4 Results

The toxicological survey data for fin fish, crustaceans and molluscs have been analysed and reported separately. These results are set out in sections 4.1, 4.2 and 4.3. Section 4.4 sets out the dietary intake data derived from the 1995 National Nutrition Survey. Section 4.5 sets out estimated dietary intakes of metals and compares these with international standards for safe exposure.

Toxicological results for fin fish

Table 3 provides a summary of the mean metal concentrations found in fin fish. The mean concentrations are low when compared to the maximum permitted concentrations set out in Standard A12 of the Food Standards Code, however a total of 27 samples exceeded the standards for inorganic arsenic, mercury and selenium.

Selenium

While selenium levels were generally well below the maximum permitted concentration, selenium accounted for 74% (n=20) of those fin fish samples exceeding the various metal standards. The data were further analysed by zone and by species to identify if either factor contributed to the high levels of selenium found in some samples. No trends were evident by species.

Metal	N	Maximum permitted conc'n (mg/kg)	Mean concentration mg/kg (95% CI)		Samples exceeding the MPH %
Total arsenic	364	No standard	2.22	(1.66, 2.28)	-
Inorganic arsenic	53	1.0	0.22	(0.14, 0.31)	1.9
Cadmium	364	No standard	0.007	(0.003, 0.01)	-
Copper	364	10.0	0.24	(0.20, 0.28)	0.0
Mercury	364	1.0	0.15	(0.12, 0.17)	1.6
Lead	364	0.5	0.008	(0.004, 0.01)	0.0
Selenium	364	1.0	0.39	(0.36, 0.42)	5.5

Table 3 Mean metal concentrations (mg/kg) and 95% confidence interval of the mean, for fin fish

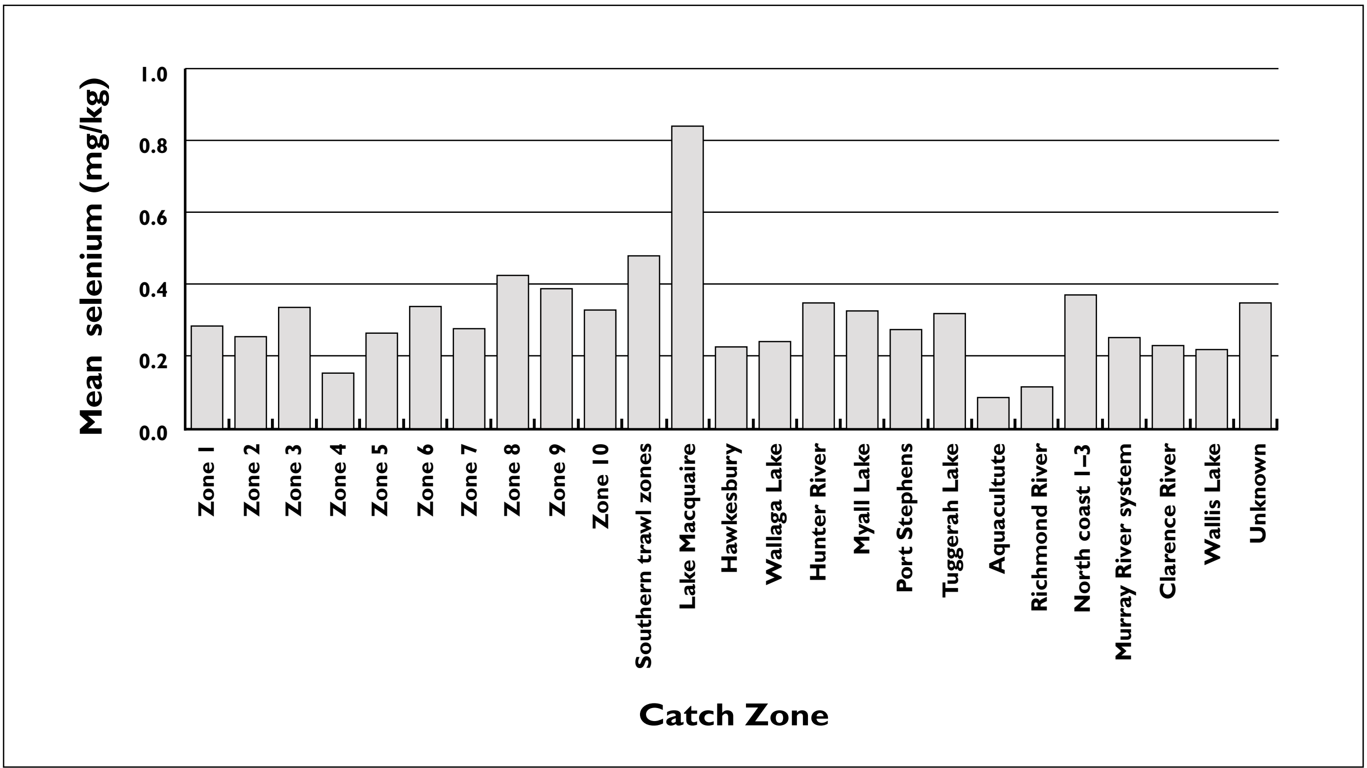

Figure 1 Mean selenium concentrations (mg/kg) in fin fish, by catch location

Figure 1 shows mean selenium concentration for each zone. There is a significant difference in the mean level of selenium in Lake Macquarie fin fish (0.87 mg/kg) compared with other locations—for example southern trawl zones 7 to 10 (0.49 mg/kg, $p = 0.003$) and zone 8 (0.43 mg/kg, $p < 0.000$).

Lake Macquarie

Of the 20 samples that exceeded the maximum permitted concentration for selenium, 17 were collected from Lake Macquarie, while the other three came from three different locations. A total of 45 Lake Macquarie fin fish were collected, giving a 37.8% failure rate for selenium. The mean selenium concentration was found to be 0.85 mg/kg (95% CI 0.70, 0.99). The highest level recorded was 1.91 mg/kg.

A variation in selenium concentrations by species might have been expected based on the results of previous surveys of Lake Macquarie fish. Thirteen species of Lake Macquarie fin fish were collected and a variation in concentration between the different species was found, as Figure 2 shows. The maximum permitted concentration was exceeded in three of five flathead, four of six whiting, four of four bream, three of four snapper, two of two yellowtail and one of one silver biddy. No mullet, shark, silver trevally, luderick, garfish, leatherjacket or tailor samples were found to exceed the maximum permitted concentration.

Mercury

The mean mercury concentration in fin fish was found to be 0.15 mg/kg. The mean concentration of mercury by species is depicted in Figure 3. All species with the exception of swordfish had a mean mercury concentration well below the maximum permitted concentration of 1.0 mg/kg.

Six of the 364 samples (1.6%) exceeded the maximum permitted concentration. Three of these were shark and three swordfish. The high levels of mercury in these species may be explained by their predatory feeding habits (biomagnification of mercury through the food chain) and not by the effects of geographical location. For this reason mercury concentrations for the different geographical locations are not reported.

Shark

Three of the 26 samples of shark samples (11.5%) exceeded the mercury maximum permitted concentration. The mean concentration of mercury in shark was found to be 0.48 mg/kg (95% CI 0.27, 0.69). The maximum found was 2.30 mg/kg.

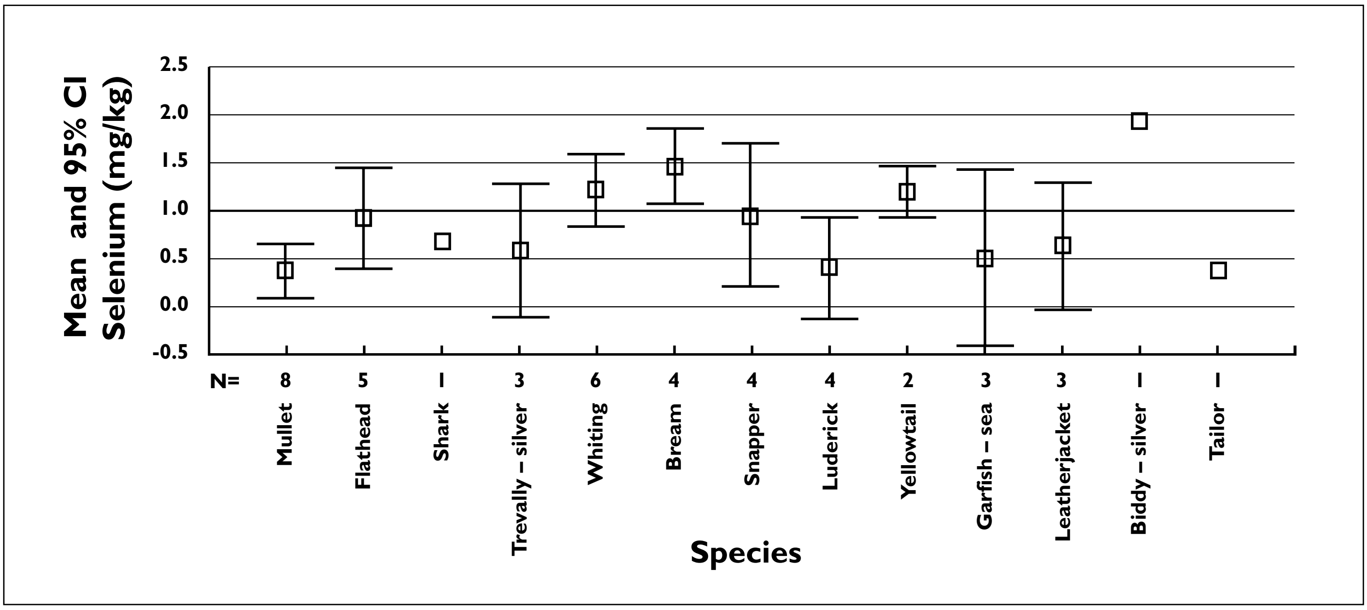

Figure 2 Mean selenium concentrations (mg/kg) and 95% confidence interval of the mean in Lake Macquarie fin fish, by species

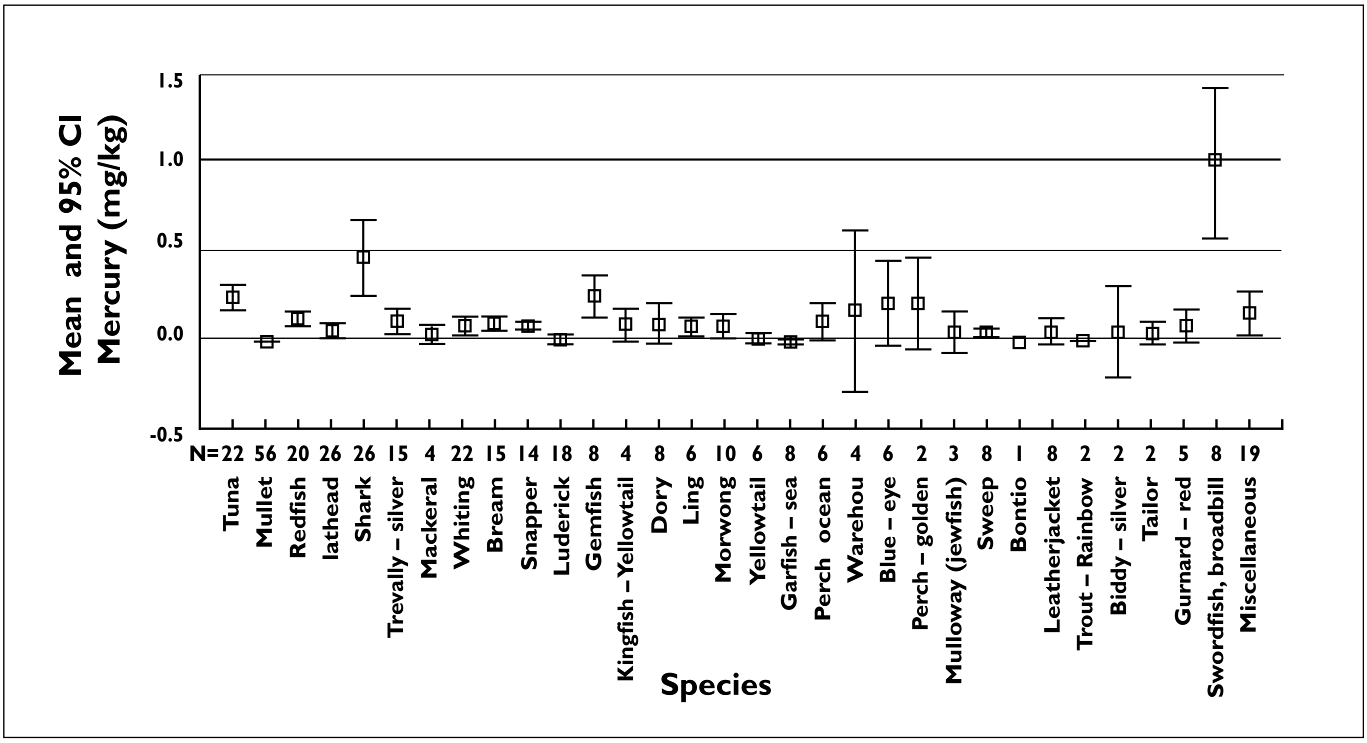

Figure 3 Mean mercury concentration (mg/kg) and 95% confidence interval of the mean in fin fish, by species

Swordfish

Three of the eight swordfish samples (37.5%) exceeded the mercury maximum permitted concentration. The mean concentration of mercury in swordfish was found to be 0.98 mg/kg (95% CI 0.63,1.32). The maximum found was 1.65 mg/kg.

Marlin

Three marlin samples were collected and included in the miscellaneous group. Two of these came from specimens 1.2 metres in length and weighing 75 kg and 78 kg. A mean mercury concentration of 0.57 mg/kg and a maximum of 0.95 mg/kg was recorded.

Inorganic arsenic

One of the 53 fin fish samples analysed for inorganic arsenic exceeded the maximum permitted concentration of 1.0 mg/kg. This sample (shark) had a total arsenic concentration of 58 mg/kg and an inorganic arsenic concentration of 1.97 mg/kg. The total arsenic concentration was the highest recorded for all 463 fish samples.

Copper

None of the 364 fin fish samples exceeded the maximum permitted concentration for copper.

Cadmium

There is no maximum permitted concentration for cadmium in fin fish.

Lead

None of the 364 fin fish samples exceeded the maximum permitted concentration for lead.

Toxicological results for crustaceans

Table 4 provides a summary of the mean metal concentrations found in crustaceans. With the exception of copper, the mean concentrations are low when compared to the maximum permitted concentrations set out in Standard A12 of the Food Standards Code. On an individual sample basis 36 of the 62 samples (58.1%) exceeded various maximum permitted concentrations. Of these, 29 samples exceeded the copper standard, six samples the selenium standard and one sample the inorganic arsenic standard.

Selenium

Six of 62 crustacean samples (9.7%) exceeded the selenium maximum permitted concentration of 1.0 mg/kg. Of these six, four were from Lake Macquarie and two from Tuggerah Lake. The highest level recorded was 1.53 mg/kg in a sample from Tuggerah Lake.

Figure 4 shows the mean selenium concentration in crustaceans for each zone. The high level of selenium in Lake Macquarie crustaceans (mean of 1.1 mg/kg) is not unexpected, and is significantly higher ($p < 0.05$) than the selenium levels found in all locations except the Hunter River. There is no significant difference between the mean level of selenium in Lake Macquarie crustaceans and Hunter River crustaceans (0.84 mg/kg, $p > 0.2$).

Mercury

None of the 62 crustacean samples exceeded the maximum permitted concentration for mercury.

Inorganic arsenic

One of the crustacean samples (a spanner crab) exceeded the maximum permitted concentration for inorganic arsenic with a level of 1.2 mg/kg. Total arsenic was found to be 29 mg/kg in this sample.

Metal	N	Maximum permitted conc'n (mg/kg)	Mean concentration mg/kg (95% CI)	Samples exceeding the MPH %
Total arsenic	62	No standard	7.04 (4.8, 9.3)	-
Inorganic arsenic	35	1.0	0.37 (0.29, 0.46)	2.9
Cadmium	62	No standard	1.01 (0.54, 1.48)	-
Copper	62	10.0	11.24 (9.4, 13.1)	46.8
Mercury	62	1.0	0.03 (0.02, 0.04)	0.0
Lead	62	0.5	0.01 (0.00, 0.03)	0.0
Selenium	62	1.0	0.47 (0.39, 0.56)	9.7

Table 4 Mean metal concentrations (mg/kg) and 95% confidence interval of the mean, for crustaceans

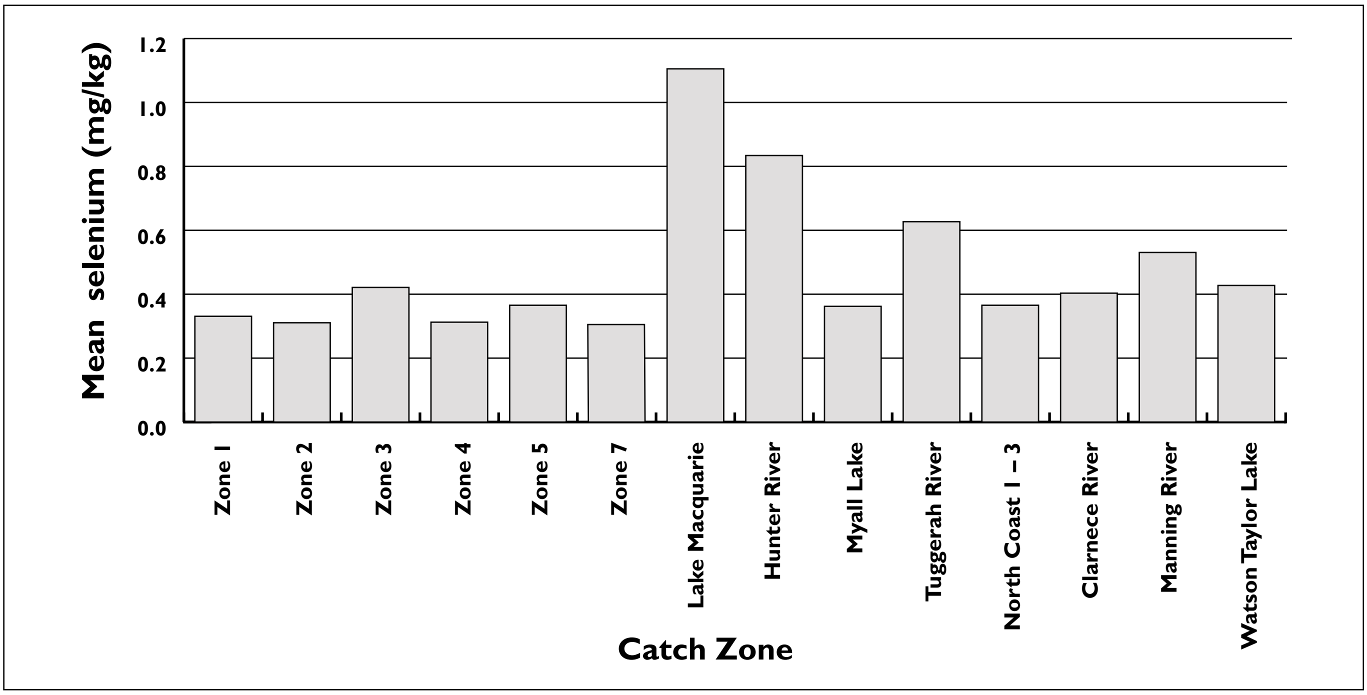

Figure 4 Mean selenium concentration (mg/kg) in crustaceans, by catch location

Copper

Twenty nine crustacean samples (46.8%) exceeded the copper standard. Of the prawn samples, 42.4% exceeded the standard, while 78.9% of the crab samples and 0% of the balmain bug samples exceeded the standard.

The mean copper concentration for all crustaceans was 11.2 mg/kg and the median concentration 9.4 mg/kg. While the mean is repo crustaceans is shown at Appendix 5.

Crab

The mean copper concentration in crab was found to be 16.0 mg/kg (95% CI 12.5, 19.5). Fifteen of the 19 crab samples exceeded the maximum permitted concentration for copper.

Figure 5 shows mean copper concentrations in crab for each catch location. The 95% confidence intervals are wide because crustaceans normally exhibit a range of concentrations. Small sample sizes have also contributed to this effect. The highest level of copper found was 37.0 mg/kg in a sample from zone 3.

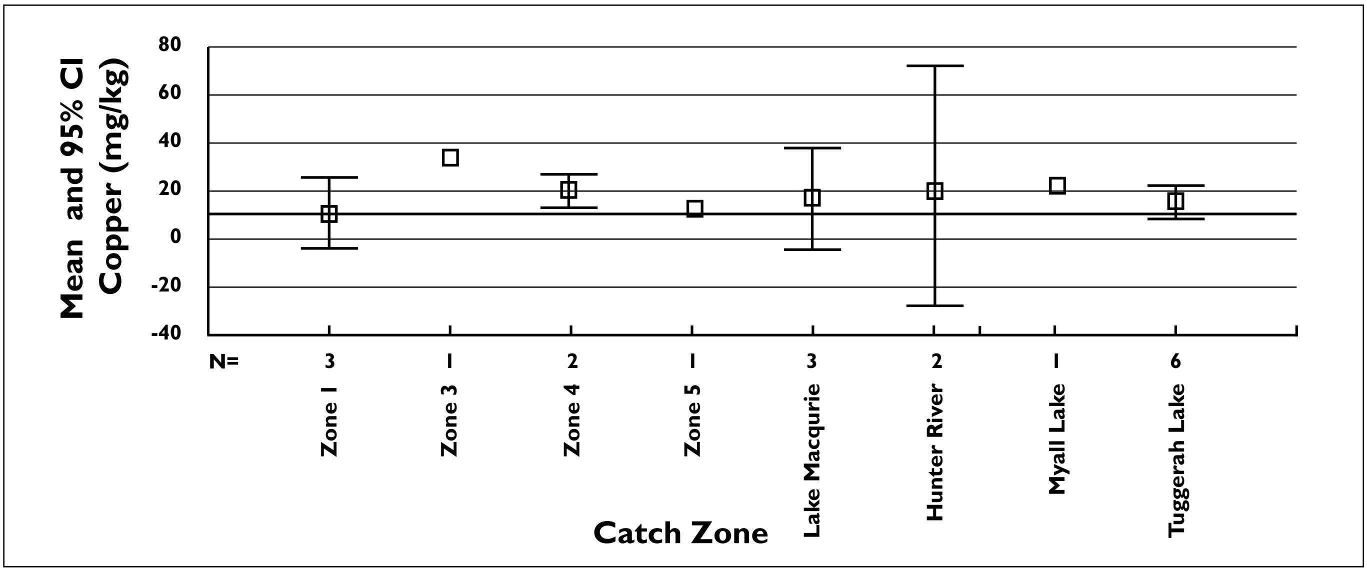

Figure 5 Mean copper concentrations (mg/kg) and 95% confidence interval of the mean in crab, by crab location

Prawns

For prawns the mean copper concentration was 10.0 mg/kg (95% CI 7.7, 12.4). Fourteen of the 33 prawn samples exceeded the maximum permitted concentration for copper. The mean concentration and 95% confidence interval of the mean for copper in prawns for each of the catch locations is shown in Figure 6. The highest concentration found was 30.0 mg/kg. This sample also came from zone 3, as did the sample with the second highest concentration (29 mg/kg). The third sample from zone 3 had a low copper concentration (8.5 mg/kg) which explains the very wide confidence interval for the zone.

Cadmium

There is no maximum permitted concentration for cadmium in crustaceans. Crustaceans exhibited a range of concentrations with the highest level recorded being 10.2 mg/kg in a crab sample from Zone 3. Sixteen percent of samples contained cadmium in concentrations greater than or equal to 2.0 mg/kg.

Figure 7 shows the mean levels of cadmium found in crustaceans from different zones. The 95% confidence intervals are wide, showing a range of copper concentrations. This is particularly evident for Zone 3.

Lead

None of the 62 crustacean samples exceeded the maximum permitted concentration for lead.

Toxicological results for molluscs

Table 5 shows the mean metal concentrations found in molluscs. No individual sample exceeded the maximum permitted concentrations set out in Standard A12 for any of the metals tested.

Dietary intakes of fish

Consumption data for fin fish, crustaceans and molluscs, derived by the Australia New Zealand Food Authority from the 1995 National Nutrition Survey, are set out in Tables 6 and 7. These data are for the raw, unprocessed commodity. Table 6 shows data for the population aged 19 or more years and Table 7 shows data for women aged between 16 and 44 years.

As Tables 6 and 7 show, only a small proportion of the survey population reported eating fish in the 24-hour survey period. Among all Australians aged 19 or more years only 11% reported eating marine fish in the 24-hour survey period, while less than 4% reported eating crustaceans and less than 2% molluscs. The intakes of diadromous fish (salmon, trout and barramundi only) are reported here, but are not included in later calculations of metal exposure. It is not known whether people consuming diadromous (only about 2% of the adult population in the survey period) do so exclusively, or whether they consume both diadromous fish and marine fish. It is unlikely however that any one individual will consume both on the same day.

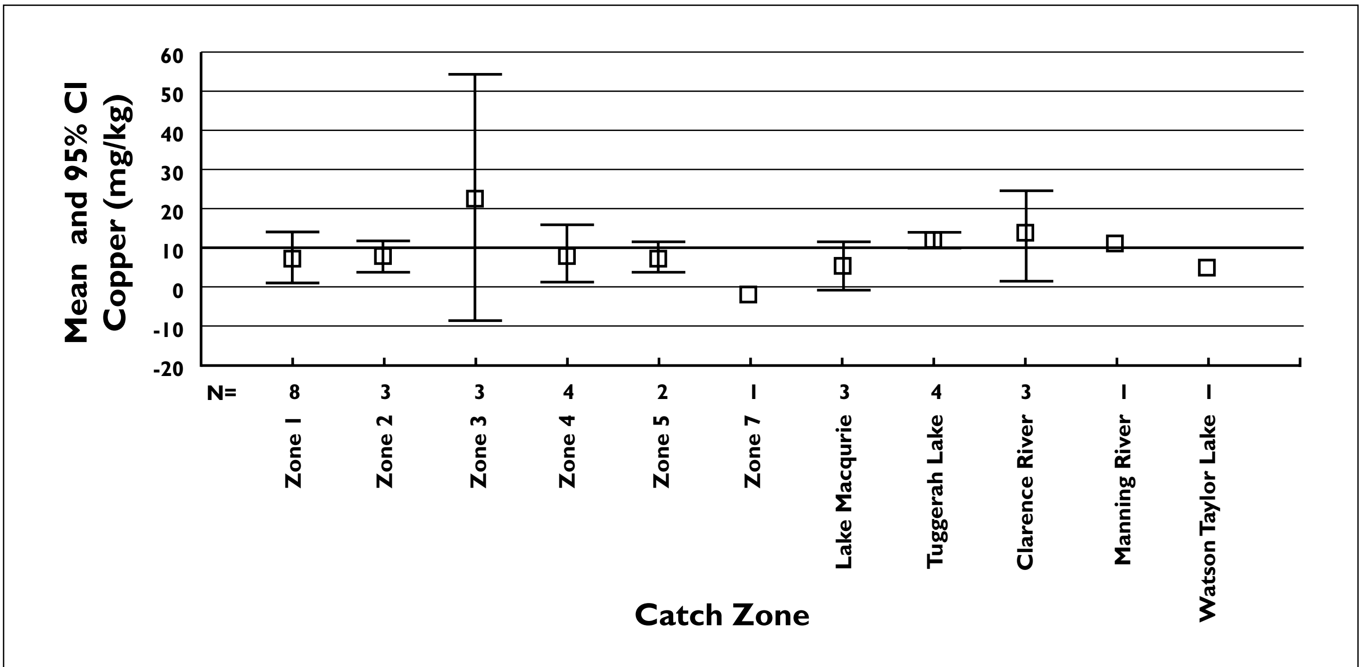

Figure 6 Mean copper concentration (mg/kg) and 95% confidence interval of the mean in prawns, by catch location

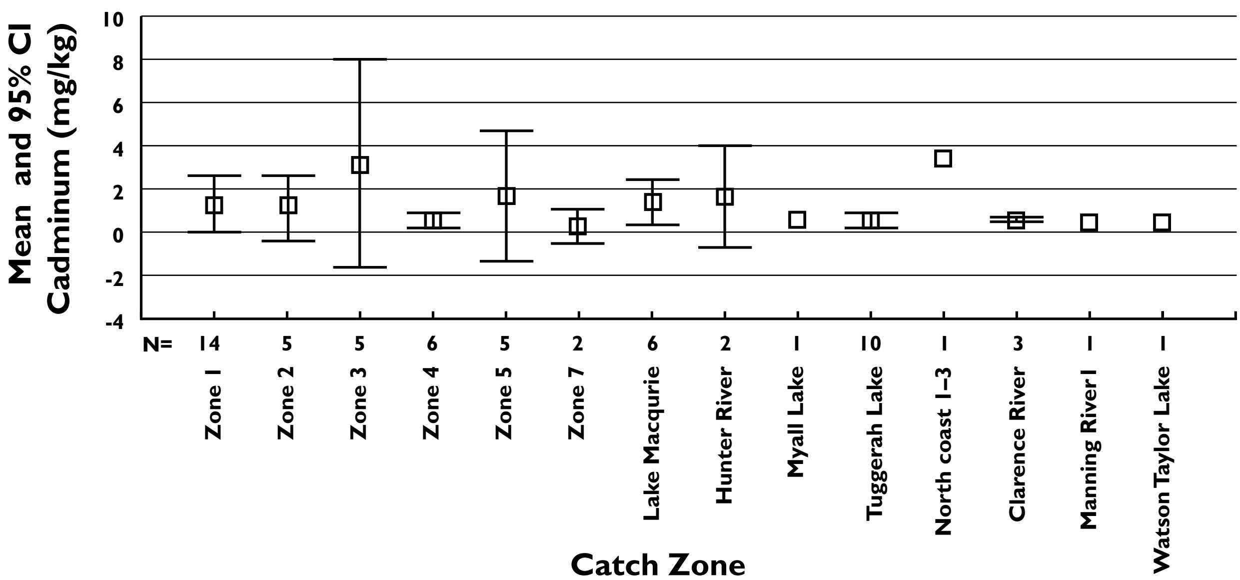

Figure 7 Mean cadmium concentration (mg/kg) and 95% confidence interval of the mean in crustaceans, by catch location

Metal	N	Maximum permitted conc'n (mg/kg)	Mean concentration mg/kg (95% CI)	Samples exceeding the MPH %
Total arsenic	37	No standard	5.59 (3.9, 7.3)	-
Inorganic arsenic	23	1.0	0.16 (0.11, 0.21)	0.0
Cadmium	37	2.0	0.17 (0.09, 0.24)	0.0
Copper	37	70.0	8.05 (4.6, 11.5)	0.0
Mercury	37	1.0	0.02 (0.01, 0.02)	0.0
Lead	37	0.5	0.02 (-0.003, 0.05)	0.0
Selenium	37	1.0	0.35 (0.28, 0.42)	0.0

Table 5 Mean metal concentrations (mg/kg) and 95% confidence interval of the mean, for molluscs

Commodity	All adults aged 19+ years	Proportion of adults consuming fish %	Adults aged 19+ years who consume fish	
	Mean intake (g/day)		Mean intake (g/day)	95th percentile intake (g/day)
Marine fish	11.6	11.0	106.1	327.2
Diadromous fish	2.4	2.2	106.9	339.1
Crustaceans	3.1	3.7	81.9	250.0
Molluscs	1.7	1.9	85.8	259.6

Source: Data provided by the Australia New Zealand Food Authority and derived from the National Nutrition Survey 1995 (Australian Bureau of Statistics customised unit record files). Baines J., Australia New Zealand Food Authority [personal communication] 1999.

Table 6 Fish consumption for adults aged 19 or more years, as raw commodity

Commodity	All women aged 16–44 years	Proportion of women consuming fish %	Women aged 16–44 years who consume fish	
	Mean intake (g/day)		Mean intake (g/day)	95th percentile intake (g/day)
Marine fish	8.8	10.0	88.0	271.9
Diadromous fish	1.9	2.0	94.1	225.9
Crustaceans	2.4	3.7	65.2	204.5
Molluscs	1.6	2.1	77.5	248.8

Source: Data provided by the Australia New Zealand Food Authority and derived from the National Nutrition Survey 1995 (Australian Bureau of Statistics customised unit record files). Baines J., Australia New Zealand Food Authority [personal communication] 1999.

Table 7 Fish consumption for women aged 16 to 44 years, as raw commodity

The mean intake of fish for the whole population is small because the proportion of the population who consume fish on any given occasion is small. The mean intake of the proportion who do consume fish is therefore much greater than the population mean. Likewise, the 95th percentile intake among people who consume fish is substantially higher than the population mean intake.

As there are toxicological concerns for some metals such as lead and mercury in relation to the developing foetus, fish consumption data for women of child-bearing age have also been included.

Table 7 shows intakes of fish by women aged 16 to 44 years. The proportion of women consuming fish is similar to the proportion of the whole adult population consuming fish. As expected however the intakes for women are less than the intakes for the whole population as women generally consume less food, by weight and by energy, than men. While absolute intake is less for women, their smaller body size means that they may still exceed safe levels of exposure which are calculated on a per kilogram of body weight basis.

Estimated dietary intakes of metals compared with internationally accepted safe exposures

For the population the average dietary exposure of a particular metal from consuming fish can be estimated by multiplying the average dietary intake of fish by the level of contaminant present in fish. The Australia New Zealand Food Authority (1998b) reports that the distribution of contaminants in food is often positively skewed and for this reason uses the median rather than the mean contaminant level in their dietary modelling.

In this study the mean contaminant level in fish is retained as skewed distributions were only particularly evident for copper and cadmium in crustaceans (see Appendix 5 for selected distribution curves). The mean dietary intake is generally used in calculations of population exposure, and this practice is followed in this report.

While consumption varies by State and Territory of residence (Australian Bureau of Statistics 1999), national dietary intake data are used in this report. As the mean intake is higher for NSW residents than the national mean, this will slightly underestimate consumption by NSW residents. The contaminant data and dietary intake data both refer to fish in its raw, unprocessed state.

Metal	Mean metal content of fin fish (mg/kg)	Mean daily consumption of fin fish, adult consumers only (g)[a]	Average dietary exposure to metals (µg/week)	Provisional tolerable weekly intake for a reference adult[b] (µg/week)
Mercury	0.15	106.1	111	350
Selenium	0.39	106.1	290	2 450[c]
Cadmium	0.007	106.1	5	490
Copper	0.24	106.1	178	245 x 103
Lead	0.008	106.1	6	1 750
Inorganic Arsenic	0.22	106.1	163	1 050

[a] This figure represents the mean intake of marine fish, as raw commodity. It does not include intake of diadromous fish as it is unlikely that the same individual would consume both marine and diadromous fish on the same day.

[b] A reference weight of 70 kg is used by both the United States Food and Drug Administration and the United States Environmental Protection Agency.

[c] JECFA has not recommended a provisional tolerable weekly intake for selenium. This figure represents the United States Environmental Protection Agency's reference dose

Table 8 Estimated dietary exposure of the fish-consuming adult population to metals from NSW fin fish, compared with internationally accepted safe exposure

As fish is a commodity consumed by only a small proportion of the population, the intakes of consumers only is a more important measure of dietary metal exposure than mean intake of the whole population. In Tables 8, 9, and 10 the intake data for consumers of NSW fin fish, crustaceans and molluscs respectively are used to estimate average dietary exposure to metals for adults who consume fish.

Fin fish

Adult population

As Table 8 shows the mean fin fish intake of 106 g per day, for those adults who consume fresh NSW fish, gives an exposure to metals that in all cases falls well within the JECFA safe intake levels.

Women of child-bearing age

For females aged 16 to 44 years who consume fish their mean intake of marine fish is 88.0 g per day. The average dietary exposure to mercury from consuming fin fish is estimated to be 92.4 mg per week, compared with the provisional tolerable weekly intake for mercury of 340 mg, for a 68 kg reference woman. This reference weight is the average Australian adult female weight (Australian Bureau of Statistics 1998). This estimation is based on the mean level of mercury found across all NSW fin fish and therefore presumes consumption of a variety of fish species. The implications for women consuming fish species high in mercury are discussed in section 5.3.3.

Crustaceans

Table 9 shows that the mean crustacean intake of adults who consume crustaceans provides an exposure to metals that falls well within the accepted standards for safe intake, except for cadmium.

The estimated intake of cadmium from crustaceans is 36% higher than the provisional tolerable weekly intake set by JECFA for a 70 kg person. If the median concentration of cadmium (0.29 mg/kg) in crustaceans were to be used instead of the mean (1.01 mg/kg), the estimated exposure from consuming crustaceans would be 166 mg per week.

Metal	Mean metal content of crustaceans (mg/kg)	Mean daily consumption of crustaceans, adult consumers only (g)[a]	Average dietary exposure to metals (µg/week)	Provisional tolerable weekly intake for a reference adult[b] (µg/week)
Mercury	0.03	81.9	17	350
Selenium	0.47	81.9	270	2 450[c]
Cadmium	1.01	81.9	579[d]	490
Copper	11.24	81.9	6.4×10^3	245×10^3
Lead	0.01	81.9	6	1 750
Inorganic Arsenic	0.37	81.9	212	1 050

[a] As raw commodity.

[b] A reference weight of 70 kg is used by both the United States Food and Drug Administration and the United States Environmental Protection Agency.

[c] JECFA has not recommended a provisional tolerable weekly intake for selenium. This figure is derived from the United States Environmental Protection Agency's reference dose.

[d] The estimated exposure to cadmium from consuming crustaceans is higher than the provisional tolerable weekly intake set by JECFA.

Table 9 Estimated dietary exposure of the fish-consuming adult population to metals from NSW crustaceans, compared with internationally accepted safe exposure

Molluscs

Table 10 shows that the mean intake of molluscs for adult consumers of molluscs gives an exposure to metals that in all cases falls well within the accepted standards for safe intake.

Metal	Mean metal content of molluscs (mg/kg)	Mean daily consumption of molluscs, adult consumers only (g)[a]	Average dietary exposure to metals (µg/week)	Provisional tolerable weekly intake for a reference adult[b] (µg/week)
Mercury	0.02	85.8	12	350
Selenium	0.35	85.8	210	2 450 [c]
Cadmium	0.17	85.8	102	490
Copper	8.05	85.8	4.8×10^3	245×10^3
Lead	0.02	85.8	12	1 750
Inorganic Arsenic	0.16	85.8	96	1 050

[a] As raw commodity.

[b] A reference weight of 70 kg is used by both the United States Food and Drug Administration and the United States Environmental Protection Agency.

[c] JECFA has not recommended a provisional tolerable weekly intake for selenium. This figure is derived from the United States Environmental Protection Agency's reference dose.

Table 10 Estimated dietary exposure of the fish-consuming adult population to metals from NSW molluscs, compared with internationally accepted safe exposure

5 Discussion

Regulatory impact

The maximum permitted concentrations for metals and contaminants set out in Standard A12, Metals and Contaminants in Food, of the Australian Food Standards Code are legally enforceable limits. Commodities found exceeding these limits may be seized to prevent their sale and the vendor may also be prosecuted. While the purpose of food standards is to protect public health and safety, failure of individual samples to meet the standards does not necessarily constitute a risk to public health. Standard A12 is currently under review and it is expected that a number of the standards for particular food commodities will be abolished in the near future.

Overall, 13.6% of samples failed Standard A12. The failure rate for fin fish was relatively low at 7.4%. However 63% of these failures were Lake Macquarie fin fish exceeding the selenium standard (a further 11% from other locations also exceeded the selenium standard). Lake Macquarie fin fish were oversampled in the toxicological survey, relative to their contribution to the NSW catch—just over 12% of all the fin fish samples collected came from Lake Macquarie, while Lake Macquarie contributes only approximately 2% to the total NSW fin fish catch (derived from data provided by Scribner and Kathuria 1996). The high levels of selenium in Lake Macquarie fish are well known and strategies continue to be developed to improve the quality of the water in the lake (NSW Health Department 1997).

In the meantime, banning the sale of fish from Lake Macquarie that exceed the selenium standard will not protect recreational fishers who consume their own catch. A more effective public health strategy is to issue local consumption advice. In an article on managing fishing in contaminated areas in Australia, Leadbitter (1992) argues for Australia to adopt an approach similar to the United States where consumption advice is issued to manage risks associated with recreational fishing in certain contaminated areas. The advice is based on risk assessment and can be species - or area-based.

Hunter Public Health Unit (1997) adopted such a strategy following release of the findings of the 1996 Lake Macquarie study. This is not however a common practice in NSW and further consideration of the merits of issuing species- or area-based consumption advice is warranted. The public health implications for recreational fishers and other potentially high consumers of Lake Macquarie fish are discussed in section 5.3.2.

The failure rate for mercury in fin fish was only 1.3%, and not unexpectedly the species involved were the large predatory species, in particular swordfish. The mean mercury concentration found in shark was lower than expected and lower than found in previous years, to the extent that the shark samples collected for the toxicological survey are representative of all NSW shark available for commercial sale. This may be a result of smaller species (as opposed to smaller specimens of larger species) reaching the market, since some of the larger species are now protected.

Of the crustacean samples, 58.1% failed Standard A12. More than 80% of these were failures for copper. While zone 3 provided the highest copper and cadmium concentrations in crustaceans, the significance of this result is unclear. The levels of metals found in crustaceans may be more a function of the physiology of crustaceans than environmental contamination. This is known to be the case for cadmium. The standard for cadmium in crustaceans was abolished in 1997, in part because a significant proportion of the catch could not meet the standard and because the concentrations of cadmium found were considered to be a result of physiological and hormonal factors (Australia New Zealand Authority 1995). The public health implications for consumers of crustaceans are discussed in section 5.3.1.

Benefits to health from eating fish

According to the United States Environmental Protection Agency (1996), fish may confer significant health benefits for both the general population and to those with certain medical conditions. Do the benefits of eating fish outweigh the risks? The United States Environmental Protection Agency (1996) chooses not to provide an opinion, but advises authorities to undertake an evaluation of the benefits and risks when determining risk-management options.

The benefits of fish consumption are well known. Fin fish in particular have a high protein content in relation to their fat content, and contain some potassium, calcium, iron, Vitamin A, thiamin, riboflavin and niacin (United States Environmental Protection Agency 1996).

Fish oil has been shown to be beneficial in decreasing coronary heart disease mortality, as evidenced by the low rates seen in Eskimo and Japanese populations, and the decreased incidence observed in prospective and intervention studies (United States Environmental Protection Agency 1996). The components of fish oil considered to be beneficial in this context are the omega-3 fatty acids eicosapentaenoic acid 20:5(n-3) and docosahexaenoic acid 22:6(n-3), which are essential in human nutrition (Nichols et al 1998a). Canola oil is the other important source of these long-chain polyunsaturated fatty acids in the Australian diet (Nichols et al 1998a).

There is a body of evidence suggesting that omega-3 fatty acids may also be useful in treating conditions such as rheumatoid arthritis because of their anti-inflammatory effects (Nichols 1998b, United States Environmental Protection Agency 1996). They may also be of benefit in modulating the immune response in severely injured patients (Myrvik 1994).

An evaluation of the risks is not so readily achieved. This study provides only very preliminary data on potential health risks for the population who consume fish caught in NSW waters. It serves however to highlight some areas of potential concern that may need to be investigated further. The identified concerns relate to the consumption of predatory species containing high levels of mercury and to the high consumption of fish taken from contaminated waterways.

Risks to public health

For the average fish consumer

While fish is not a staple food in the Australian diet it can provide a significant proportion of dietary metal contaminants. Fin fish is the major source of dietary exposure to mercury, crustaceans are one the major sources of dietary exposure to cadmium, and fish in general is a major source of dietary exposure to arsenic.

Mercury

The Australia New Zealand Food Authority (1999a) estimates that as much as 73% of the mercury in the diet of the Australian population could come from non-predatory marine fish. This rises to almost 90% if predatory marine fish are consumed. Other foods contribute very small amounts of mercury. Therefore exposure levels for the adult fish-consuming population, as shown in Table 8, are well within safe limits. Some caution in interpreting these results is necessary however as exposure has been calculated using the mean mercury concentration found in a wide variety of fin fish. Mercury levels vary according to species, and exposure levels may not be safe if intake is restricted to species with higher mercury levels. This point is explored further in sections 5.3.2 and 5.3.3. As Tables 9 and 10 show, dietary exposure to mercury from consuming crustaceans and molluscs is minor.

Selenium

For people consuming a variety of fin fish, dietary selenium exposure is well within safe limits as Table 8 shows.

Arsenic

Arsenic exposure is not considered to be of concern as arsenic is almost always found in the organic form (as arsenobetaine) in fish, rather than the more toxic inorganic form. A regression analysis shows that inorganic arsenic accounts for only 2% of total arsenic in the samples analysed for both (see Appendix 6). Exposure to inorganic arsenic from consuming fin fish, crustaceans and molluscs, as Tables 8, 9, and 10 show, is minor.

Cadmium

The exposure of the consumer of crustaceans to metals is shown in Table 9. The exposure to cadmium is higher than expected and appears to exceed the provisional tolerable weekly intake set by JECFA. This apparent exposure may not however be a true reflection of actual exposure as:

- the mean intake for consumers may not reflect a consistent daily intake of this magnitude. It is more likely that individuals who consume crustaceans consume them sporadically. The United States Food and Drug Administration (1993) reports that, for the United States population at least, the mean daily intake of crustaceans by consumers of crustaceans, calculated over a 14 day period, is only 9 g, and 19 g at the 90th percentile of intake.
- the distribution of cadmium in crustaceans is highly skewed. The median concentration is 0.29 mg/kg, compared with the mean of 1.01 mg/kg. The median concentration in this instance is a more appropriate measure of likely exposure. Therefore the exposure to cadmium calculated in Table 9 errs on the side of caution as using the median cadmium concentration instead of the mean would decrease estimated exposure by more than three-fold.

In determining exposure to cadmium other dietary sources of cadmium need to be taken into account as some foods are significant contributors of cadmium – potatoes contribute 39% and white bread 11% to the total cadmium intake of the average Australian adult (Australia New Zealand Food Authority 1996).

Taking these other sources into account gives a suggested maximum weekly intake of about 375g of crustaceans containing a mean of 1 mg/kg cadmium or about 1.3 kg per week if the median cadmium concentration of 0.29 mg/kg is used. The exposure to cadmium for the average consumer of crustaceans is well within acceptable limits if the median level is used to calculate exposure.

Copper

Dietary exposure to copper from the consumption of fin fish, crustaceans and molluscs is low, as Tables 8, 9 and 10 show. There is a very small exposure to copper from consuming crustaceans although almost 47% of crustacean samples exceeded the standard for copper. While crustaceans are a rich source of copper, they are consumed in small quantities and so make a minor contribution to the total dietary intake of copper.

These results indicate that the standard for copper in crustaceans may be too conservative. The Australia New Zealand Food Authority has recently reviewed the toxicological and exposure data for copper. The Authority is considering abolishing the standard for copper in fish and replacing it with voluntary guideline levels to be known as generally expected levels (Australia New Zealand Food Authority 1999b). Copper levels in NSW fish generally fall within these proposed guideline levels (see Appendix 7).

Lead

Dietary exposure to lead from the consumption of fin fish, crustaceans and molluscs is extremely small. This report has only considered the dietary intakes of adults and not of children, although given the levels of lead present in fish it is unlikely that fish will make a significant contribution to the exposure of children to lead.

For high consumers

The Working Group on Mercury in Fish (1980) collected fish consumption data from people expected to be high consumers of fish. They found a predominance of people on a diet, people associated with the fishing industry and people from non-Australian backgrounds among the highest consumers of fish. Those associated with the fishing industry were reported to consume on average 1 kg of fish per week. A number of respondents from non-Australian backgrounds were also associated with the fishing industry, so it is not clear whether country of birth or occupation best explains high consumption patterns. The surveys were conducted in 1976–77 and no further studies of these particular groups or others who may also be high consumers appear to have since taken place. Further work on the identity of high consumers and on their dietary habits may be warranted.

This section briefly discusses the implications for the hypothetical high consumer of fish containing elevated levels of mercury and selenium.

Mercury

The NSW swordfish catch has increased substantially over the last two decades. In 1978 swordfish was reported as being a rarely caught fish and a luxury food item (NSW Health Commission 1978). In 1998 almost 206 000 kg of swordfish was sold through the Sydney Fish Markets alone (Gordon S., Master Fish Merchants' Association [personal communication] 1999). The unprecedented availability and affordability of swordfish may be a cause of some concern if this species is consumed in large quantities, or in preference to other fish species. The mercury content of this fish is relatively high, and higher than in any other species including shark which has historically been the species of concern.

Adding to this concern is the potential for swordfish to be the subject of a marketing campaign on the basis of its beneficial polyunsaturated fatty acid content. A recent CSIRO study of the oil content of Australian fish (Nichols et al 1998a) reported that swordfish had substantially higher levels of omega-3 fatty acids than any other fish analysed—1059 mg/100 g, compared with the mean for fin fish of 210 mg/100 g, and for beef, chicken and lamb of 22, 19 and 18 mgs/100 g respectively (Johnson 1998). The media have already reported that swordfish 'was found to be the single richest natural source of beneficial omega-3 oils, with almost double the content of every other fish' (Rogers 1998, p.16).

The funding body for the fish oil study, the Fish Research and Development Corporation (1998), has now initiated a feasibility study into a five to ten year marketing strategy on the health benefits of consuming fish. While the nutritional benefits of consuming fish are unquestioned, care will need to be exercised if a campaign promoting swordfish as a superior source of omega-3 fatty acids is planned. Information on the need to consume a variety of species of fish should accompany any such campaign. Specific consumption advice may also be necessary.

The provisional tolerable weekly intake set by JECFA for mercury is 5 mg/kg body weight. In the worst case scenario where swordfish is the only fish consumed, a 70 kg reference adult would reach the provisional tolerable weekly intake with a weekly intake of 318 g of swordfish (assuming a mean mercury concentration of 0.98 mg/kg and assuming predatory marine fish provide 89% of the mercury found in the total diet). It should be noted that the provisional tolerable weekly intake includes a safety factor of one order of magnitude.

The 95th percentile intake of marine fish for Australian adults is 327 g per day. It is highly unlikely that these high consumers will consume a fish meal every day, however less frequent intakes of this size could still pose potential health risks. For this reason fish consumers should be advised to consume a variety of fish species.

Fish caught in contaminated waterways

The United States Environmental Protection Agency (1997) has set monthly consumption limits for chronic systemic endpoints for 25 high priority chemical contaminants, including a number of metals. Where the concentration of selenium in fish is 0.9 mg/kg (as the mean for Lake Macquarie fin fish was found to be), the Agency advises that no more than 30 large (340 g) servings of fish per month should be consumed by a reference adult of 70 kg, equivalent to 2.5 kg of fish per week.

This presumes no other sources of selenium in the diet. As the margin between the physiological requirement and the level causing toxic effects is small, other sources do need to be considered. The Australia New Zealand Food Authority (1999a) estimates that the average Australian has a dietary intake of 506 mg of selenium per week from foods other than marine fish. Therefore the consumption limit for fish containing selenium at the levels found in Lake Macquarie is reduced to 2 kg per week – still a very large amount. While unlikely, it is possible that local recreational fishers or other high consumers may consume Lake Macquarie fish in greater quantities than this. Consumption advice, discussed in section 5.1, could be of benefit to this particular group.

These calculations indicate that the Australian maximum permitted concentration for selenium is too conservative and serves only to potentially remove from sale fish that are considered safe to eat in normal quantities. The Australia New Zealand Food Authority has recently reviewed the toxicological and exposure data for selenium and is considering abolishing the standard for selenium in fish. In its place the Authority may set voluntary guideline levels known as generally expected levels (Australia New Zealand Food Authority 1999b). The levels of selenium in NSW fish generally fall within these proposed guideline levels (see Appendix 7).

For women of child-bearing age

The United States Food and Drug Administration (1994) recommends that pregnant women and women of child-bearing age who may become pregnant should not consume shark or swordfish more than once per month to protect the developing foetus from any adverse effects of methyl mercury exposure. z

The United States Environmental Protection Agency (1997) reference dose for mercury of 0.1 mg/kg body weight/day has been estimated from available developmental toxicity data and is considerably less than the safe exposure level set by JECFA (5 mg/kg body weight/week). This seven-fold difference in estimated safe exposure levels has significant implications for consumption advice directed to women of child-bearing age. If this reference dose is applied to the example given in section 5.3.2, then swordfish should be consumed only six times per year by women who may become pregnant. Interestingly, the Minnesota Department of Health advises pregnant women not to eat shark or swordfish at all and to limit their intake of canned tuna to one meal per week (Australia New Zealand Food Authority 1999a).

It is beyond the scope of this study to determine whether this very conservative reference dose should be adopted as a guide or standard for the general population. Also, the United States Environmental Protection Agency's consumption advice is calculated on the basis of meal size. Advice that relates to meal size is likely to be confusing to many consumers and so it may be more appropriate to consider adopting the advice offered by the United States Food and Drug Administration, at least until the issue of developmental toxicity is further clarified.

The in utero effects of mercury at levels of maternal exposure lower than those recorded in the three large scale poisonings are still the subject of research, evaluation and intense debate. New evidence, apparently contradicting the United States Environmental Protection Agency's assessment, has recently been published.

A large, long term study in the Seychelles reported finding no adverse neurological effects in infants, even though their mothers ate on average 12 fish meals each week (Davidson et al 1998). A total of 771 cohort mother-child pairs were followed until the children were aged 66 months. Prenatal exposure to methyl mercury reportedly had no impact on developmental outcomes in the children under study. Unexpectedly, postnatal exposure to mercury was associated with enhanced performance in some of the neurodevelopment domains. The authors suggested that high levels of fish consumption may be beneficial to neurological development, perhaps because of omega-3 fatty acids or other constituents and irrespective of mercury contamination.

In a critique of the Seychelles study, Mahaffey (1998) warns against generalising the results to other populations as the mercury concentration in the fish consumed in the Seychelles is low, ranging from 0.05 to 0.2 parts per million (0.05 to 0.2 mg/kg). These levels are low in comparison to the levels found in some contaminated US waterways. While these levels are similar to the levels found in NSW fish generally, they are low in comparison to the levels found in NSW predatory fish. Mahaffey (1998) also recommends that more sensitive tests of child development should be employed before drawing any firm conclusions from the Seychelles study.

Another study conducted in the Faroe Islands where the meat and blubber of pilot whales is regularly consumed found evidence of cognitive deficiencies in children aged seven years associated with prenatal exposure to mercury (Davidson et al 1998). Pilot whale meat was reported to have a mean mercury concentration of 1.6 mg/kg. Davidson et al (1998) suggested that these adverse findings might be explained by the presence of polychlorinated biphenyls and other contaminants in the blubber, and not by the methyl mercury present in the meat. This conclusion appears erroneous as the cognitive effects persisted after statistical control for the presence of polychlorinated biphenyls (Mahaffey 1998).

In summarising her critique of the Seychelles study, Mahaffey (1998) states that the fish consumption advice, issued by regulatory authorities in the United States recommending restrictions on fish intake for women of child-bearing age, should continue to be followed.

6 Conclusion

The aims of this study were twofold. The first aim was to determine the levels and patterns of metal contamination in NSW fish, and the second was to identify any potential public health risks that could be associated with current Australian dietary intakes of fish.

The levels of metals found in the NSW fish supply are generally low and well within acceptable limits. Overall, 13.6% of the samples exceeded one or more of the metal standards. Of the fin fish samples 7.4% exceeded one or more of the metal standards while 58% of the crustacean samples exceeded one or more of the metal standards (noting that there is no standard for cadmium in crustaceans and fin fish). No mollusc samples exceeded any of the standards.

For fin fish, the metals mercury and selenium were found at levels exceeding the standards. Swordfish was found to contain high levels of mercury and Lake Macquarie fish in general were found to contain high levels of selenium. For crustaceans most of the failures (80%) were for copper, although a small proportion were failures for selenium (17%) and inorganic arsenic (3%).

Where regulatory standards were exceeded, public health was not necessarily compromised for a complex range of reasons, including the dated nature of some of the current regulatory standards. This was evident for the selenium and copper standards. While copper levels were found to be high in crustaceans, the estimated dietary exposure was minor in comparison to internationally accepted safe limits. Similarly, a significant proportion of the samples from Lake Macquarie exceeded the selenium standard. An assessment of the data showed however that intakes of fish would have to be very high to pose any potential health risks. The Australia New Zealand Food Authority has recognised the need to review these standards.

Comparing the toxicological results from this study with available historical data indicates that metal levels in NSW fish available for human consumption have not changed to any extent over the last few decades, and may even have decreased in the case of mercury. An apparent decline in the mercury concentration of fish is probably more a function of the smaller size of predatory fish reaching the market than a decrease in environmental mercury levels. This study provides further evidence that the mercury found in NSW fish comes from naturally occurring sources in the environment and not from human activity.

Mercury, selenium and cadmium were identified as the metals of potential public health concern in this study. It should be noted that this report focuses on the NSW fish supply and the implications for consumers who consume fish from NSW waters. In 1994–95 NSW farmed or caught fish accounted for only 10% of sales in the restaurant and catering industry in NSW (Anon. 1997). Fish caught in other locations, whether interstate or overseas, may have different metal contaminant profiles than NSW fish.

Safe exposure levels of mercury vary between authorities, depending on the assessment criteria used. The potential for adverse developmental effects in children following in utero exposure to levels of mercury causing no apparent effect in the mother has resulted in a downward reassessment of safe exposure levels by at least one highly respected authority, the United States Environmental Protection Agency. The mercury levels found in NSW swordfish in particular, and to a lesser extent shark, may expose the developing foetus to unnecessary risks. The current and future potential growth in the swordfish market needs to be considered and consumption advice framed accordingly.

Contamination of Lake Macquarie fish with selenium is a potential problem if consumption of locally caught fish is high. The recreational or commercial fisher or other high consumer may be at risk if consuming very large quantities of locally caught fish, especially species such as bream and flathead that feed on other small fish and so contain higher levels of selenium than other species. The average consumer is not at any risk from consuming Lake Macquarie fish.

While there is no standard for cadmium in crustaceans, the data provided in this report suggest that even the average crustacean consumer exceeds internationally accepted safe intakes, without taking other sources of dietary cadmium into account. This may not be a reflection of actual exposure as cadmium levels found in crustaceans vary widely and show a highly skewed distribution, and consumers tend to eat crustaceans sporadically rather than daily. It is concluded that cadmium is probably not a metal of concern in relation to crustacean consumers. There are however inadequate data on the dietary habits of high consumers and this may be an area warranting further study.

In summary, the levels of metal contaminants found in the NSW fish supply are generally low and do not pose any health risks to the fish-consuming population, given current Australian dietary intakes of fish. Some sub-groups of the population may however need to receive advice about safe levels of consumption.