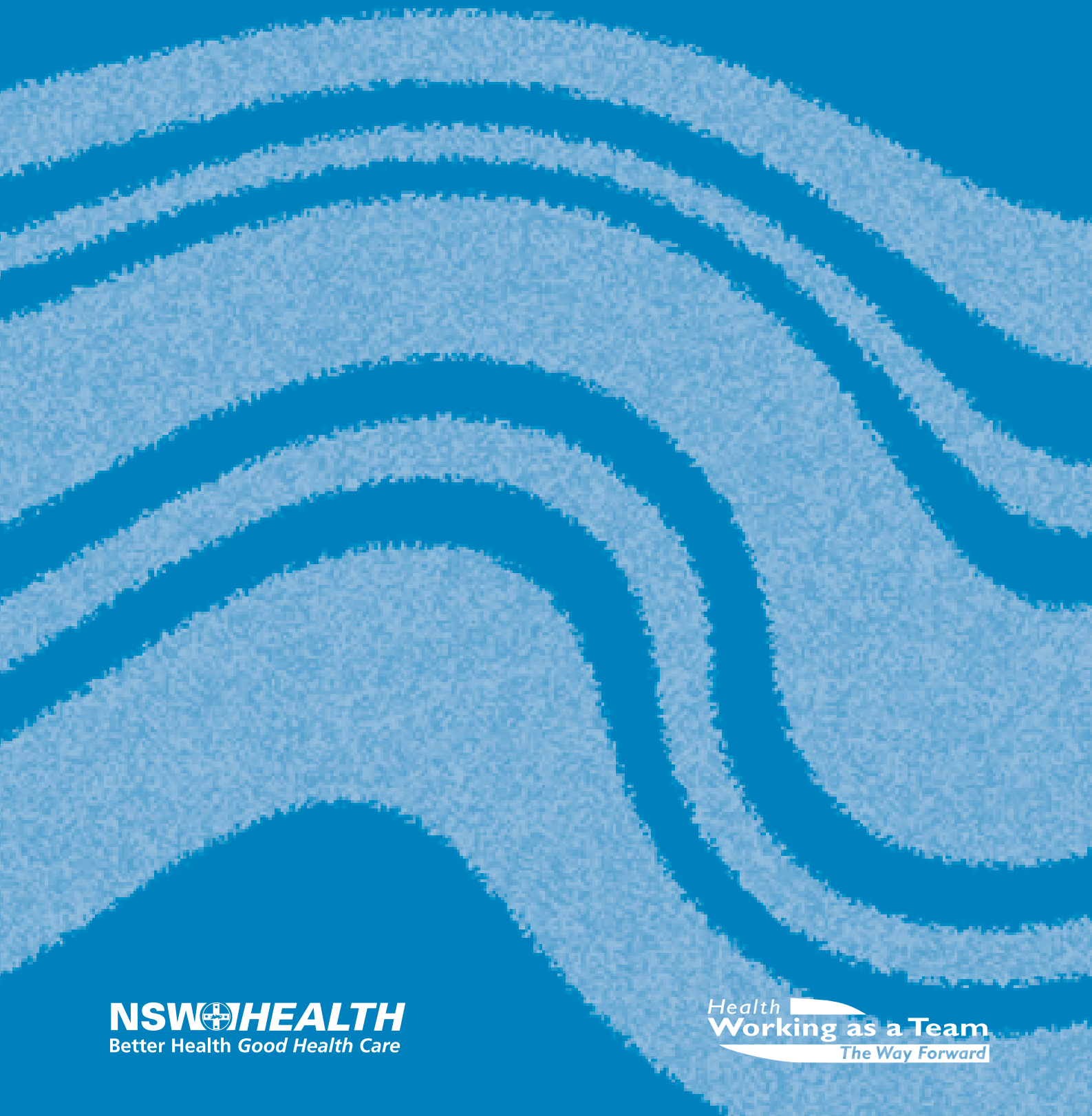
Metal contamination of major

NSW FISH SPECIES

available for human consumption



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Abstract

While Australian dietary intakes of fish are relatively small, fish is a commodity of potential public health concern as it can be contaminated with a range of environmentally persistent chemicals, including metals. Some population sub-groups may be at risk of adverse health effects because of increased sensitivity to the metal contaminants found in fish or because dietary habits expose them to higher levels of such contaminants.

This study investigated the levels and patterns of metal contamination in the NSW commercial fish supply. To assess regulatory compliance, the levels of the metals mercury, selenium, cadmium, copper, lead and arsenic were compared to the Australian standards for metal contaminants in food. To determine if consumers are at risk from consuming fish, dietary intake data derived from the recently conducted National Nutrition Survey were used in combination with the toxicological data to estimate dietary exposure to metals. Estimated exposures for the population consuming NSW fish were then compared with internationally accepted safe exposure levels. The levels of metals found in the NSW fish supply were generally found to be low and well within the limits for contaminants in food set by the Australia New Zealand Food Authority. Overall, 13.6% of the samples exceeded one or more of the metal contaminant standards. Excessive selenium accounted for 74% of the fin fish failures, mercury 22% and inorganic arsenic four per cent. Excessive copper accounted for 80% of the crustacean failures, selenium 17% and inorganic arsenic three per cent. No mollusc samples exceeded the standards.

Mercury and selenium were identified as the metals of potential public health concern. Mercury is a developmental toxicant and the mercury levels found in NSW swordfish, and to a lesser extent shark, may expose the developing foetus to unnecessary risks. Women who may become pregnant should receive advice on safe consumption of shark and swordfish, particularly in view of the potential growth of the swordfish market in NSW. Fish from Lake Macquarie were found to have high levels of selenium. The recreational fisher or high consumer may be at some risk of adverse health effects if consuming very large quantities of locally caught fish. This group should continue to be provided with advice on safe levels of consumption. Advice on safe consumption should also be provided to recreational fishers who may consume quantities of fish taken from any other waterway where contamination has been identified.

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Acknowledgments

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Introduction

The Food and Agriculture Organisation and the World Health Organisation both recommend that governments monitor the levels of pesticides and contaminants in food. This recommendation comes in response to increasing concern over the health effects of various contaminants, including metals, found in the food supply (Australia New Zealand Food Authority 1998a).

Australian dietary intakes of fish (the term fish in this report includes fin fish, crustaceans and molluscs) are small in comparison to intakes of meat and poultry- dietary survey data show that, on average, adult Australians eat five to seven times more meat and poultry, by weight, than they do fish (Australian Bureau of Statistics 1997). Nevertheless, fish is a commodity of potential public health concern as it can be contaminated with a range of chemicals such as metals, organochlorine pesticides, organophosphate pesticides, herbicides, polyaromatic hydrocarbons, polychlorinated biphenyls and dioxins, some of which are environmentally persistent (United States Environmental Protection Agency 1996).

While there is little evidence that pesticides or polychlorinated biphenyls pose a problem in Australian fish (Australia New Zealand Food Authority 1996 and 1998a), some metals such as mercury have periodically raised concern. Metals present in the environment may be naturally occurring or may be present as a result of industrial, agricultural or urban activities. Fish tend to take up and concentrate metals by a process known as bioaccumulation. Biomagnification, the progressive accumulation of metals through the food chain, also occurs.

While no single case of overt metal poisoning resulting from the consumption of fish has been reported in Australia, the potential for adverse short- and long-term health effects in some population sub-groups cannot be discounted. This is because some people may be increasingly exposed or may be more sensitive to the effects of metal contaminants, and some of the effects of metal toxicity can be subtle and difficult to detect and measure.

It is timely to review the metal contaminant load of the New South Wales fish supply and the potential dietary metal exposure of the population. While there is no evidence to suggest that metal contaminants, except perhaps for mercury, present in NSW fish could pose any potential health risks, confirmatory data are needed. A review of the available evidence on safe levels of exposure to metals will provide the context for interpreting the public health significance of dietary exposure to metal contaminants. Where metals levels are found to be well within safe limits, public and regulatory authority concern can be allayed. Where there is any evidence for concern, the need to issue advice on consumption or implement stronger regulatory measures will be discussed.

Aims

To determine the levels and patterns of metal contamination in selected species of NSW fin fish, crustaceans and molluscs, and to identify potential health risks that might be associated with current Australian dietary intakes of these commodities.

Objectives

- To determine the concentrations of the metals mercury, cadmium, lead, copper, selenium and arsenic in 50 common species of commercial NSW fish by analysing data collected in a 1997-98 toxicological survey conducted by NSW Health.
- To identify any variation in the levels of these metals, and to identify if fish species or catch location are factors contributing to the variation.
- To compare the levels of metals found with the Australian regulatory standards that are set out in Standard A12, Metals and Contaminants in Food, of the Australian Food Standards Code.
- To examine the 1995 Australian National Nutrition Survey data to ascertain current intakes of fish by the Australian population, and to determine if consumers are at risk of excess exposure to metals and therefore are at risk of adverse health effects from consuming NSW fish.
- To identify any potential public health risks and identify if preventive public health strategies relating to dietary exposure from metal contaminants in fish are required.

2 Backgrounds

The metal contaminants of interest in this study are mercury, lead, cadmium, selenium, copper and arsenic. These metals were selected because they are known to accumulate in the environment and in fish, and are known to cause serious adverse health effects if consumed in sufficient quantities.

Acceptable limits for metals in fish

For Australian regulatory purposes a maximum permitted concentration is set for contaminants in food when the health of consumers cannot be safeguarded by other mechanisms. Such mechanisms may include promoting good agricultural, manufacturing or veterinary practice, introducing zoning restrictions for land use or introducing environmental safeguards (Australia New Zealand Food Authority 1998b).

These maximum permitted concentrations are determined by the Australia New Zealand Food Authority and are set out in Standard A12 of the Food Standards Code. The maximum permitted concentrations for metals in fish are shown in Table 1. In setting maximum permitted concentrations the Authority establishes the upper range of the contaminant normally found in a food produced under best practice conditions, and compares likely dietary intake with accepted health standards. Any maximum permitted concentration must be considered safe at the upper end of the range of dietary intakes of the population.

The health standards used by Australia are the reference acceptable exposure values established by the Joint FAO/WHO Expert Committee on Food Additives (Australia New Zealand Food Authority 1998b). These values, in the case of metals, are expressed as provisional tolerable weekly intakes (PTWIs). For a contaminant such as selenium, no provisional tolerable intake has been set. For some contaminants different toxicological criteria have led to acceptable exposure levels being set by other authorities that are different to the levels being recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

Standard A12 is currently under review by the Australia New Zealand Food Authority as some of the maximum permitted concentrations may be outdated or may not reflect Australia's international trade obligations. For this reason provisional tolerable weekly intakes or other internationally accepted standards will also be used in this study to assess the relative safety of the NSW fish supply. Table 2 shows these international standards for safe exposure.

Metal	Food commodity concentration (mg/kg)	Maximum permitted
Inorganic arsenic	Fin fish, crustaceans and molluscs	1.0
Cadmium	Molluscs	2.0
Copper	Foods not containing a food otherwise specifieda	10.0
Lead	Foods not containing a food otherwise specifieda	0.5
Mercury	Fin fish, crustaceans and molluscs which cannot be sampled in accordance with clause (7)	1.0
Selenium	Foods not containing a food otherwise specified[a]	1.0

[a] The category 'foods not containing a food otherwise specified' is used for all metals except cadmium to capture food commodities not specifically listed. By default fin fish, crustaceans and molluscs fall into this category.

Table 1 The Australian Food Standards Code maximum concentrations of metals permitted in fish

Metal	Standard setting agency	Standard	Reference
Inorganic arsenic	JECFA	PTWI of 15 µg per kg body weight per week	WHO 1989
Cadmium	JECFA	PTWI of 7 µg per kg body weight per week	WHO 1989
Copper	JECFA	PTWI of 3500 µg per kg body weight per week	WHO 1982
Lead	JECFA	PTWI of 25 µg per kg body weight per week	WHO, cited in ANZFA 1998a
Mercury	JECFA	PTWI of 5 µg per kg body weight per week	WHO 1972
	USEPA	Reference dose of 0.1 µg per kg of body weight per day[a]	USEPA 1995
Selenium	JECFA	No recommendation	
	USEPA	Reference dose of 5.0 µg per kg of body weight per day	USEPA 1991

PTWI = Provisional Tolerable Weekly Intake

[a] the United States Environment Protection Authority reference dose for mercury is based on developmental toxicity data obtained from 81 mothers and their infants who were exposed in utero in the methyl mercury poisoning incident that occurred in Iraq in the 1970s. Exposure levels not associated with adverse in utero effects (such as developmental delays in the infants) were determined by modelling the exposure levels of the mothers as measured by the mercury concentration of their hair. The reference dose includes a safety factor of ten.

Table 2 Internationally accepted safe levels of exposure to metals

What levels of metal contamination have previously been found in NSW fish

NSW State Fisheries survey of NSW fin fish

In the mid-1970's NSW State Fisheries undertook a survey of metal contamination in nine species of commercial NSW fin fish (Bebbington et al 1977). The samples were analysed for mercury, cadmium, lead, arsenic, copper, zinc and selenium. The concentrations of cadmium, zinc, copper and lead were within the standards then set by the National Health and Medical Research Council. Seven per cent of the samples exceeded the mercury standard (then set at 0.5 ppm) and 21% of samples analysed for arsenic exceeded the standard (then set at 1.5 ppm arsenic, as As2O3).

The researchers did not report mean metal concentrations for the total sample, rather the mean for each of the nine species collected. Also, the standards setting out the maximum permitted concentrations of metals in fish have changed since this study was conducted so the proportion of samples failing the standards cannot be used for historical reference. The study did highlight the need to evaluate fish consumption data to determine any health risks associated with the mercury levels found. It also noted that different forms of arsenic may have different toxicities, and recommended further work be done to determine the health risks associated with the form of arsenic found in fish. This survey was apparently the first of its kind carried out in NSW.

NSW State Fisheries and Health Commission of NSW survey

A survey of the mercury levels in fish passing through the Sydney Fish Markets was conducted by the two government agencies between 1976 and 1978. No data were published, but a press release reported that the larger specimens of several species of shark exceeded the mercury standard of the day (Health Commission of NSW 1978). While swordfish was also found to have high levels of mercury, it was not considered to present a threat to public health as it was then marketed in very small numbers.

NSW State Fisheries survey of fin fish from northern NSW

A survey of mercury contamination of fin fish from the Tweed, Richmond and Clarence Rivers in northern NSW was conducted in 1980 (Chvojka and Williams 1981). Fungicides containing methyl mercury were being used in the area to treat sugar cane cuttings prior to planting, and concern was raised about the potential for mercury to be washed into nearby rivers and then be taken up by fish. The researchers found no elevated levels of mercury in the four species of fish surveyed.

1989–93 NSW Health survey

One thousand and ninety five samples of NSW fish were collected from commercial outlets on an ad hoc basis over a period of four years and analysed for mercury, cadmium, lead, copper and zinc (NSW Health unpub.). Almost 3% of the samples collected failed the standard for mercury. All were shark and swordfish. The cadmium standard (then set at 0.2 mg/kg) was exceeded in 31% of crustacean samples and the copper standard in 24 per cent. No failures for lead or zinc were reported. While some catch location information was collected, geographical variation of metal contaminants was not examined.

1996 Lake Macquarie survey

In 1996 Hunter Public Health Unit initiated a study of Lake Macquarie fish in response to concerns expressed about the health risks associated with metal contamination of Lake Macquarie (Wlodrczkyk and Beath 1997). Lake Macquarie is one of the major sources of commercial estuarine fish in NSW, ranking sixth in 1992-93 (Scribner and Kathuria 1996). It is also a popular recreational fishing site. Metal contamination found in Lake Macquarie has been attributed to pollutants being released from the two nearby coal burning power stations and the lead-zinc smelter. Selenium is released into the atmosphere as a result of the burning of coal by the power stations, while lead, zinc, copper, cadmium and arsenic are being released from the smelter. There may also be other sources of the metals found in Lake Macquarie.

Between January and June 1996, 1 164 samples were collected and analysed for selenium, arsenic, mercury, zinc, copper, lead and cadmium. While a small number of samples exceeded the standards for copper, lead and cadmium, 59% of sample homogenates exceeded the standard for selenium. In one area near a power station, 88% of the sample homogenates exceeded the standard. The mean level of selenium for all sample homogenates was found to be 1.19 mg/kg.

Selenium concentrations were found to vary by catch location and by species. Species variations were attributed to the various feeding habits of fish, with bream and flathead showing the highest mean concentrations of selenium of the species surveyed.

1997 report by 'A Current Affair'

In late 1997 Channel Nine's 'A Current Affair' program expressed concern at the excessive levels of mercury found in some fish. The program had obtained and analysed seventeen samples of shark, swordfish and marlin for mercury. Fourteen samples (82%) were found to contain mercury in excess of the maximum permitted concentration of 1.0 mg/kg. The NSW Health Department was asked to respond to allegations it was doing little to protect public health by permitting the sale of such fish, particularly shark as it is frequently used as the unspecified fish in 'fish and chips'. The Department had commenced the toxicological survey of NSW fish that is the basis of this study, but comment on mercury contamination would have been premature, based on the small number of samples that had been analysed at the time.

3 Methods

This report uses data from two surveys to calculate the levels of metal contaminants the population may be exposed to from consuming NSW fish. The first data source is the toxicological survey designed and conducted by NSW Health to establish the levels of metal contaminants present in the NSW fish supply. The second data source is a national dietary survey that provides estimations of the dietary intakes of various commodities, including fish, by the Australian population. Each survey is described below.

Toxicological survey

The toxicological survey was a cross-sectional study that aimed to identify the mean levels of metal contaminants found in the fresh, unprocessed NSW fish. The survey also aimed to characterise variation in metal contaminant levels by individual species, by broad taxonomic group (fin fish, crustaceans and molluscs) and by catch location. It examined the metal contaminant levels of the flesh of fin fish (muscle, skin-off), crustaceans and cephalopod molluscs only. No analyses were done on other parts of these fish such as the head or organs where some metals are preferentially stored (Australia New Zealand Food Authority 1995). The whole animal was analysed in the case of bivalve molluscs. The survey was conducted between June 1997 and June 1998.

The metals of interest were mercury, cadmium, lead, arsenic, selenium and copper. These metals were selected because they are found in fish and are toxic if chronically consumed in sufficient quantities. Zinc was not included in this survey although it was included in the 1989-93 NSW Health survey. Its exclusion was based on the fact that none of the 1 056 samples collected in that survey exceeded the maximum permitted concentration for zinc. Additionally, zinc is an essential element in human nutrition and Australian intakes may not always meet recommended dietary intakes. The 1995 National Nutrition Survey recorded a mean daily zinc intake by women aged 19 or more years of 9.7 mg (Australian Bureau of Statistics 1998), while the recommended dietary intake is 12 mg per day for adult women, 16 mg per day for pregnant women and 18 mg per day for lactating women (National Health and Medical Research Council 1991).

While the 1989-93 NSW Health survey also reported that no samples exceeded the maximum permitted concentration for lead, lead was included in this survey because it is a cumulative poison that affects the nervous system, particularly the developing nervous system in the foetus, and in infants and children. The presence of lead in the environment is a current public health issue.

Sampling frame

The sample was drawn from fish caught and sold in NSW. Species included in the sampling frame were selected according to their contribution, by weight, to the total NSW catch. The exception was bivalve molluscs. As the shell weight of bivalves constitutes most of the weight, the estimated flesh weight only was used. For the purposes of this survey, the flesh weight for all bivalve molluscs was estimated to be 7% of the total weight.

At the time the survey was designed the most recent catch data available were for the year 1992–93 (Scribner and Kathuria 1996). Using this data source, 50 species of fin fish, molluscs and crustaceans were selected to provide good representation of the NSW fish supply. Budgetary and workforce restraints meant that a total of 500 samples could be collected and analysed over the survey period.

Appendix 1 shows the species selected, their total catch weight for the year 1992–93, their predominant source and the calculated proportional sample numbers. Two species of fin fish and four species of molluscs that would have been excluded on the basis of weight, were included as either the landed catch was known to have increased since 1992–93, or because of potential concern about metal contamination. Swordfish was included because the catch has increased substantially in the last few years and, as a large predatory fish, it is more likely to contain higher levels of mercury. Murray cod was included to increase representation of inland river

systems that may accumulate metals from agricultural run-off. A small number of pipi, abalone, cockle and blue-lipped mussel samples were included to broaden representation of bivalve molluscs beyond Sydney rock oysters which account for 95% of the bivalve mollusc catch. The common and scientific names of the species selected are reported in Appendix 2.

Sample collection

Fish samples were collected from the major fish cooperatives along the NSW Coast. Cooperatives were selected as they were considered more likely than retail outlets to be able to provide catch location data. Seven Public Health Units cover the coastal region of NSW-Central Sydney, Central Coast, Illawarra, Hunter, Mid North Coast, Northern Rivers and Southern NSW. These seven units participated in the study, as did South Western Centre who offered to collect samples from inland rivers and aquaculture farms. The coastal zoning used by NSW Fisheries was used if the precise catch location for ocean species was unknown. A map of these zones is at Appendix 3.

Metal assays

The NSW Government laboratory, the Division of Analytical Laboratories, undertook the metal assays. The analytical methods are described in Appendix 4.

While the maximum permitted concentration for arsenic in fish is for the inorganic form, the analytical procedure is technically difficult and not routinely undertaken. For this reason total arsenic was analysed in the first instance and where found to be high the sample was further analysed for inorganic arsenic. The United States Food and Drug Administration (1993) estimates that in shellfish (bivalve molluscs and crustaceans) inorganic arsenic is about 10% of total arsenic. The Ministry of Agriculture, Fisheries and Food in the United Kingdom reports that inorganic arsenic accounts for approximately 1-3% of total arsenic in fish (MAFF 1997), while the Australia New Zealand Food Authority (1999a), following the practice in New Zealand, assumes a proportion of six per cent. While the Division of Analytical Laboratories did not set an action level, samples whose total arsenic exceeded 3 mg/kg were generally analysed for inorganic arsenic.

The limits of detection in the assays conducted by the Division of Analytical Laboratories were as follows:

Cadmium	<0.01 mg/kg
Mercury	<0.01 mg/kg
Lead	<0.02 mg/kg
Selenium	<0.01 mg/kg
Copper	<0.05 mg/kg
Total arsenic	<0.10 mg/kg
Inorganic arsenic	<0.10 mg/kg

Where a metal were not detected, the samples were recorded as having a zero concentration. This may underestimate the dietary exposure to metals from fish. The Australian Market Basket Survey (Australia New Zealand Food Authority 1998a) assigned a value to both 'trace' or 'not detected' results. This more conservative approach results in an overestimation of metal contamination, but is justified as a worst case scenario. It was not considered necessary in this survey to assign numerical values to 'not detected' results as the contribution of fish to the total diet is small.

Limitations of the survey

A total of 470 fish samples were collected, falling short of the planned 503 samples. Only 40 of the 50 selected species were sampled, although eleven additional species not included in the sampling plan were collected. Appendix 1 gives details of the actual samples collected. While the convenience sampling protocol provided Public Health Units with a great deal of flexibility in collecting samples, it also meant that it was unlikely that all samples would be collected as planned. Some species were significantly undersampled. In the case of tuna, undersampling occurred because of seasonal availability and difficulty in ensuring that individual samples could be taken from different specimens. Species such as abalone and lobster proved to be too costly for Public Health Unit inspectors who had no forward budget for purchasing samples. Some species were oversampled, mostly because they were readily and cheaply available.

While the effects of location on metal levels were examined, this survey was not intended to be an environmental audit. Samples were collected from various locations throughout NSW on a convenience basis only. Therefore the samples collected do not necessarily represent the landed catch for each location, nor may be truly representative of the whole NSW catch.

Analysis of toxicological data

Of the 470 samples collected and analysed for metals, seven were excluded from the data analysis as they were not caught in NSW waters. Twenty samples whose catch location was not reported or not known have been included. Another 19 samples of fish species not specified in the sampling plan have been included and coded as miscellaneous. Therefore a total of 463 samples were included in the data analysis. Of these 364 were fin fish, 62 crustaceans and 37 molluscs.

SPSS for Windows (student version 7.5) was used to analyse the data. The mean concentration and 95% confidence interval of the mean for all metals for fin fish, crustaceans and molluscs were calculated and then compared with the maximum permitted concentrations set out in Standard A12 of the Food Standards Code. The median concentrations were also calculated and reported in those instances where the distribution of metal concentration was found to be skewed.

As the maximum permitted concentrations are legally enforceable limits, all samples exceeding these limits were identified and reported. The data from these samples were further examined to determine if either species or catch location were factors contributing to the high metal levels. In some circumstances mean metal levels between groups were compared using the independent-samples *t* test. Additionally, the average dietary exposure to metals from consuming fish was calculated. This exposure was compared with the provisional tolerable weekly intake or other internationally accepted safe levels of exposure to assess the relative safety of the NSW fish supply.

1995 National Nutrition Survey

The National Nutrition Survey was conducted by the Australian Bureau of Statistics and the Commonwealth Department of Health and Family Services between February 1995 and March 1996 (Australian Bureau of Statistics 1997). The survey was conducted on a sub-sample of respondents to the National Health Survey. Approximately 13 800 participants aged two years and over participated. For all participants a 24-hour food recall record was obtained. In addition to the 24-hour food recall, a food frequency questionnaire was administered to those respondents aged 12 years and older to assess usual frequency of intake of 107 food items and 11 vitamin and mineral supplements over the previous 12 months.

Limitations of the survey

The 24-hour recall is a cross-sectional method used to establish food intakes and food consumption patterns for the population. The population mean intakes may be reliable as a population measure, but are not reliable for individuals unless serial 24-hour recalls are conducted (Dwyer 1994). The Australian Bureau of Statistics (1998b) highlights the fact that the 24-hour intake is self-reported and therefore is likely to underestimate actual consumption. The response rate for the survey was 61.4%, and while adjustments have been made to reduce bias the Australian Bureau of Statistics (1997) advises caution in analysing and interpreting the data.

Analysis of the 1995 National Nutrition Survey data

The Australia New Zealand Food Authority provided dietary intake data. The data were derived from the 1995 National Nutrition Survey customised unit record file provided by the Australian Bureau of Statistics and subsequently run through the DIAMOND (dietary modelling of nutritional data) program operated by Australia New Zealand Food Authority.

The consumption data provided by the Australia New Zealand Food Authority is different to that published by the Australian Bureau of Statistics (1997) as the DIAMOND program calculates:

- The estimated quantity of fish present in mixed dishes and in seafood products, unlike the 1995 National Nutrition Survey which codes mixed dishes and products as fish, if fish is the major component. For example the DIAMOND recipe database estimates battered fish products to contain only 55% fish.
- DIAMOND also calculates the raw commodity equivalent of foods. The 1995 National Nutrition Survey data are for foods as consumed. DIAMOND uses the factors 1.3, 1.0 and 1.2 to convert cooked fin fish, crustaceans and molluscs respectively to the raw commodity.

  (Baines J., Australia New Zealand Food Authority [personal communication] 1999).

The data provided by the Australia New Zealand Food Authority (Baines J., Australia New Zealand Food Authority [personal communication] 1999) included:

- mean and median intakes (grams per day) of marine fish, diadromous fish, crustacean and molluscs, as the raw commodity, for the adult population aged 19 or more years and for women aged 16–44 years. Diadromous fish are species that can live in both fresh and salt water and includes salmon, trout and barramundi only.
- mean, median and 95th percentile intakes (grams per day) of marine fish, diadromous fish, crustacean and molluscs, as the raw commodity, for adult fish-consumers aged 19 or more years and for female consumers aged 16–44 years.

No data from the food frequency questionnaire had been published by the Australian Bureau of Statistics at the time this report was prepared.