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Mercury concentrations of two toothfish and three of its prey species from the Pacific sector of the Antarctic

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Abstract: Muscle tissue samples were collected from Antarctic toothfish (*Dissostichus mawsoni* Norman) and Patagonian toothfish (*D. eleginoides* Smitt) in 1998 and from *D. mawsoni* and three of its prey species - Whitson's grenadier (*Macrourus whitsoni* (Regan)), ice fish (*Chionobathyscus dewitti* Andriashev & Neyelov), and blue antimora (*Antimora rostrata* (Günther)) - in 2006 to determine their mercury. Mercury levels were highly variable both within and between the five species studied but were positively correlated with fish length in four of the species. Once the factors length and year had been accounted for, the mercury levels in *D. eleginoides* were more than four times greater than in *D. mawsoni*. The low levels of mercury in *D. mawsoni* relative to its prey species and the four-fold difference in mercury concentrations between it and *D. eleginoides* were unexpected. Reasons for these different levels of bioaccumulation were explored including differences in diet, growth and longevity, and location. Differences in bioaccumulation between the two toothfish species could be explained partly through differences in their geographic distribution and differences in trophic position. However, the low levels of mercury in *D. mawsoni* relative to its prey species can only be explained by a lower rate of mercury assimilation and/or a higher rate of mercury elimination by *D. mawsoni*.

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Introduction

From a human health perspective there is a continuing need to monitor mercury levels in fish, particularly in species that are important commercially and whose characteristics and habitat are typical for accumulating mercury. In general, little work has been done on the levels of mercury in Antarctic fish species. However, an exception is Patagonian toothfish (*Dissostichus eleginoides* Smitt), where several studies have shown that this species has elevated mercury levels (Mendez *et al*. 2001, McArthur *et al*. 2003, Guynn & Peterson 2008).

Mendez *et al*. (2001) carried out a study on a small number of *D. eleginoides*. The eighteen samples had a mean mercury concentration of 0.40 mg kg^{-1} (range 0.12–0.73 mg kg^{-1}) and showed a significant correlation between mercury content and fish weight. McArthur *et al*. (2003) carried out a study on small (< 100 cm) *D. eleginoides* and one of its prey items, warty squid (*Moroteuthis ingens* (Smith)), from Macquarie Island. The mean mercury level for *D. eleginoides* was 0.33 mg kg^{-1} (range 0.12–0.59 mg kg^{-1}). Significant correlations were found between fish weight and mercury concentration, and fish length and mercury concentration. More recently, mercury levels were presented for *D. eleginoides* collected from three distinct stocks (Guynn & Peterson 2008). Comparisons were made between gender, length, weight, and area, with size differences or location being probable explanations for the geographic differences in mercury found. Mean mercury concentrations were 0.23 mg kg^{-1} for South Georgia, 0.80 mg kg^{-1} for Prince Edward Island, and 0.73 mg kg^{-1} for the Chilean EEZ.

With the development of the fishery for Antarctic toothfish (*Dissostichus mawsoni* Norman) in the Ross Sea (Hanchet *et al*. 2010), it has become important to determine whether the mercury concentrations in this species are within the permissible level of 0.5 mg kg^{-1} set by the New Zealand Food Safety Authority (NZFSA). Given the geographic variation in levels of *D. eleginoides* between different areas, it was also considered important to determine the mercury levels for this species in the north of the Ross Sea, where it is at the southernmost extreme of its range (Hanchet *et al*. 2010). Many papers involving mercury levels have also discussed bioaccumulation and trophic transfer of mercury up the marine food chain (e.g. Bargagli *et al*. 1998, McArthur *et al*. 2003, Piraino & Taylor 2009). We therefore decided to also determine mercury levels in the main prey species of toothfish. Muscle tissues were used as an indication of mercury concentration in all species although we acknowledge that it may vary at a different rate interspecifically in other tissues.

Within the Ross Sea region, the diet of *D. mawsoni* has been well studied. In the coastal waters around McMurdo Sound, adults feed on Antarctic silverfish (*Pleuragramma antarcticum* (Boulenger)) (Eastman 1985). On the continental

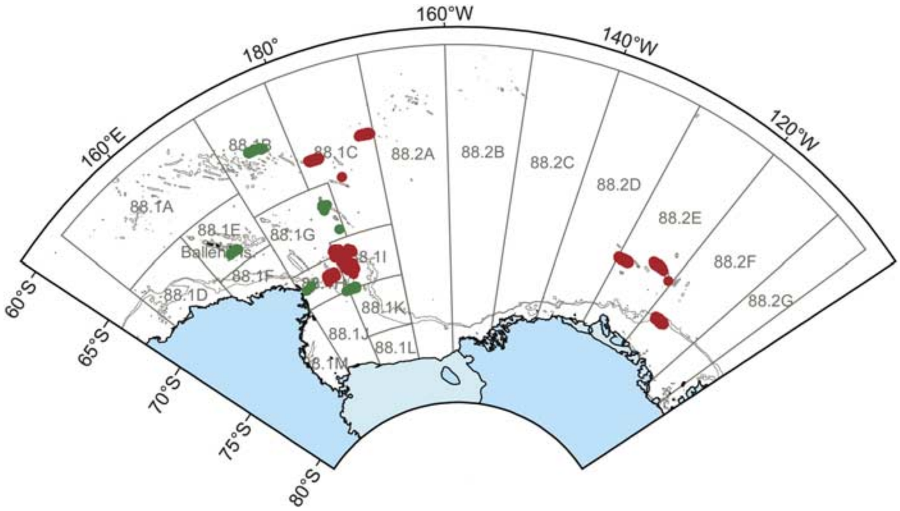

Fig. 1. Locations of mercury samples collected by year (red = 2006, green = 1998). Points jittered to show locations of multiple samples. CCAMLR management areas and depth contours at 1000 and 2000 m are also shown.

slope of the Ross Sea they feed mainly on De Witts ice fish (*Chionobathyscus dewitti* Andriashev & Neyelov) and Whitson's grenadier (*Macrourus whitsoni*), whilst on the northern seamounts and ridges they feed on *M. whitsoni* (Regan) and the blue antimora (*Antimora rostrata* (Günther)) (Fenaughty *et al*. 2003, Stevens 2004). In open oceanic waters adults feed on small squid (Yukhov 1971). Subadult *D. mawsoni* (50–100 cm TL) tend to prey mainly on various species of icefish, notothens, other small fish species, and glacial squid (*Psychroteuthis glacialis* Thiele) (Stevens 2006). The diet of *D. eleginoides* in the Ross Sea region has not been published, but elsewhere it has a mainly piscivorous diet with varying proportions of cephalopods and crustacea (Goldsworthy *et al*. 2002).

We were restricted to obtaining samples from the longline fishery, and so were unable to obtain samples of *P. antarcticum* or squid for analysis. We therefore selected *C. dewitti*, *M. whitsoni*, and *A. rostrata* as the three prey species to study. The five species examined have quite different distributions. *D. mawsoni*, *M. whitsoni*, and *C. dewitti* are generally found in higher latitudes south of the Antarctic Polar Front (Gon & Heemstra 1990). In contrast, Patagonian toothfish (*D. eleginoides*) is widespread throughout the Southern Ocean, typically extending north from the Antarctic Polar Front into sub-Antarctic waters of the Atlantic, Pacific and Indian oceans, whilst the blue antimora, (*Antimora rostrata*) is even more widespread extending north to the equator in abyssal depths (Gon & Heemstra 1990). All five species are circumpolar in distribution and are known to overlap in the areas immediately to the south and north of the Antarctic Polar Front, especially in the area to the north of the Ross Sea (Hanchet *et al*. 2010).

So the aims of the study were three-fold: i) to provide the first published data on the mercury level of *D. mawsoni*, ii) to provide estimates of mercury levels of *D. eleginoides* in the Ross Sea region for comparison with other areas, and iii) to investigate whether there was evidence of mercury bioaccumulation in toothfish related to their prey species.

Materials and methods

Sampling

During February and March 1998 muscle tissue samples for *D. eleginoides* and *D. mawsoni* were collected by New Zealand Ministry of Fisheries observers on a longline vessel from the north of Subarea 88.1 (Fig. 1).

Table I. Mean mercury levels (and range), mean length (and range), and proportion of males to females by species for samples collected in 1998 and 2006.

Species	Mercury (mg kg^{-1})		Length (cm)		Sex ratio
	No.	Mean (range)	No.	Mean (range)	
1998 data					
D. mawsoni	30	0.10 (0.04–0.33)	30	105.3 (64–152)	0.53
D. eleginoides	30	0.43 (0.15–0.97)	30	95.3 (51–134)	0.30
2006 data					
D. mawsoni	253	0.16 (0.02–0.70)	253	133.2 (60–194)	0.50
D. eleginoides	1	0.57	1	108	0.00
M. whitsoni	102	0.38 (0.01–1.10)	102	57.6 (40–88)	0.34
C. dewitti	72	0.20 (0.01–0.62)	59	39.0 (28–49)	0.15
A. rostrata	104	0.19 (0.04–0.68)	103	56.3 (28–71)	0.07

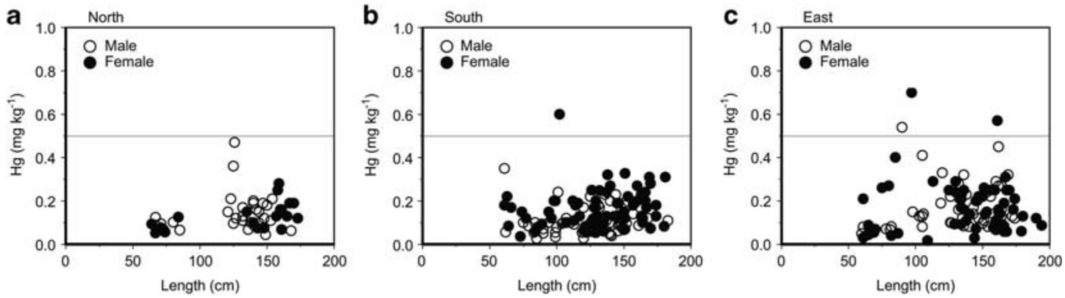

Fig. 2. Mercury (Hg) levels and total length for *D. mawsoni* sampled in 1998 and 2006.

During the 2006 season (December 2005–February 2006) additional muscle tissue samples from *D. eleginoides*, *D. mawsoni*, *C. dewitti*, *M. whitsoni*, and *A. rostrata* were collected by New Zealand Ministry of Fisheries observers from three longline vessels. There was some initial uncertainty regarding species identification of the ice-fish collected which were not always identified to species level. However, the results of a recent study indicate that the majority of ice-fish caught in the fishery are *C. dewitti* (Sutton *et al*. 2008). Muscle sampling protocols differed slightly between the toothfish and the prey species. For the two toothfish species, sampling was stratified by location, sex and length. For each of the prey species, samples from 25 large adults from each of two regions north and south of 70°S were requested. Samples comprised a "mini-fillet" of muscle tissue of *c*. 50 g, and were placed in a sealed bag labelled with fish and set number, and then stored frozen.

Samples were collected from three different broad geographic areas (Fig. 1). Samples from CCAMLR Small Scale Research Units (SSRUs) 881.H, 881.I, 881.J, and 881.K were collected from 720–1480 m depth on the continental slope of the Ross Sea. Samples from SSRUs 881.B, 881.C, and 881.G came from the northern seamounts and ridges, which are separated from the continental slope of the Ross Sea by relatively deep water. Samples from 88.2E and 88.2F were from an area of seamounts and banks to the east of the Ross Sea, but represent a similar ecological region to the northern group of SSRUs.

Analytical techniques

The 1998 and 2006 samples were analysed by Hill Laboratories, Hamilton, New Zealand in April 2004 and April-May 2007 respectively for total mercury. Approximately 0.5 g of each sample was weighed into a capped polypropylene digestion tube. Then, 2.5 ml of concentrated nitric acid (HNO_3) and 0.5 ml of concentrated hydrochloric acid (HCl) added to each digestion tube and the contents gently shaken. The samples were digested by placing the tubes on to a pre-heated block set at 100°C for 1 hr and then removed and cooled. The digested solutions were diluted to a specified volume with water, shaken well to ensure thorough mixing and filtered through a 5 μm filter into separate vials. Aliquots from the diluted digests were then analysed on a Perkin Elmer Sciex Elan Inductively Coupled Plasma–Mass Spectrometer (ICP-MS). This system consists of a variable speed peristaltic

Table II. Summary of mean mercury levels (and range) and mean length (and range) by species and area for all samples combined.

Species	Area	Mercury (mg kg^{-1}) No.	mean	range	Length (cm) No.	mean	range
D. mawsoni	north	49	0.14	0.04–0.47	49	129.3	64–173
	south	128	0.14	0.03–0.60	128	128.0	61–183
	east	106	0.17	0.02–0.70	106	133.5	60–194
D. eleginoides	north	30	0.45	0.16–0.97	30	96.4	51–134
	south	1	0.15	–	1	75.0	–
C. dewitti	south	49	0.14	0.01–0.61	36	35.9	28–46
	east	23	0.30	0.04–0.62	23	43.9	36–49
A. rostrata	north	38	0.24	0.10–0.68	38	53.8	34–71
	south	42	0.10	0.04–0.48	41	57.2	28–67
	east	24	0.25	0.13–0.37	24	58.7	50–68
M. whitsoni	north	30	0.42	0.01–1.10	30	52.0	40–64
	south	47	0.36	0.01–0.82	47	62.0	40–68
	east	25	0.38	0.16–0.69	25	56.0	40–73

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Table III. Summary of the analyses for each species where significant (df = degrees of freedom).

Species	Significant parameters	df	Reduction in residual deviance (%)	F	Probability
D. mawsoni	Length, year	2	9	13.6	< 0.001
D. eleginoides	Length, depth	2	42	10.1	< 0.001
D. mawsoni + *D. eleginoides*	Species, length, year	3	32	48.5	< 0.001
C. dewitti	Length, depth	5	58	13.6	< 0.001
A. rostrata	Length, area	4	62	39.1	< 0.001

pump, nebuliser, argon gas plasma (1500 W), vacuum chambers, quadrupole, and a combined pulse counting/analogue detector. Mercury was monitored using its Hg201 isotope(s), chosen for its abundance/sensitivity and corrected for known isobaric interferences. The instrument was calibrated against standards of known concentration and Lu175 internal standard correction was used to monitor, and correct for, instrument performance. Precision at the detection limit (DL) is by definition ± 67% for uncertainty of measurement (UoM) at the 95% confidence level (0.002 ± 0.0013) reducing to about ± 20% relative.

Statistical analyses

For each fish sample (labelled with set number and station number), the following data were obtained from the CCAMLR observer database: vessel name, SSRU, latitude and longitude, depth, date, length (down to the nearest cm), measurement method and sex. Because part of the tails of *M. whitsoni* are often missing, observers measure snout-vent length (SVL) for all fish and total length (TL) where the tails are intact. Total length was used for summarizing the data and for the statistical analysis. Where TL was not recorded an estimate of TL was obtained from SVL using the following equations: SVL = 0.3287 TL + 0.511 for males and SVL = 0.3917 TL - 1.9855 for females after Marriott *et al.* (2003). In addition, otoliths were collected from *D. mawsoni* for age determination.

A stepwise linear model was carried out to determine the best predictors of mercury concentration for each species using the R statistical package (R Development Core Team 2009). Preliminary analyses and the resulting diagnostic plots suggested that the residual errors from models of the mercury levels were lognormally distributed, and hence levels were analysed using the response variable $\log_e$ (mercury concentration). The variables offered to the model included sex, length, length as a function of sex, and where available, area, depth, year (to compare data from 1998 and 2006). Area comprised three groups of SSRUs: north (SSRUs 88.1A–G), south (SSRUs 88.1H–L), and east (SSRUs 88.2E–F). Linear, 2-degree and 3-degree polynomial transformations were also considered for the continuous data (i.e. length and depth) in evaluating each of the models. Although weight was recorded for each fish, these were not used as explanatory variables for the model. Recent research has shown that the condition of some *D. mawsoni* is much poorer in the north than in the south (Fenaughty *et al*. 2008) and there was some concern that the condition may affect the mercury levels. However, preliminary analysis showed that there was no correlation between mercury content and condition for *D. mawsoni*.

We also carried out an equivalent analysis where the two toothfish species were combined into a single model. The aim here was to determine if there was a significant difference in mercury concentration between the two species once other potentially confounding factors were allowed for in the model. We considered this analysis was justified because both species overlap in distribution in the northern area and have a similar maximum length and age (Gon & Heemstra 1990, Horn 2002).

The Akaike Information Criteria (AIC) was used to determine the significance of each variable, where residual sum of squares was penalized by twice the number of parameters times the residual mean square of the initial model (Akaike 1974). Terms were added in order of greatest reduction in AIC in a stepwise manner, until a final model was chosen from a sequence of steps that minimized the AIC statistic. Diagnostic plots were examined for each model run.

Otoliths from a total of 186 of the *D. mawsoni* were aged using the ageing methodology of Horn (2002). However, a preliminary analysis suggested that length performed

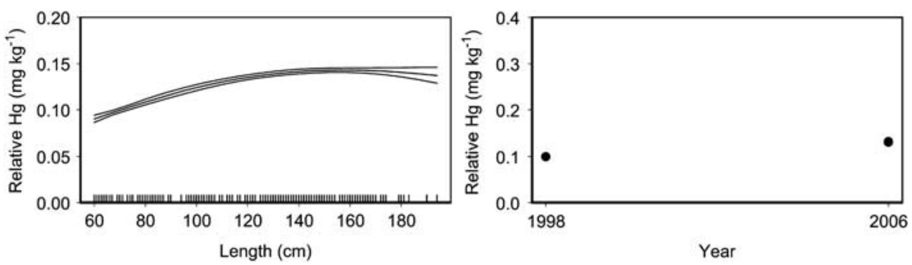

Fig. 3. Relative effects for the *D. mawsoni* model for length (left) and year (right) with 95% confidence limits.

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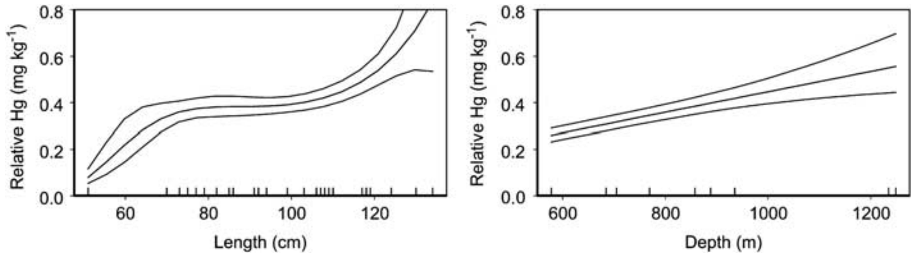

Fig. 4. Relative effects for the *D. eleginoides* model for length (left) and depth (right) with 95% confidence limits.

better than age as a predictor of mercury concentration and so age was excluded from further analysis.

Results

Mercury concentrations varied considerably both within and between the five species examined (Table I). Mercury levels for individual *D. mawsoni* are shown as an example in Fig. 2, but concentrations for all five species showed a similar level of variability. The mean values for *D. mawsoni* and *D. eleginoides* from the 1998 samples were 0.10 and 0.43 mg kg^{-1} respectively. For *D. eleginoides* 11 (37%) of the samples exceeded the New Zealand food safety level of 0.5 mg kg^{-1}, whilst all of the *D. mawsoni* samples were within the safety level. The mean estimate of *D. mawsoni* from the 2006 samples was 0.16 mg kg^{-1} (slightly higher than the 1998 samples), of which four (1.6%) of the samples exceeded the food safety level (Fig. 2). Only one *D. eleginoides* sample was collected in 2006 (Table I). Although mean levels of mercury in *D. mawsoni* differed between the two sampling periods, the mean (and range) of fish lengths also differed between the two periods.

The three prey species had intermediate mercury concentrations, with mean estimates for *M. whitsoni*, *C. dewitti*, and *A. rostrata* of 0.38, 0.20, and 0.19 respectively (Table I). There was a large range in mercury concentrations for all three species, and each species had some individuals exceeding the food safety level of 0.5 mg kg^{-1}. Mean mercury levels were similar between areas for *D. mawsoni* and *M. whitsoni*, but different for the other species (Table II). In general, mean mercury levels were lower for fish in the south.

Regression analyses

The model fits were reasonable, with model diagnostic plots showing no major departures from normality or strong evidence of heteroscedasticity. Details of the regression models are given in Table III.

The regression model for *D. mawsoni* contained two significant variables: length (as a linear term) and year ($P < 0.001$). The predicted effects of length and year are given in Fig. 3. The model suggested mercury concentration increased by about 50% across the length range examined. While including length as a function of sex resulted in a small improvement in the model fit, it was not significant. The 2- and 3-degree polynomial functions of length were not significant. Year had a small, but significant, effect with samples taken in 1998 being about 20% lower than samples collected in 2006.

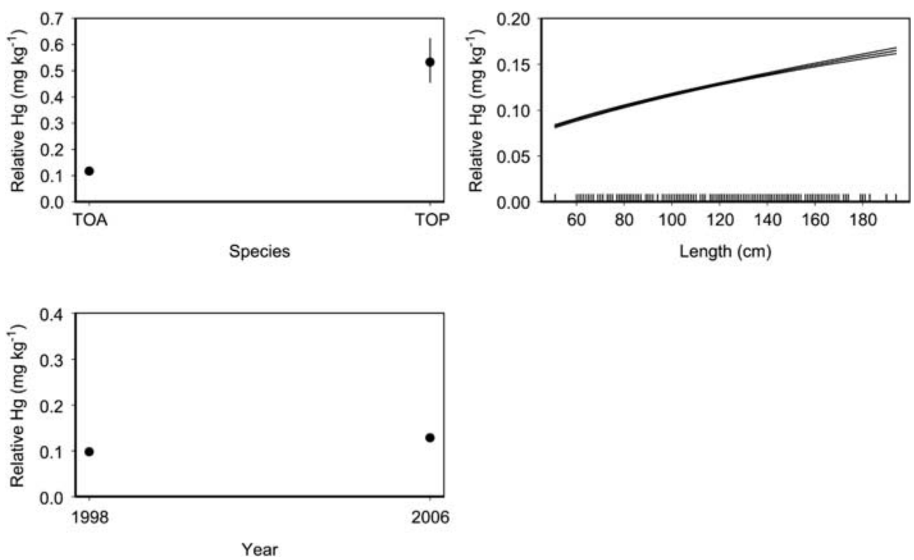

Fig. 5. Relative effects for the *D. mawsoni* and *D. eleginoides* combined model for species, length, and year with 95% confidence limits.

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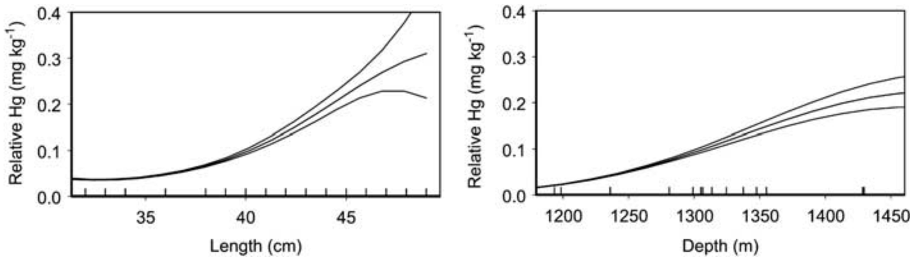

Fig. 6. Relative effects for the *C. dewitti* model for length (left) and depth (right) with 95% confidence limits.

The regression model for *D. eleginoides* contained two significant variables: length and depth ($P < 0.001$). Area was not included as a variable for model selection as no samples were collected from the east and only one sample from the south. The model suggested mercury concentration increased linearly with both length and depth (Fig. 4). Mercury levels increased by almost 200% across the length range examined. The inclusion of length as a function of sex resulted in a small improvement in the model fit, but was not significant. The 2- and 3-degree polynomial functions of length were not significant.

The combined toothfish regression model contained three significant variables: species, length, and year ($P < 0.001$). Mercury concentration was four times higher in *D. eleginoides*, and increased linearly with length in both species (Fig. 5). Mercury concentrations in samples taken in 1998 were about 20% lower than in samples collected in 2006. As with the single species models, the inclusion of length as a function of sex resulted in a small improvement in the model fit, but was not significant.

The *C. dewitti* regression model contained two significant variables: length (as a cubic term) and depth (as a quadratic term) ($P < 0.001$). Mercury concentration increased with length and depth of capture (Fig. 6). Length as a function of sex did not result in a significant improvement of model fit.

The *A. rostrata* regression model contained two significant variables, length (as a quadratic term) and area ($P < 0.001$). Mercury concentration generally increased with fish length (Fig. 7). Area had a significant effect with samples taken from the south having a much lower level of mercury concentration. Length as a function of sex did not result in a significant improvement of model fit.

The *M. whitsoni* regression model found no significant terms, suggesting no relationship with length, depth, area, or sex.

Discussion

Comparison with other studies on Antarctic fish

The results of the analyses suggest large intra- and inter-specific differences in mercury concentration. The highest levels were recorded for *D. eleginoides*, which were only collected from the area north of the Ross Sea. The mean value of 0.43 mg kg^{-1} in the current study was slightly higher than that of 0.33 mg kg^{-1} recorded for *D. eleginoides* from around Macquarie Island (McArthur *et al*. 2003). However, there were significant relationships between mercury concentration and fish length in both studies and when the two relationships were plotted the results are similar (Fig. 8). Two other studies have provided mean estimates of mercury concentration together with mean fish length or fish weight for *D. eleginoides*. Mendez *et al*. (2001) recorded mercury concentrations ranging from 0.12–1.16 $mgkg^{-1}$ from samples collected from the south-west Atlantic Ocean. They found a strong linear relationship between mercury concentration and fish weight and noted that a fish of about 10 kg would have a mean mercury level of about 0.40 mg kg^{-1}. Based on the length-weight relationship for *D. eleginoides* from South Georgia (SC-CCAMLR 2009), this weight equates to a fish length of about 100 cm. This mercury level is close to the predicted mean mercury level of 100 cm in the current study (Fig. 8). Guynn & Peterson (2008) compared mercury concentrations from off Chile, South Georgia and the Prince Edward Islands. The mean mercury level for South Georgia was considerably lower than the regression from the present study, whilst the mean levels for Chile and the Prince Edward Islands were considerably higher (Fig. 8). Guynn & Peterson (2008) also reported positive relationships between mercury concentration and fish length and fish weight. The present study is the first to have found a significant positive relationship of mercury level with depth for *D. eleginoides*.

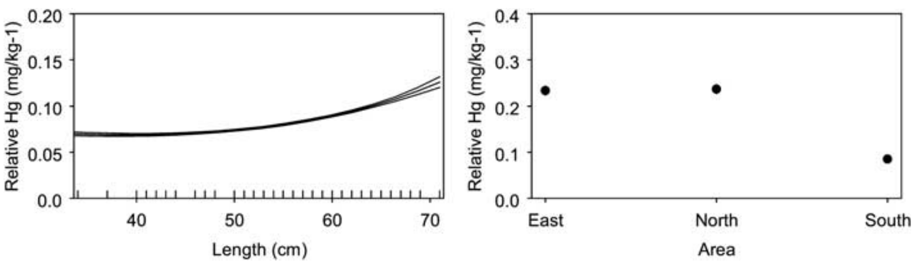

Fig. 7. Relative effects for the *A. rostrata* model for length (left) and area (right) with 95% confidence limits.

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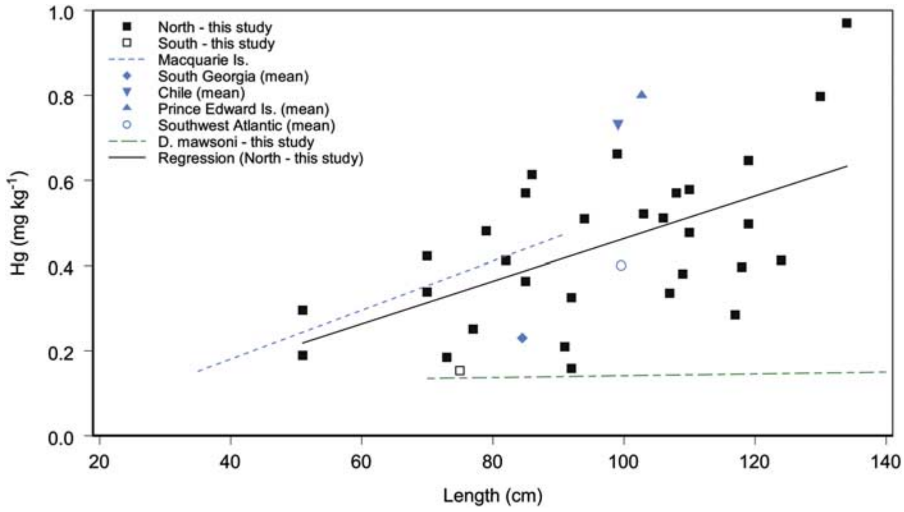

Fig. 8. Comparison of mercury levels versus fish length for *D. eleginoides* from various studies: North and South and solid regression line (this study); Macquarie Island (MacArthur *et al.* 2003); South Georgia, Chile, Prince Edward Islands (Guynn & Peterson 2008); SW Atlantic (Mendez *et al.* 2001).

Few data are available on mercury concentrations for other Antarctic fish species, and we could find no comparable published data on mercury levels for the other four species examined in the current study. Estimates of mercury concentrations from *A. rostrata* collected from the mid-Atlantic had a mean level of 1.1 mg kg^{-1} (range 0.6–1.5), but these were considered to be highly elevated because of their proximity to hydrothermal vents (Martins *et al.* 2006). As in our study, they found a significant relationship between mercury levels and fish length. In the western Ross Sea, Bargagli *et al.* (1998) reported mean mercury levels of 0.29, 0.47 and 0.83 mg kg^{-1} for three *Trematomus* species and of 0.34 mg kg^{-1} for the icefish *Chionodraco hamatus* (Lönnberg). These values are all somewhat higher than the mean values for *C. dewitti*, *A. rostrata*, and *D. mawsoni* from the Ross Sea slope in this study.

So what level of risk to human health is posed by the fishery?

The permissible level of mercury set by the New Zealand Food Safety Authority (NZFSA) is 0.5 mg kg^{-1}. A similar level is set for imports by Australia and Canada, whilst the United States and European Union set import levels at 1.0 mg kg^{-1} (Guynn & Peterson 2008). The Ross Sea toothfish fishery catches almost exclusively *D. mawsoni*, with catches of *D. eleginoides* amounting to only 1% of the total catch over the course of the fishery (Hanchet *et al.* 2010). Only four (1.6%) of the *D. mawsoni* samples exceeded the 0.5 mg kg^{-1} threshold and none exceeded the 1.0 threshold. For *D. eleginoides*, 11 (37%) of the samples exceeded the 0.5 threshold and none exceeded the 1.0 threshold. However, there is a strong relationship between length and mercury concentration for *D. eleginoides*. The mean length of *D. eleginoides* caught in the fishery is about 100 cm (Hanchet *et al.* 2010), which equates to a mean mercury level of about 0.4 mg kg^{-1} (Fig. 8). So levels of mercury recorded from the Ross Sea toothfish fishery as a whole are low and comparable to faster growing shorter-lived white fish such as cod and halibut (Guynn & Peterson 2008).

Bioaccumulation and trophic transfer

There was evidence for bioaccumulation of mercury with length in four out of the five fish studied, resulting in higher mercury levels in larger fish. Similar patterns have been observed in most other studies on mercury levels in fish (e.g. Bank *et al.* 2007, Guynn & Peterson 2008, Piraino & Taylor 2009). There was also some evidence for variation in mercury levels with location. In the regression models, area was only significant for *C. dewitti* and *A. rostrata*, with lower mean mercury concentration in samples from the continental slope of the Ross Sea (south) than in those from the seamounts to the north and the east. Geographic location has been found to be an important factor in mercury accumulation in other studies (Guynn & Peterson 2008, Piraino & Taylor 2009). As discussed previously, Guynn & Peterson (2008) found significantly lower mercury levels in *D. eleginoides* samples collected at South Georgia compared to samples collected further north in Chile and the Prince Edward Islands, and hypothesized that the Antarctic Polar Front may lend some protection from anthropogenic sources of mercury contamination. In the current study all samples were collected from well south of the Antarctic Polar Front.

The most surprising result in the current study was the low levels of mercury in *D. mawsoni* relative to its prey species and the four-fold difference in mercury concentrations between it and *D. eleginoides*. Bioaccumulation factors in the range 2–5 have been reported as typical between trophic levels (Evans *et al.* 2000, Trudel *et al.* 2000). Therefore, the mercury levels in a long-lived predator such as *D. mawsoni* would be expected to be at least twice that of its main prey species. Although bioaccumulation does appear to occur with

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D. mawsoni, as evidenced by the increase in mercury levels with fish length, the mean mercury levels in even the largest toothfish are still considerably lower than that of the mean levels in the three prey species studied here.

Clearly the bioaccumulation of mercury will depend on where fish live during various parts of their life cycle, how long they spend there, and what they feed on whilst there. Both toothfish species are known to be primarily piscivorous, feeding on a wide range of different fish species and/or cephalopods depending on their size and location (Yukhov 1971, Eastman 1985, Goldsworthy *et al*. 2002, Fenaughty *et al*. 2003, La Mesa *et al*. 2004). Within the Ross Sea region, sub-adult (60–100 cm TL) *D. mawsoni* are believed to reside mainly on the continental shelf and upper slope of the Ross Sea and adjacent coastline (Hanchet *et al*. 2008), where they feed mainly on small fish (78%) - including icefish (33%), *Trematomus* spp. (13%), and *M. whitsoni* (14%) - and glacial squid *P. glacialis* (21%) (Stevens 2006). Larger *D. mawsoni* ($>$ 100 cm TL) are found throughout the Ross Sea region down to at least 2000 m depth, but the main fishing grounds, and probably the main centres of toothfish abundance, are on the continental slope of the Ross Sea and some of the seamounts, banks, and ridges to the north of the Ross Sea (Hanchet *et al*. 2008, 2010). The diet of larger toothfish varies considerably throughout the Ross Sea region. In the coastal waters around McMurdo Sound, adults feed primarily on *P. antarcticum* (Eastman 1985). On the continental slope of the Ross Sea they feed mainly on *C. dewitti* and *M. whitsoni*, whilst on the northern features they feed on *M. whitsoni* and *A. rostrata* (Fenaughty *et al*. 2003, Stevens 2004). In open oceanic waters adults feed on small squid (Yukhov 1971). It is believed that once mature (at age 12–15 years) *D. mawsoni* undertake regular migrations to the northern grounds to spawn (Fenaughty 2006, Hanchet *et al*. 2008). Their residence time on these northern grounds is uncertain, but based on the pattern of tag-recaptures is likely to be less than two years, after which they move back to the Ross Sea slope and shelf, where productivity is higher and food is more plentiful, to regain condition before spawning again.

In contrast, the life history and feeding of *D. eleginoides* in the Ross Sea region is quite uncertain. In general, *D. eleginoides* are more abundant in sub-Antarctic waters to the north of 60°S (Gon & Heemstra 1990). Within the Ross Sea region, the catch of *D. eleginoides* has been almost entirely taken from SSRUs 88.1A and 88.1B and has comprised mainly adult fish ranging from 70–130 cm TL (Hanchet *et al*. 2010). The location of the smaller fish is uncertain but probably lies to the north of the Convention Area. At Macquarie Island the diet of *D. eleginoides* comprised 58% fish (mainly unidentified fish and *Bathylagus* sp.), 32% cephalopods (mainly squid), and 10% crustaceans (Goldsworthy *et al*. 2002). Elsewhere, their diet appears to be dominated mainly by a variety of fish species depending on location with varying proportions of cephalopods and crustaceans (Goldsworthy *et al*. 2002). Nothing has been published on its diet in the Ross Sea region, but out of four stomachs examined recently three contained fish remains - grenadiers and eel cods (Muraenolepidae) - and one contained squid remains (*P. glacialis*) (D. Stevens, NIWA, personal communication 2010).

Both toothfish species have similar growth rates and longevity in this region attaining a mean length of about 100 cm by about age 10 years and maximum ages in excess of 50 years (Horn 2002, Hanchet *et al*. 2010). Although the mean length of the toothfish differed between samples, the interspecific difference in mercury levels was still evident once fish length had been taken into account within the combined regression model. Given that they have similar growth rates the differences in mercury content are therefore unlikely to be due to age. The difference in mercury levels between the two toothfish species could be accounted for, at least in part, by their location and trophic status. *Dissostichus eleginoides* spends its life in the north of the Ross Sea region where mercury concentrations tend to be higher than in the south. In contrast, *D. mawsoni* spends its early life on the shelf and slope of the Ross Sea where mercury levels are lower. Although adult *D. mawsoni* are caught on the northern grounds, their short residence times there means that their mercury levels remain significantly lower than for *D. eleginoides* and are not significantly different from *D. mawsoni* caught in the south. The diet of the two species appears to be broadly similar with both species being primarily piscivorous but also feeding to a varying extent on cephalopods depending on length and location. Bank *et al*. (2007) found that slight difference in trophic position between two sympatric snapper species gave rise to substantial differences in mercury bioaccumulation. Until more data are available on the diet of *D. eleginoides* in the Ross Sea region it is difficult to rule out slight differences in trophic position, together with the effects of location, as being the main factors in the differences in the bioaccumulation rates of mercury between the two species.

The low mercury levels in *D. mawsoni* compared to their three main prey species is much harder to explain. Although there is some potential for regurgitation of particular prey items, and for misidentification of prey during feeding studies, it would appear that the prey species examined during the current study do form the bulk of the diet of *D. mawsoni.* The feeding study reported by Fenaughty *et al*. (2003) was based on an examination of almost 10 000 stomachs over two years and across a wide range of depths, whilst other unpublished studies have provided very similar results (Stevens 2004, 2006). We therefore conclude that *D. mawsoni* either has a low rate of mercury assimilation from its prey or a high rate of mercury elimination. As far as we are aware, these rates have not been estimated for toothfish, although experiments and modelling of elimination rates have been carried out for a wide range of other fish species (Trudel & Rasmussen 1997, Evans *et al.* 2000).

In addition to such experiments, further research is needed on the bioaccumulation and trophic transfer of

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mercury in *D. mawsoni* and *D. eleginoides* and should focus on the collection of more *D. eleginoides* mercury samples from the Ross Sea slope, analysis of diet of *D. eleginoides* from throughout the Ross Sea region, examination of mercury levels in other potential storage tissues such as the liver and kidneys, and analysis of the mercury content of other prey species including *P. antarcticum* and *P. glacialis*.

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