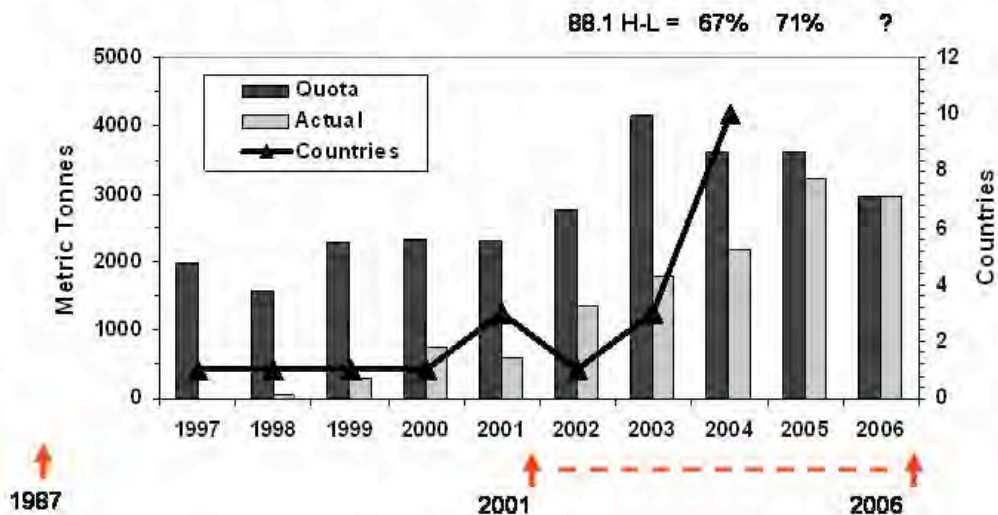


Figure 1. The commercial catch of toothfish in the Ross Sea beginning in the 1997 season (data from Dunn & Hanchet 2006). Not included is the IUU take, which began when the CCAMLR-authorized take began as well. The present paper will compare attributes of catches made by scientists in McMurdo Sound (indicated by the arrows), using 1987 as typical of the pre-industrial era, and 2001-06 to show trends in recent years of apparent toothfish abundance in the southern Ross Sea.

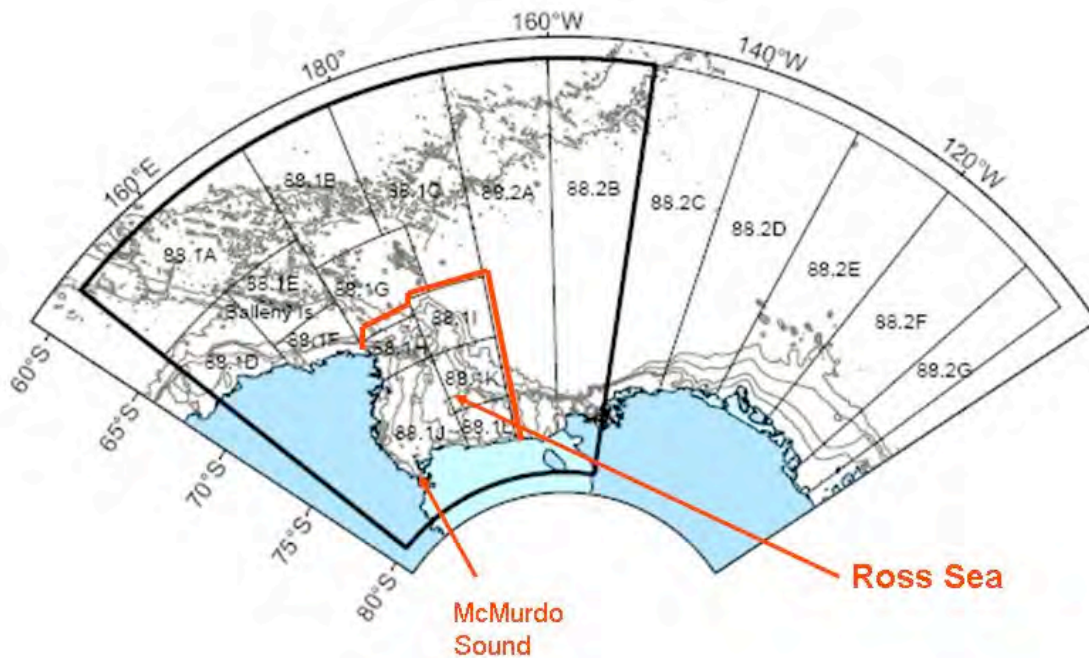


Figure 2. The Ross Sea showing location of McMurdo Sound, site of a scientific catch of toothfish since 1971, and the SSRUs of the shelf and slope. An industrial fishery has been in place since 1996.

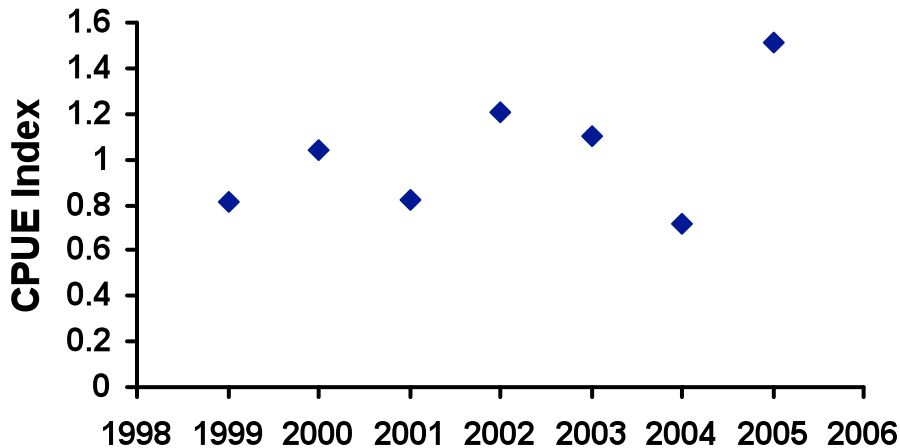


Figure 3. The average CPUE Index for the industrial catch throughout the Ross Sea; data from Dunn & Phillips (2005).

Research on the fish of McMurdo Sound began in the 1960s and has continued almost annually ever since, with projects conducted by scientists from the USA and New Zealand. Most of this work was directed toward understanding adaptations of Antarctic fish for life in freezing temperatures. In 1971, scientists began to catch Antarctic toothfish to obtain fish to use in laboratory experiments,

and in the next few years perfected catch techniques and also began to catch far more than needed for laboratory research. The latter fish were measured, weighed, tagged and released. Presented here is a description of that effort and a comparison to the industrial catch.

Also presented here are trends in the abundance of at least one predator of toothfish in the McMurdo Sound vicinity: the fish-eating (ecotype 'c') killer whale.

DESCRIPTION OF FISHING

Fishing occurred primarily from one site, about 4 km west of McMurdo Station in 500 m of water using a winch with 3/32-inch wire and a 25 kg weight attached to the bottom end to keep the wire under tension: a vertical set line. The lines were set through a hole drilled through the annual fast ice; a heated fish house was placed over the hole. Initially 15-22 two meter-long leaders about 20-25 m apart were fished, but quickly it was found that most of the fish were caught near the bottom. Water depth was about 500 m. Subsequently, hooks were spaced 3 to 5 m apart starting 10 m from the bottom to avoid scavenging by benthic amphipods. Sometimes 12 hr sets were made but most were 24 hr sets. Some ran 48 hr if poor weather prevented travel but those fish were pretty well "beat out" so this long a soak time was avoided. Initially live *Pagothenia borchgrevinki* were used for bait, but after it was found that dead bait worked just as well, New Zealand yellow eyed mullet, cut in half, were used.

Many of the fish were injected with a few mls of tetracycline to mark the scales and otoliths in case they were recaptured. The fish were placed in a V-trough (with a wet cloth over their eyes), measured to the nearest cm, weighed to the nearest pound, tagged with a numbered 'Floy' dart tag and a tail locking tag, injected and released. This procedure required about 3-5 minutes.

Beginning around 2001, the fishing site moved slightly closer to McMurdo Station because of conflict with the Sea Ice Runway location and the requirement of being well away from the aircraft approach to the runway. The 2001 site appeared to fish (catch frequency) as well as the earlier site in its initial use.

CHARACTERIZATION OF THE CATCH

Since 1972 ~4500 fish have been caught and ~250 have been kept for experiments including those that were not going to live (which were used for human food in some cases). The largest fish caught was ~120 kg (165 cm) and the smallest 5 kg; the average was 25-30 kg (Fig 4). Specimens <85 cm have rarely been caught, likely indicating their scarcity, as large mature adults would eat them. In addition, small fish if on the line very long appear to have been attacked by the larger fish as they often had lots of parallel teeth marks on both sides of their body and were missing many scales. The Russians have a record of a small toothfish (~1 m long fish in the stomach of a 1.7 m fish). Because standard, stainless steel, long-shank hooks were used (not short-shank with the

gap of the tip being less than that at the lower part of the curve, like a tuna hook), most of the big fish were lost. The evidence for this is that some of the hooks were straightened out or broken.

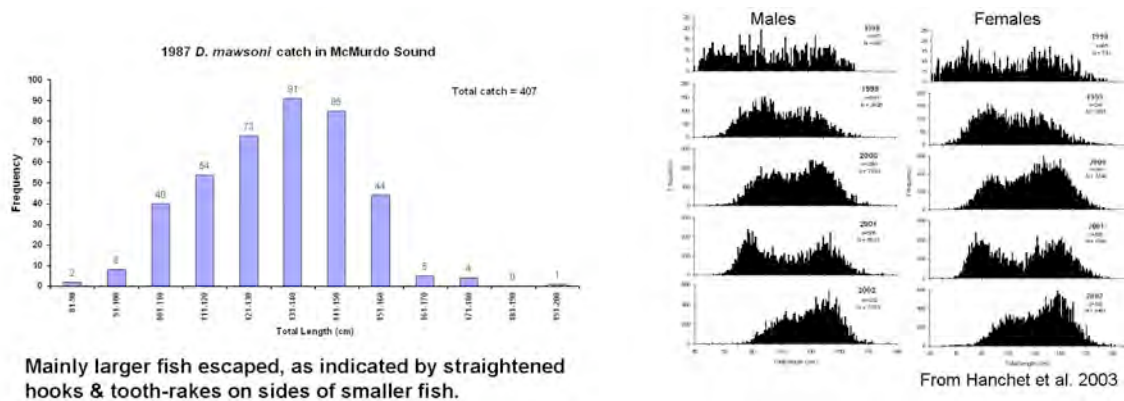


Figure 4. A comparison of the length-frequency of toothfish caught by scientists in McMurdo Sound with the fish caught in the industrial fishery in the Ross Sea.

Of the 4000+ fish tagged and released in McMurdo Sound, 13 have been recaptured at the McMurdo fishing site, with annual growth rate being 1.5 cm in length and 1 kg in mass per year. These values are slightly below those reported in the industrial catch. One McMurdo Sound fish was recaptured by the Russian boat “Yantar”, and the New Zealand fleet has recaptured 4; some of the recaptures have been outside of the Ross Sea. One of the NZ recaptures had been injected with tetracycline and showed that, indeed, the annuli corresponded to yearly growth rings (CCMLAR publication). Most recaptured fish have been “away” from McMurdo Sound for 4-5 years and the longest has been gone 7 years. For unknown reasons none of the earliest tagged fish have been recaptured.

CATCH SUCCESS

Before commercial fishing began in 1996, the scientific catch varied from year to year depending upon the fishing effort, which was determined by factors such as priority of laboratory experiments, sufficient help and weather. In general, though, 200-500 were caught in the 2.5 mo season, setting once a day, every year. We view 1987 as a typical year (Fig. 4-6). The field season began in early October (scientist arrival on the ice). The catch generally began to drop during late Nov/early Dec, when mainly smaller ones (15-20 kg) were caught. By mid-December very few were caught. In some years there were reports of fish being caught by the seals hauled out at the ice shelf/sea ice transition near Scott Base during January and February. A 60 kg fish with its gut stuffed full of *P. antarcticum* was obtained during February.

From 2003 on, especially, the catch dropped off. The fact that all baits were present indicated that few toothfish were passing through the waters. However seals at fishing sites sometimes brought up small fish, 15-20 kg (see Ponganis & Stockard 2007), which in some cases were good enough for lab experiments. Not enough fish have been caught since 2002 to do any tagging and releasing.

**SUMMARY OF CPUE FOR MCMURDO SOUND,
with effort beginning in 1971**

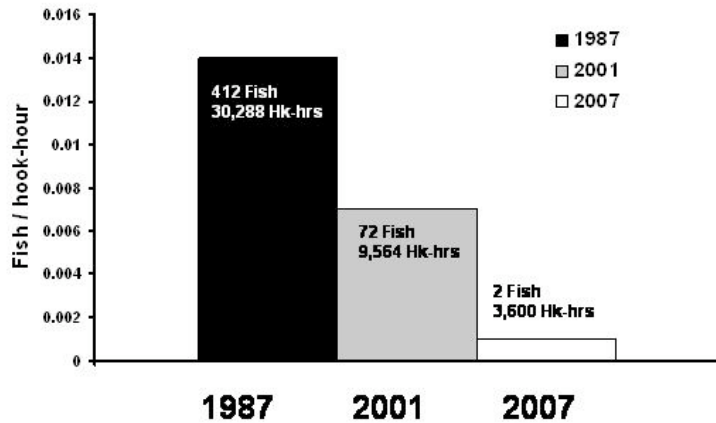


Figure 5. The catch-per-unit effort of one pre-industrial-era year compared to two recent, industrial-era years for toothfish caught in McMurdo Sound (A. DeVries unpubl. data).

**SUMMARY OF RECENT CATCH, MCMURDO SOUND;
with CPUE of 2001-2002 already reduced compared to
previous years.**

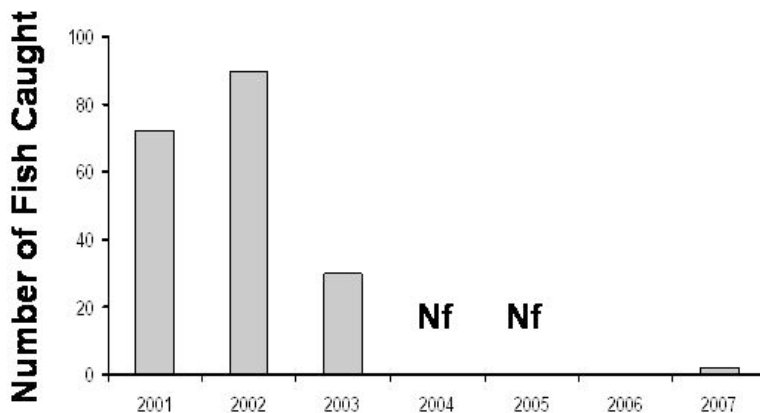


Figure 6. A summary of catch success, uncorrected for effort, for toothfish caught by all scientists in McMurdo Sound. See Fig 5 for more detailed data about corrected CPUE in 1987, 2001 and 2007. Nf = no fishing. None were caught in 2006 in spite of 7 sets, fished 24 hours, comprised of 12 hooks; in 2001 ten sets were made.

DECLINE IN THE PREVALENCE OF FISH-EATING KILLER WHALES IN MCMURDO SOUND

As noted, the type 'c' Killer Whale preys on toothfish in the Ross Sea. Many observations have been made of killer whales surfacing in the waters of the McMurdo Ice Channel with toothfish in their mouth (Ainley et al. 2006a). The numbers of these predators have been logged consistently by daily watches conducted at Cape Crozier, Ross Island, just outside of McMurdo Sound. These watches occur daily, weather permitting, and last at least an hour long and involve scanning the waters in sight, from an altitude of 400 m (Ainley et al. 2006b).

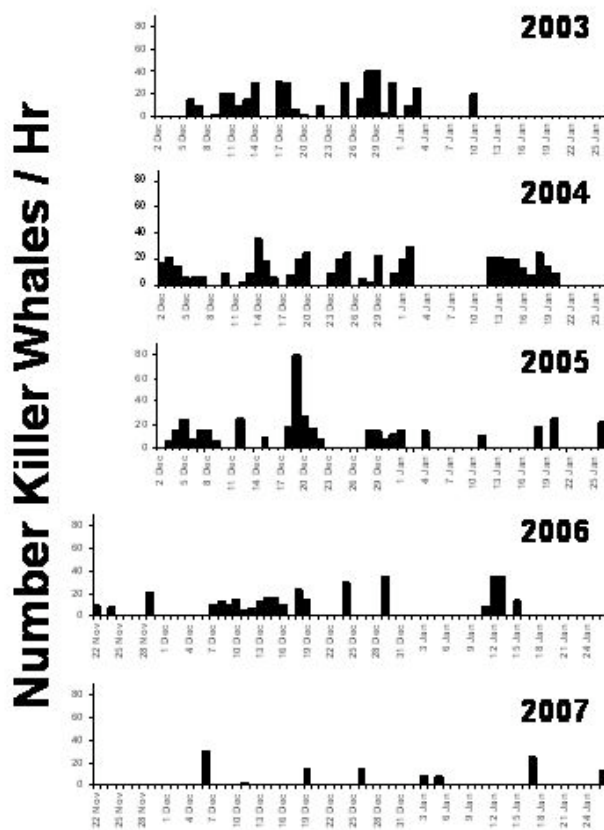


Figure 7. A summary of the number of type c Killer Whales seen from a lookout at Cape Crozier, Ross Island. Data for 2004 and 2005 from Ainley et al. (2006b); sightings based on 1-3 hr spent each day, weather permitting, scanning waters within sight from a vantage point 400 m high.

Sighting at Cape Crozier began to become infrequent in January 2006 (when two long-line vessels began fishing), compared to previous years, with very few seen in 2007. Very few were seen in McMurdo Sound in 2007, although the sighting effort is less ideal and is affected by fast ice. In 2007, as well, the Adélie Penguins nesting at Cape Crozier fed on silverfish to a greater degree during chick feeding (late Dec-Jan) than they had for 14 years of previous sampling at

that site (Fig 8; Ainley et al. unpubl. data). Normally they feed first on krill and then switch to fish when krill-eating baleen whales show up (Ainley et al. 2006a).

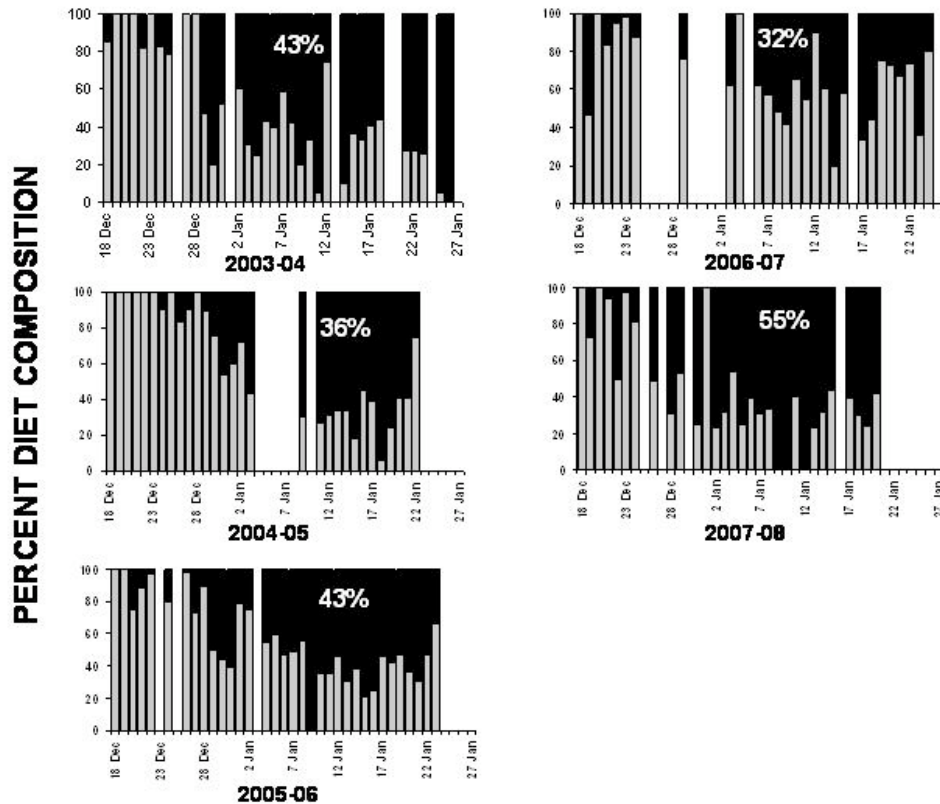


Figure 8. Diet of penguins at Cape Crozier, Ross Island (see Ainley et al. 2006a for methods). Percentages represent proportion of silverfish in diet during the period 18 Dec to 20 Jan, the period common to all years shown here.

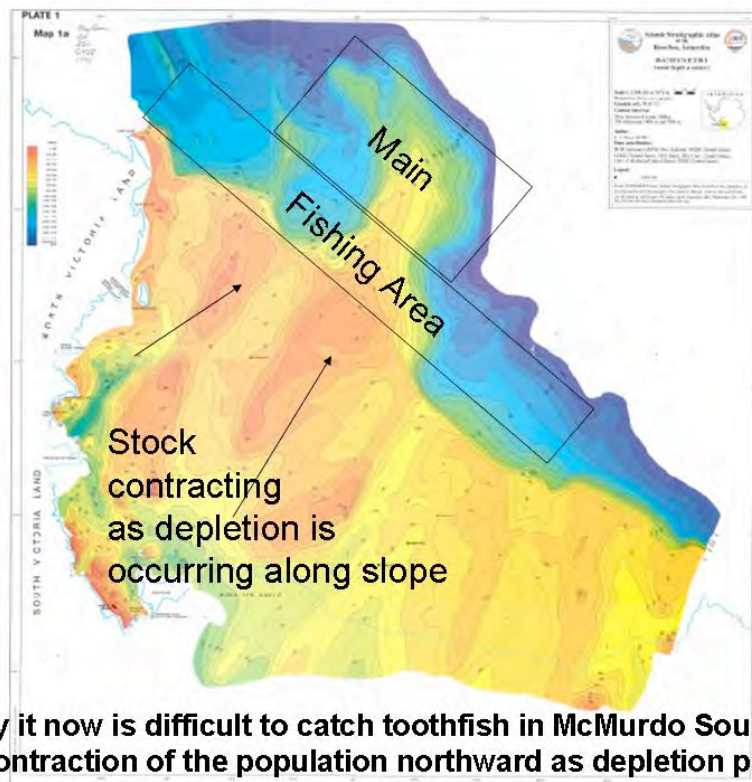
DISCUSSION

The fact that the presence of toothfish in the Sound declines seasonally, as indicated by the scientific catch data, with timing corresponding to the arrival of Killer Whales may not be a coincidence. Occurring at that time as well is the appearance of a large number of newly weaned Weddell seals, another toothfish predator. A similar seasonal pattern of fish movement/presence-absence relative the dynamics of top-predators has been proposed for deep-living fish on the Scotia Shelf (Eversen 1970).

We interpret the annual trends in scientific CPUE as indicating a contraction of the Ross Sea population of toothfish northward as industrial fishing continues to remove fish from the central portion of the stock, principally from the Ross Sea continental slope (where fishing is concentrated). Given that the fish live to 50 years, there has been no replacement to compensate for the increased extraction rate above what natural predators take. Complementing these trends in the southern Ross Sea is the reduction in presence of the fish-eating Killer

Whale. Killer Whales likely are moving as well to occupy waters where the toothfish are still abundant, as indicated by human CPUE.

Involved in these trends may be a trophic cascade resulting in more forage fish and less krill for Adélie Penguins to consume, a cascade related to the disappearance of the toothfish which competes for the same fish prey with the penguins. The toothfish is a major predator of silverfish, which is the major predator of crystal krill (*Euphausia crystallophias*; Ainley et al. 2006 and references therein). Fewer toothfish perhaps leads to more silverfish and, owing to increased predation among the latter, less krill. With toothfish disappearing there may now be more silverfish and less krill available to the penguins, thus leading to a change in penguin diet. In 2007, the penguins at Cape Crozier, and elsewhere on Ross Island, had one of the best breeding seasons among the previous 10. Thus, a change in prey composition and not a reduction of prey appears to have been involved. Whether or not Weddell seals have been affected is not known; as they are long-lived k-selected species, no perturbation in population size would be evident for decades. There is no monitoring of seal diet underway. Nor is there any monitoring of seal populations outside of McMurdo Sound, nor of their post-breeding movements, both of which would likely be affected by an altered Ross Sea food web.



McMurdo Sound, and perhaps the southern reaches as well of the larger Ross Sea, appears now to be without, effectively, its major piscine predator, the toothfish, which certainly should be *the* major predator in the ecosystem (e.g.

Sheffer et al. 2005). Given that the large majority of tag recoveries of fish tagged over the shelf have been accomplished over the slope and to the north (see Dunn & Hanchet 2006b), we recommend that the Ross Sea toothfish fishery reduce its catch significantly until:

1. The McMurdo Sound/southern Ross Sea toothfish population is restored;
2. A research program is set in place to investigate the ecological ramifications of this perturbation to the McMurdo Sound food web, thus, to assess ecosystem effects of the fishery and ecosystem recovery potential, as required in Article 11 of the CCAMLR convention; and
3. A monitoring program is developed in order to keep track of ecosystem trends throughout the Ross Sea over the long term, also in line with Article 11 of the Convention, at the least, by establishing time series of predator populations (seals, whales) along Victoria Land.

The reduction in TAC should include a moratorium on fishing over the shelf, i.e. SSRUs 88.1J, K, L, and a reduced TAC for 88.1G, H and I.

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