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Short Note
Antarctic toothfish heads found along tide cracks of the McMurdo Ice Shelf

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On 15 November 2009, we found 45 Antarctic toothfish (*Dissostichus mawsoni* Norman) heads along a 3 km stretch of the 10–15 km long tide crack that ran east–west in the McMurdo Ice Shelf just north of Bratina Island (Fig. 1). From 77°59.1'S, 165°36.2'E, we walked along the crack to a seal breathing hole at 78°00.1', 165°31.3'. We walked the same stretch on 7 December, finding also two pieces of fish skin, each 15–20 cm long; and again in November 2010, when we found no new heads.

There were 17 heads within a 16–25 m^2 area (Fig. 1) at the western end with the remainder occurring mostly as singles, although in a couple of places 2 or 3 were found. All but one at the seal hole were freeze-dried and thus had been present for more than a year. Most had been attacked by South Polar skuas (*Stercorarius maccormicki* Saunders), which had successfully pulled apart the brain cavity, leaving few otoliths.

In 29 intact heads, we measured the distance from the anterior point of the upper jaw to the posterior edge of the orbit. This distance is 14% of total length (TL; based on fig. 8 in DeWitt *et al*. 1990, fig. 6.2 in Eastman 1993 and two preserved specimens). Thus, the mean TL of these fish was 79.3 ± 1.7 (s.e.) cm, range 60.3–107.0 cm (median 78.6), the same size as those pursued by Weddell seals (*Leptonychotes weddellii* Lesson) as summarized in Ainley & Siniff (2009).

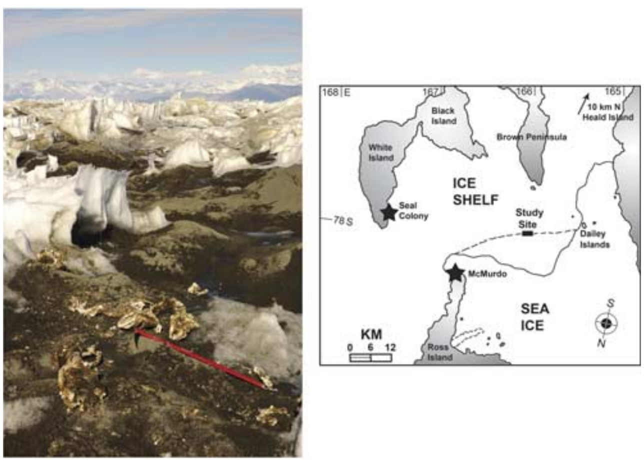

Fig. 1. Left: fish heads at easternmost end of tide crack search. Right: study site (black bar) and other locations mentioned; stars = closest seal colonies, dashed line = crack, which broke free in 2011.

Our observations are consistent with those of Swithinbank *et al*. (1961) and Gow *et al*. (1965), who found similar deposits of fish heads at a tide crack ~ 20 km west of our study area, where the McMurdo Ice Shelf meets the multiyear fast ice at the Dailey Islands (77°52'S, 165°18'E; Fig. 1). They reported 50 specimens (all toothfish; P.K. Dayton, personal communication 2010), including several in clumps. A photograph reveals at least two, including a whole fish measuring 142 cm TL; several heads were larger than that of the latter. They concluded, and we agree, that these large fish resulted from seal predation. We encountered four mummified Weddell seals (including a pup) but no live seals during our walks. Helicopter pilots, regularly flying over, often observed one to a few seals hauled out near the crack in late summer (Dustin Black, personal communication 2010).

Weddell seals characteristically remove the heads of large toothfish before consuming the rest (Ainley & Siniff 2009). We believe the heads clog the seals' breathing holes and are expelled by them, as indicated by the relatively fresh head that we found. Toothfish of this size are approaching or have achieved neutral buoyancy, reached at ~ 96 cm TL (Near *et al*. 2003), and with the accumulation of fat in their tissues, including cranial bones (fig. 6e in Fenaughty *et al*. 2008), the heads of large toothfish float. Seals maintain the same holes for many weeks, leading to accumulation of heads. That fish head distribution was limited to near the tidal crack confirms deposit on the surface by seals, not by non-biogenic ice processes, as is the case for invertebrates (Dayton *et al*. 1969).

We reason that toothfish heads are not found along cracks in the relatively thin annual fast sea ice elsewhere in the McMurdo Sound region (the thinnest ice in these active cracks is $\leqslant 1$ m thick) is because holes are common and seals have little need to keep them clear, and the low under-ice topography allows fish "debris" to be easily swept away by currents. The seals would have more of a challenge finding and keeping holes open in McMurdo Ice Shelf cracks, which are narrow and involve ice ~15 m thick on either side; blockage by large fish heads would present a problem to seals needing to breathe (P.K. Dayton, personal communication 2010, who dove through these cracks).

How long the heads we encountered had accumulated at the surface is unknown. Gow *et al.* (1965) concluded that carbon dating cannot provide valid dates for these heads. Despite their large size, toothfish skulls contain a considerable amount of cartilage and the bones are thin and weakly mineralized (Eastman & DeVries 1981). Because cartilage quickly dehydrates in the dry polar air and the thin bones become disarticulated and scattered, we suspect, tenuously, that these heads were on the ice for < 10 years.

The finding of 17 heads at what must have been a single breathing hole perhaps indicates that large toothfish were previously more abundant than they are now in McMurdo Sound (DeVries *et al.* 2008). Our findings are also graphic testimony to the prevalence of toothfish in the diet of Weddell seals, and perhaps offer insight into their relative importance to the seals during the winter and early spring. Until recently, the trophic importance of this fish to the seals was unknown, not having been revealed by examination of stomach contents, nor scats, because the seals do not consume toothfish bones or otoliths and the soft lipid-rich muscle of the toothfish quickly becomes unrecognizable in the seal's stomach. Sampling to use biochemical analyses has not been adequate to answer this question either (Ainley & Siniff 2009).

The importance of toothfish to Weddell seals that use the ice shelf cracks has far reaching implications. An isolated, genetically distinct Weddell seal population exists at White Island at another broad, permanent crack (78°00'S, 167°28'E; Gelatt *et al.* 2010), about 30 km east of our study site. Castellini *et al.* (1984) set fish traps at White Island and concluded that small fish were locally abundant enough to sustain the seal population, not knowing that these seals had larger toothfish to eat as well. During a camera-equipped ROV dive through a similar crack near Heald Island (78°21'S, 163°27'E), we encountered an ~80 cm toothfish at 80 m depth. There was no evidence of seals near Heald Island, 35 km from the ice shelf edge, but the presence of toothfish indicates that seal prey extend at least this far. The seals at the Bratina Island study crack seemingly were isolated like the White Island seals, as the edge of the Ice Shelf was 20 km away at both locations. We hypothesize that a lack of heads at the White Island crack may be due to currents that are three times stronger there (20.5 vs 7.6 $cm\,s^{-1}$) than near the McMurdo Ice Shelf, and are parallel to the crack, creating a flushing motion (see discussion of currents in Barry & Dayton 1988). At the Bratina crack, currents are perpendicular and this, coupled with 1–2 m tidal drop of the free portion of the ice shelf, would have created a periodic barrier to water flow, turbulence and, therefore, a "backwater" effect to help trap the heads. Supporting this idea, the deposits of heads at the Dailey Islands were in cracks also oriented across-current.

It is possible that the presence of large toothfish is what attracts seals and entices them to remain at under-ice-shelf localities despite the challenge of maintaining breathing holes and foraging continuously from the same fixed point. If toothfish are important to the isolated White Island seals' existence, the recent severe reduction of toothfish in McMurdo Sound (DeVries *et al.* 2008) could have grave negative repercussions for this interesting, scientifically unique population of seals.

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References

Ainley, D.G. & Siniff, D.B. 2009. The importance of Antarctic toothfish as prey of Weddell Seals in the Ross Sea: a review. *Antarctic Science*, **21**, 317–327.

Barry, J.P. & Dayton, P.K. 1988. Current patterns in McMurdo Sound, Antarctica and their relationship to local biotic communities. *Polar Biology*, **8**, 367–376.

Castellini, M.A., Davis, R.W., Davis, M. & Horning, M. 1984. Antarctic marine life under the McMurdo Ice Shelf at White Island: a link between nutrient influx and seal population. *Polar Biology*, **2**, 229–231.

Dayton, P.K., Robilliard, G.A. & DeVries, A.L. 1969. Anchor ice formation in McMurdo Sound, Antarctica, and its biological effects. *Science*, **163**, 273–274.

DeVries, A.L., Ainley, D.G. & Ballard, G. 2008. Decline of the Antarctic toothfish and its predators in McMurdo Sound and the southern Ross Sea, and recommendations for restoration. *CCAMLR Document WG-EMM-08/21*. Hobart, TAS: CCAMLR.

Dewitt, H.H., Heemstra, P.C. & Gon, O. 1990. Nototheniidae. *In* Gon, O. & Heemstra, P.C., *eds. Fishes of the Southern Ocean*. Grahamstown, South Africa: J.L.B. Smith Institute of Ichthyology, 279–331.

Eastman, J.T. & Devries, A.L. 1981. Buoyancy adaptations in a swim-bladderless Antarctic fish. *Journal of Morphology*, **167**, 91–102.

Eastman, J.T. 1993. *Antarctic fish biology*. San Diego, CA: Academic Press, 322 pp.

Fenaughty, J.M., Eastman, J.T. & Sidell, B.D. 2008. Biological implications of low condition factor "axe handle" specimens of the Antarctic toothfish, *Dissostichus mawsoni*, from the Ross Sea. *Antarctic Science*, **20**, 537–551.

Gelatt, T.S., Davis, C.S., Stirling, I., Siniff, D.B., Strobeck, C. & Delisle, I. 2010. History and fate of a small isolated population of Weddell seals at White Island, Antarctica. *Conservation Genetics*, **13**, 721–735.

Gow, A.J., Weeks, W.F., Hendrickson, G. & Rowland, R. 1965. New light on the mode of uplift of the fish and fossiliferous moraines of the McMurdo Ice Shelf, Antarctica. *Journal of Glaciology*, **5**, 813–828.

Near, T.J., Russo, S.E., Jones, C.D. & Devries, A.L. 2003. Ontogenetic shift in buoyancy and habitat in the Antarctic toothfish, *Dissostichus mawsoni* (Perciformes: Nototheniidae). *Polar Biology*, **26**, 124–128.

Swithinbank, C.W.M., Darby, D.G. & Wohlschlag, D.E. 1961. Faunal remains on an Antarctic ice shelf. *Science*, **133**, 764–766.