**PCAS 15 (2012/2013)**

**Critical Literature Review**
**(ANTA602)**

---

# The values of the Antarctic Toothfish *(Dissostichus mawsoni)*

Richard Kennedy

Student ID: 35501879

---

Word count: 2957 (excluding abstract and references)

Abstract (ca. 200 words):

The Antarctic Toothfish (Dissostichus mawsoni) is an apex predator found only in the Southern Ocean. Antarctic Toothfish are commercially harvested. The industry is controversial since it involves humans interfering with a 'pristine' environment. Many environmental groups are concerned that Toothfish fishing could be detrimental to the food web structure of the Southern Ocean due to Antarctic Toothfish having an apex role within the ecosystem, being long lived, and the fact that little is known about their reproduction. The fisheries for Toothfish are managed by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). The Toothfish is valuable as an economic resource for nations involved in harvesting, and also valuable from ecological, and scientific perspectives. This industry appears to contradict the environmentally friendly values of New Zealanders; on closer analysis this may not be the case. With careful management the values of the Antarctic Toothfish can be maintained for future generations. Most of the literature comes from the scientific community with little or no publications available from industry bodies on either matters of sustainability or economics.

The Antarctic Toothfish (*Dissostichus mawsoni*) is found only in the Southern Ocean and has been commercially harvested for the past sixteen years. The Antarctic Toothfish industry is controversial, with debate focusing on arguments of economics and of leaving a "pristine untouched" environment. Many environmental groups are concerned that the fishing could be detrimental to the entire food web structure of the Southern Ocean. The Toothfish is considered a significant resource for a number of reasons: economic value as a fishery; ecological value as part of a food web; scientific value, especially for bioprospecting; and of cultural importance. The significance of maintaining an environment that is perceived as untouched is one that varies significantly between cultures. From a New Zealand perspective, on the surface interfering with the Southern Ocean appears to be against the nations cultural identity however this is not necessarily the case. There are also doubts as to just how 'pristine' the Southern Ocean really is and whether this should be used as an argument to protect the Toothfish.

The Antarctic Toothfish, which is also known as the Giant Toothfish, Mawsons Toothfish, Mawsons Codfish and Antarctic Cod, is an apex fish predator (Smith, Gaffney, & Purves, 2001). It is found only within the Southern Ocean with a circumpolar distribution south of the Antarctic Convergence (Eastman, 1993). The flesh from the fish is marketed all around the world and is particularly popular in North America where it is valued for its mild creamy flesh (Stokstad, 2010) The Antarctic Toothfish and the Patagonian Toothfish (*Dissostichus eleginoides*) are both marketed as Chilean Sea Bass despite being evolutionarily distinct and inhabiting separate geographical areas; the Patagonian Toothfish inhabits regions above the Antarctic Convergence (Ainley, Brooks, Eastman, & Massaro, 2012). Adult Antarctic Toothfish grow up to 1.5 metres in length and have been reported to be as old as 48 years (Ainley et al., 2012). Toothfish have been caught at depths of up to two kilometres and show strong depth stratification, with older fish being found at greater depths (Agnew, 2000). Toothfish are the dominant fish within the ecosystem, although compete with marine mammals and penguins in certain geographical areas (Fenaughty, Stevens, & Hanchet, 2003). Although theories about the reproduction and lifestyle of the Toothfish have been proposed, relatively little is known about their spawning or development (Hanchet, Rickard, Fenaughty, Dunn, & Williams, 2008). Because the Antarctic Toothfish is mostly found below 65˚ South, the fisheries falls under the jurisdiction of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (Agnew, 2000).

Historically, fisheries were based in the immediate vicinity of ports (Ainley et al., 2012). As fish stocks decreased and demand increased fisheries began to look further afield (Ainley et al., 2012). Advances in fisheries technology enabled harvesting from locations and depths previously inaccessible or economically unviable (Ainley et al., 2012). Commercial long-line fishing for the Patagonian Toothfish began in the mid 1980s (Agnew, 2000). Rapid growth in the market and the high value of the fish led to the development of illegal unregulated fisheries (Agnew, 2000). Both legal and illegal fisheries usually utilize long line methods, or gill netting (Österblom & Sumaila, 2011). Illegal fisheries, coupled with poor management led to localised depletions in Patagonian Toothfish stock within ten years following the commencement of fishing (Ainley et al., 2012).

Commercial fishing of the Antarctic Toothfish began in the summer of 1996/1997 when a single vessel from New Zealand began fishing in the Southern Ocean in order to gather information for CCAMLR (Hanchet et al., 2008). Antarctic Toothfish fishing represents the world's southernmost fishery and currently involves an average of fifteen vessels (Ainley et al., 2012). Harvesting usually begins in December following the sea ice breakup, utilizing a similar approach as that used on the Patagonian Toothfish (Ainley et al., 2012). The flesh from Toothfish is commonly sold for upwards of fifty dollars a kilogram (Ainley et al., 2012). Current fisheries involve vessels flagged from Argentina, Spain, United Kingdom, Korea, Norway, Russia, Ukraine, Uruguay, South Africa in addition to New Zealand (Ainley et al., 2012).

CCAMLR, is the only non government organisation with fisheries jurisdiction in the Southern Ocean; it is tasked with the management and sustainability of Toothfish (Agnew, 2000). In order to manage Toothfish CCAMLR sets annual quotas for the allowed catch (Agnew, 2000). However, unregulated pirate harvesting poses a large problem with estimates from 2001 suggesting pirate vessels may be taking ten times the allotted CCAMLR quota (Smith et al., 2001). In the last few years a decline has been seen in pirate fishing following the implementation of a Catch

Documentation Scheme (CDS) and also the rise of genetic testing (Smith et al., 2001). The CDS was adopted in 1999 aiming to minimise unregulated fisheries by acting as a mechanism for tracking the trade in Toothfish through the entire supply chain (Agnew, 2000). It is now possible to distinguish between fish species easily using DNA, even where the fish has been processed at sea and is truncated or filleted; such identification was impossible in the past (Smith et al., 2001). The use of genetic testing means that it is harder for illegally caught fish to be sold on open markets (Smith et al., 2001). As a slow growing fish which take up to eight years to reach sexual maturity, Toothfish are inherently susceptible to overfishing (Eastman, 1993). There is a fear that the Antarctic Toothfish will follow the Patagonian Toothfish with localised population decreases and closed fisheries (Ainley et al., 2012).

Fishery management is reliant on a high quality data input of both current stock levels and reproductive rates in order to accurately predict what level of fishery is sustainable (Agnew, Hillary, Mitchell, & López Abellán, 2009). Currently the status of the Toothfish fishery is classified by CCAMLR as exploratory due to a lack of data (Jacquet et al., 2010). As such a 'precautionary management' principle is being applied which involves decreasing the population to fifty percent of carrying capacity in order to reach maximum sustainable yield (Ainley et al., 2012). This particular management principle is based upon the idea that larger fish prevent recruitment, so removal will increase survival and recruitment (Ainley et al., 2012). The approach relies on sound knowledge of pre-fishing biomass coupled with an understanding of the niches inhabited by all stages of influence and how this influences catch (Ainley et al., 2012). One final piece on information required is the knowledge that the fishery was at carrying capacity prior to the commencement of fishing in 1996/1997.

It has been questioned whether utilizing this approach is truly precautionary due to the depth stratification of different age groups (Ainley et al., 2012). There is currently conflicting information in terms of population stability, with catch per unit effort data suggesting depletion although catch at length analysis suggests a stable population (Brandão & Butterworth, 2009). Opposing models differ in predictions for the future with certain scenarios currently giving rise to concern of a probable future decrease in catch rate and depletion of the resource (Brandão & Butterworth, 2009).

Modelling by CCAMLR in 2009 showed that a sustainable yield would be only one quarter of the current catch rate (Agnew et al., 2009). Further research is required to ascertain population dynamics, and it has been suggested that data may be gathered by the industry prior to commencement of commercial fishing (Agnew et al., 2009). Although CCAMLR views the fishery as exploratory, consumers see the fishery as sustainable as it was certified as sustainable by the Marine Stewardship Council in 2009 (Jacquet et al., 2010). Recently a large decrease in both the size of fish caught and the number has been observed, which has lead to certain individuals questioning the sustainability of the CCAMLR model (Field, 2012). Fishery selection pressures can alter the average size of individuals through taking larger individuals selecting towards smaller fish (Brandão & Butterworth, 2009).

In the 2011/2012 season 730 tonnes were landed in New Zealand which represented an export value of twenty million New Zealand dollars (Trevett & Bennett, 2012). The catch by New Zealand represents more than half of the annual CCAMLR quota (Ainley et al., 2012). Any harvesting from New Zealand is carried out by Sanford Limited who, to date, have minimal media releases accounting for profits. Globally, based upon the value of the flesh and the CCAMLR quota, the fisheries has an 175 million dollar market (Ainley et al., 2012). The economic benefit of the Toothfish industry was the reason for New Zealand pulling out from a joint proposal with the United States to create a Ross Sea Marine Protective Area which would have resulted in all fisheries within that region being closed (Ainley et al., 2012).

Toothfish act as an Apex fish predator, which is an important role in the maintenance of an healthy ecosystem (Prugh et al., 2009). To date there has not been a integrated research effort carried out by CCAMLR to gather ecosystem data in the Ross Sea and to ascertain the effect that Toothfish removal may have (Nicodemus-Johnson, Silic, Ghigliotti, Pisano, & Cheng, 2011). A decrease in the population of apex predators can lead to an increase in the abundance of predators directly below in the food chain which can ultimately lead to a decrease in prey populations (Prugh et al., 2009). As the Southern Ocean food web is relatively simple, it is at a greater risk of being disturbed than a number of other ecosystems which have multiple redundancies (Ainley et al., 2012). Toothfish prey on a number of smaller marine organisms, with studies showing that two thirds of their diet is composed of fish and the further third of squid (Prugh et al., 2009).

Toothfish themselves are an important prey for seals and whales (Kim, Ainley, Pennycook, & Eastman, 2011). The Weddell seal (*Leptonychotes weddelli*) consumes 0.8 to 1.3 Toothfish per day (Petrov & Tatarnikov, 2011). It is currently thought that the presence of Toothfish entices Weddell seals under the ice shelf and is vital for the hunting under the ice shelf behaviour currently demonstrated (Kim et al., 2011). The decline in Toothfish numbers is particularly problematic to seal populations that are genetically isolated from others, such as the White Island Weddell seal (Kim et al., 2011). A decline in the number of Toothfish available to Weddell seals could potentially result in a cascade of changes within the mega fauna; other prey do not providing the same nutritional return in relation to energy expended to catch them, therefore other prey are not able to compensate for the loss of Toothfish for energetic reasons (Kim et al., 2011). In addition to consumption by seals, in deeper waters, Toothfish are consumed by both Sperm whales (*Physeter macrocephalus*) and Elephant seals (*Mirounga leonina*) (Kim et al., 2011). As a number of these species are still recovering from past exploitation the depression of prey could have significant effects on population stability (Kim et al., 2011). The population of Killer whales (*Orcinus orca*) within the Ross Sea is declining and it is thought that this may be linked to decreasing Toothfish numbers (Ainley, Ballard, & Olmastroni, 2009). Overall, the Antarctic Toothfish is an important nutritional component of ecosystems in the Southern Ocean and in particular the Ross Sea (Ainley et al., 2012). The ecosystem effect is not limited to the removal of Toothfish, rather the use of long line fishing methods historically resulted in high levels of bycatch in particular of Albatross and Petrels (Agnew, 2000). Recently there have been significant improvements, but many birds are still caught by the fishery (Ainley et al., 2012).

The scientific value of the fish extends to encompass both the ecological value of the fish and the potential knowledge, medicinal benefits and commercially valuable compounds that could be gained from the organism; this idea is also termed bioprospecting. Antarctic Toothfish have relatively unique physiology on many levels due to physiological adaptations to the polar conditions of the Southern Ocean (Morton, 2012). The Southern Ocean environment is one of the harshest environments for ectothermic teleosts since sea temperatures are perpetually below freezing (Cheng & Detrich, 2007). Toothfish are ectotherms with a body temperature which is the same as the surrounding water (-1.9˚C) and thus require mechanisms to prevent the freezing of water within their body (Kristiansen & Zachariassen, 2005). The formation of ice crystals within organic tissue is generally highly detrimental, due to the crystals physically puncturing cellular membranes as well as altering the osmolarity of cells (Cheng & Detrich, 2007). Toothfish are able to survive in ice laden waters because of a specific glycoprotein (Cheng & Detrich, 2007). This glycoprotein is of biochemical interest and is a thermal hysteresis protein factor that prevents the formation of ice crystals within the Toothfish through rearrangement of water molecules and separating the freezing point from the melting point (Nicodemus-Johnson et al., 2011). Thermal hysteresis factors are seen as potentially having a broad number of uses, in particular the prevention of tissue damage when freezing crop plants as well as other biological tissues (Cheng & Detrich, 2007). To date there have been no published studies into specific bioprospecting of Toothfish, potentially due to the secrecy of pharmaceutical companies.

The Antarctic Toothfish industry involves the removal of a species from one of the environments on earth which has had the least human impact and it is therefore viewed by many as pristine (Halpern et al., 2008). The idea of interfering with a pristine system is one that would appear to directly conflict with the cultural identity of New Zealanders and represent a negative value (Miller, 2010). Generally, there is a link between cultural attitudes and behaviour and from this it would be expected that New Zealand would ban such a fishery due to the aforementioned conflict (Field, 2012; Hini, Gendall, & Kearns, 1995). However, based upon the idea that CCAMLR and the MSC rate the industry as sustainable, the Toothfish industry is consistent with the Ministry of Fisheries (Now Ministry of Primary Industries) brief of maximising fisheries within environmental limits (Ministry of Fisheries, 2009). Although New Zealanders tend to feel they are environmentally conscious, there is no strong evidence that they are any more environmentally aware or motivated than any other population (Miller, 2010). Rather than New Zealand being '100% Pure' there are numerous threats to the nations freshwater and biodiversity (Miller, 2010). While New Zealanders claim to have a clean green identity, fishing within the 'pristine' Southern Ocean is more of a social norm than an issue (Halpern et al., 2008; Miller, 2010). Even still, economically and politically it is not in the interest of New Zealand to be responsible for the decline of a species in a perceived pristine location such as the Southern Ocean (Ainley et al., 2012).

The indigenous Māori of New Zealand have customary cultural rights to fish many waters in and around New Zealand based on long standing traditions (Levine, 1987). Appropriate technology for the fishing of Toothfish has only been available for the past fifty years, therefore the fishery is not part of any long term tradition (Ainley et al., 2012). The availability of new technology does not mean that the activity is not part of cultural identity, rather technology can be rapidly incorporated into identity so therefore by extension the change to fisheries can rapidly be included within identity (Ministry of Social Development, 2009).

The value of leaving the Antarctic Toothfish, and the Southern Ocean as an example of a pristine untouched environment is hard to quantify (Halpern et al., 2008). However, while it is a widely held belief amongst the public that Antarctica and the surrounding ocean is a pristine environment, scientists in reality do not believe that this is the case (Croxall, Trathan, & Murphy, 2002). Anthropogenic climate change has resulted in large changes to sea ice dynamics and oceanic temperatures and these changes will only accelerate with a steadily warming global climate (Croxall et al., 2002) The Southern Ocean ecosystem has had a number of significant perturbations through hunting and fishing (Blight & Ainley, 2008). In the 1800s and 1900s, the Southern Ocean, saw large decreases in cetacean, seal and penguin populations and more recently, a number of demersal fish were fished to commercial extinction (Blight & Ainley, 2008). The fisheries have been particular adverse towards top predators potentially resulting in greater ecosystem effects (Croxall et al., 2002). Historically exploited organisms have shown little signs of recovery suggesting the environment will not recover to the ‘pristine’ state of the past (Blight & Ainley, 2008). Another organism Krill (*Euphausia superba*) the foundation of the Antarctic food chain are in serious decline due to altered sea ice dynamics (Williams, 2007). The decline of Krill is being exacerbated by newly exposed water from climate change allowing greater access to fishing boats (Williams, 2007). Although many believe that the Southern Ocean is valuable as an untouched pristine environment it is fact an environment that has been altered by man in the past, and will continue to be changed due to fishing and climate change pressures.

The Antarctic Toothfish has considerable value as an economic resource, a source of biological material and ecologically as an important member of the Southern Ocean Ecosystem. The harvesting of the Toothfish does not appear to be against the cultural identity of New Zealanders and within a few years it could well become part of the identity. Regardless of the values it is imperative that the species is carefully managed to prevent overfishing leading to an ecosystem collapse. The loss of the Antarctic Toothfish from the Southern Ocean ecosystem would result in substantial ecological, scientific and economic losses. These loses may be able to be minimized with careful management of the Toothfish population to maintain these values leaving a valuable resource for future generations.

References

Agnew, D. J. (2000). The illegal and unregulated fishery for toothfish in the Southern Ocean, and the CCAMLR catch documentation scheme. *Marine Policy*, *24*(5), 361–374.

Agnew, D. J., Hillary, E., R., Mitchell, R., & López Abellán, L., J. (2009). Status of the coastal Stocks of Dissostichus Spp. in East Antarctica (Divisions 58.4.1 and 58.4.2). *CCAMLR Science*, *16*, 71–100.

Ainley, D. G., Ballard, G., & Olmastroni, S. (2009). An Apparent Decrease in the Prevalence of "Ross Sea Killer Whales" in the Southern Ross Sea. *Aquatic Mammals*, *35*(3), 334–346.

Ainley, D. G., Brooks, C., Eastman, J., & Massaro, M. (2012). Unnatural Selection of Antarctic Toothfish in the Ross Sea, Antarctica. In F. Huettmann (ed.), *Protection of the Three Poles* (p. 337). Springer Japan.

Blight, L. K., & Ainley, D. G. (2008). Southern ocean not so pristine. *Science (New York, N.Y.)*, *321*(5895), 1443–1443.

Brandão, A., & Butterworth, D., S. (2009). A proposed management procedure for the toothfish (Dissostichus eleginoides) resource in the Prince Edward Islands vicinity. *CCAMLR Science*, *16*, 33–69.

Cheng, C.-H. C., & Detrich, H. W. (2007). Molecular ecophysiology of Antarctic notothenioid fishes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *362*(1488), 2215–2232.

Croxall, J. P., Trathan, P. N., & Murphy, E. J. (2002). Environmental Change and Antarctic Seabird Populations. *Science*, *297*(5586), 1510–1514.

Eastman, J. T. (1993). *Antarctic fish biology: evolution in a unique environment*. San Diego: Academic Press.

Fenaughty, J. M., Stevens, D. W., & Hanchet, S. M. (2003). Diet of the Antarctic toothfish (Dissostichus mawsoni) from the Ross Sea, Antarctica (subarea 88.1). *CCAMLR Science*, *10*, 113–123.

Field, M. (2012, March 18). McMurdo Sound's toothfish population at risk. *Stuff.co.nz*. New Zealand.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., … Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science*, *319*(5865), 948–952.

Hanchet, S. M., Rickard, G. J., Fenaughty, J. M., Dunn, A., & Williams, M. J. (2008). A hypothetical life cycle for Antarctic toothfish (Dissostichus mawsoni) in the Ross Sea region. *CCAMLR Science*, *15*, 35–53.

Hini, D., Gendall, P., & Kearns, Z. (1995). The link between environmental attitudes and behaviour. *Marketing Bulletin*, *6*, 22.

Jacquet, J., Pauly, D., Ainley, D. G., Holt, S., Dayton, P., & Jackson, J. (2010). Seafood stewardship in crisis. *Nature*, *467*(7311), 28–9.

Kim, S. Z., Ainley, D. G., Pennycook, J., & Eastman, J. T. (2011). Short Note: Antarctic toothfish heads found along tide cracks of the McMurdo Ice Shelf. *Antarctic Science*, *23*(5), 469–470.

Kristiansen, E., & Zachariassen, K. E. (2005). The mechanism by which fish antifreeze proteins cause thermal hysteresis. *Cryobiology*, *51*(3), 262–280.

Levine, H. B. (1987). The Cultural Politics Of Maori Fishing: An Anthropological Perspective On The First Three Significant Waitangi Tribunal Hearings. *The Journal of the Polynesian Society*, *96*(4), 421–443.

Miller, C. L. (2010). *Implementing Sustainability□: The New Zealand Experience* (1st ed.). Hoboken: Taylor & Francis.

Ministry of Fisheries. (2009). *Fisheries 2030: New Zealanders maximising benefits from the use of fisheries within environmental limits*. Wellington, N.Z: Ministry of Fisheries.

Ministry of Social Development. (2009). *The social report,  te pūrongo oranga tangata: indicators of social well-being in New Zealand*. Wellington, New Zealand: Ministry of Social Policy.

Morton, J. (2012, October 11). Doco finds high-powered forum. *The New Zealand Herald*. Auckland, New Zealand.

Nicodemus-Johnson, J., Silic, S., Ghigliotti, L., Pisano, E., & Cheng, C.-H. C. (2011). Assembly of the antifreeze glycoprotein/trypsinogen-like protease genomic locus in the Antarctic toothfish Dissostichus mawsoni. *Genomics*, *98*(3), 194–201.

Österblom, H., & Sumaila, U. R. (2011). Toothfish crises, actor diversity and the emergence of compliance mechanisms in the Southern Ocean. *Global Environmental Change*, *21*(3), 972–982. doi:10.1016/j.gloenvcha.2011.04.013

Petrov, A. F., & Tatarnikov, V. A. (2011). Results of investigation of the diet of antarctic toothfish Dissostichus mawsoni (Nototheniidae) in the Lazarev Sea. *Journal of Ichthyology*, *51*(1), 131–135.

Prugh, L. R., Stoner, C. J., Epps, C. W., Bean, W. T., Ripple, W. J., Laliberte, A. S., & Brashares, J. S. (2009). The rise of the mesopredator. *Bioscience*, *59*(9), 779–791.

Smith, P. J., Gaffney, P. M., & Purves, M. (2001). Genetic markers for identification of Patagonian toothfish and Antarctic toothfish. *Journal of Fish Biology*, *58*(4), 1190–1194.

Stokstad, E. (2010). Behind the Eco-Label, a Debate Over Antarctic Toothfish. *Science*, *329*(5999), 1596–1597.

Trevett, C., & Bennett, A. (2012, September 8). `Hero for the Planet’ gives NZ message on oceans. *The New Zealand Herald*. Auckland, New Zealand.

Williams, N. (2007). Southern worries. *Current Biology*, *17*(22), R939–R940.