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WORKING GROUP ON MERCURY IN FISH

# REPORT ON MERCURY IN FISH
# AND FISH PRODUCTS

to

CO-ORDINATING COMMITTEE ON METALS IN FISH AND FISH PRODUCTS

1979

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# MEMBERSHIP OF THE WORKING GROUP ON MERCURY IN FISH AND FISH PRODUCTS

(Dates in parentheses refer to Working Group meetings)

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|---|---|
| Dr D.A. Hancock | - Chairman, Western Australian Department of Fisheries and Wildlife (19/11/75 to 31/5/79) |
| Dr R. Fitzsimmons | - Commonwealth Department of Health (31/5/79) |
| Dr R.H.C. Fleming | - Commonwealth Department of Health (18/12/75 to 7/9/78) |
| Mr M. Jackson | - Commonwealth Department of Health (7/5/76 and 31/5/79) |
| Mr J.L. Maclean | - Commonwealth Department of Primary Industry, Technical Secretary (19/11/75 to 29/6/78) |
| | - CSIRO (7/9/78 to 31/5/79) |
| Mr P. Millington | - Commonwealth Department of Primary Industry, Technical Secretary (7/12/78 to 31/5/79) |
| Mr M.J. Sanders | - Victorian Ministry for Conservation (19/11/75 to 31/5/79) |
| Dr O.A. Woodward | - CSIRO (19/11/75 to 24/7/78) |

Secretariat (Commonwealth Department of Primary Industry)

- Mr S.A. Medza (18/12/75 to 7/9/78)
- Mr R.E. Pattison (15/12/77 and 7/12/78 to 27/2/79)
- Ms A. Russell-French (19/11/75 and 31/5/79)

REPORT OF THE WORKING GROUP
ON MERCURY IN FISH
AND FISH PRODUCTS

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# REPORT OF THE WORKING GROUP ON MERCURY IN FISH AND FISH PRODUCTS

## 1. INTRODUCTION

In 1971, the Australian National Health and Medical Research Council (NH & MRC), in the report of the seventy-third Session, recommended to the States and Territories that their legislation should be amended to permit an increased level of mercury in fish. The previous maximum recommended level had been 0.03 mg/kg (ppm) in all foods. The new levels recommended were a maximum of 0.5 mg/kg of mercury in fish, crustaceans, molluscs, the fish content of fish products and the fish content of canned fish. In all other foods the maximum level was to remain at 0.03 mg/kg.

The recommendation regarding the maximum permitted levels of mercury in fish and other foods was adopted by the Commonwealth Department of Customs and Excise (now the Bureau of Customs) and by all States except South Australia, which subsequently introduced a maximum level of 1 mg/kg in crustacea, molluscs, fish and the fish content of fish products.

On February 13, 1975 the Attorney-General's Department prepared a draft regulation providing a consumer product safety standard for the mercury content of fish. This draft regulation was referred to an Inter Departmental Committee which met on February 18, which proposed some redrafting of the regulation. The regulation was intended to take effect under Section 62 of the Trade Practices Act 1974 and set a maximum limit of 0.5 mg/kg of mercury calculated as the metal in fish or fish products. Fish was defined to include crustaceans and molluscs; fish products were considered to be any food in which fish is an ingredient. Penalties of up to $50,000 for corporations and $10,000 or six months imprisonment for individuals were to apply.

In March 1975, the Australian Fisheries Council's Co-ordinating Committee on Metals in Fish and Fish Products met to discuss the implications to the fishing industry of this proposal by the Attorney-General to implement and police a product safety standard, setting 0.5 mg/kg mercury level for fish. The Co-ordinating Committee recommended to Standing Committee on Fisheries that steps be taken to ensure that no further action be taken under the Trade Practices Act until:

"(a) the matter has been fully considered by the relevant Ministers for Fisheries and for Health;

(b) the relevance of the proposed National Food Act has been investigated;

(c) the NH & MRC has been asked to re-examine the validity of the present standard in the light of the most recent evidence;

(d) various fishery authorities can complete examination of heavy metal levels in commercial species to allow a proper assessment of desirable control measures and methods of determining compliance."

The Co-ordinating Committee also recommended that a comprehensive study should be made to assess the pattern of consumption of fish by Australians to determine whether mercury levels in Australian fish were likely to lead to adverse effects on health. These recommendations were subsequently endorsed by Standing Committee and the Australian Fisheries Council.

The Attorney-General indicated that he would await the results of the Australian Fisheries Council's meeting in September 1975 before considering any further action to implement the Regulation. The Secretary of the NH & MRC advised the Co-ordinating Committee on June 27, 1975 that the Food Committees of NH & MRC were prepared to examine all the recent evidence pertaining to the validity of the present standard of 0.5 mg/kg adopted by the NH & MRC and outlined details of the basic data which would be required (Appendix 1).

Australian Fisheries Council at its meeting on October 3, 1975 made the following resolutions:

"1. Council endorsed the concern expressed by the Standing Committee on Fisheries on the likely consequence to the Australian fishing industry of enacting a Regulation under the Trade Practices Act 1974 for the purpose of implementing and policing a product safety standard on mercury levels (0.5 ppm) in Australian fish and agreed that the control of food standards by other than health legislation was inappropriate and undesirable.

2. Council noted that all States except South Australia had adopted the National Health and Medical Research Council's recommended standard of 0.5 ppm total mercury in fish. In this regard, the South Australian Minister advised that the standard in his State had been changed from 5.5 ppm to 1 ppm and would be reviewed within two years in the light of the evidence presented. The 1 ppm standard would be maintained until the review had been completed.

3. In view of the serious lack of information on the role of fish in Australian diets, Council agreed that a small working group of officers comprising Dr D.A. Hancock, Western Australia (Convenor), Mr J. Maclean, Australian Department of Agriculture, Dr P. Philpott, Australian Department of Health, Dr. O. Woodward, CSIRO and Mr M. Sanders, Ministry for Conservation, Victoria, should be appointed to identify the areas of weakness in current programs or data and suggest areas for further work, in co-operation with the National Health and Medical Research Council.

4. The group would report to the Co-ordinating Committee on Metals in Fish and Fish Products, and would give priority to the planning and implementation of an Australia-wide survey to examine the role of fish in total diet, possibly an extension of the proposed Australian Department of Agriculture consumer preference survey of fish in Victoria. Individual States should continue with mercury analyses on an ad hoc basis. However, in view of the expected heavy expenditure of time and finance which would be involved in extensive mercury analyses of fish, consideration of the latter should await the preliminary results of the dietary survey. Similarly, the dietary survey is expected to identify essential toxicological studies.

5. Council agreed that finance should be sought from the Fishing Industry Research Trust Account, and the support of the Australian Fishing Industry Council should be requested, and that the appropriate Minister of the Australian Government and the National Health and Medical Research Council should be made aware of Council's intention to collect the additional information needed to support a review of mercury standards, noting that it could well be two years before such a review can be completed. The consequences of these proposals to any actions by the Australian Government will be relevant to the deliberations of the working group."

The Working Group on Mercury in Fish held its first meeting in November 1975 and met regularly thereafter. The composition of the Group was as recommended by Council with the exception of Dr Philpott, whose place on the Working Group was taken by Dr R. Fleming of the Department of Health, Chairman of the NH & MRC's Food Science and Technology Subcommittee. Dr Woodward resigned from the Working Group in May 1978 and her place as CSIRO representative was taken by Mr Maclean who had left the Department of Primary Industry to join CSIRO. Mr P. Millington was nominated as Mr Maclean's successor from the Department of Primary Industry. Dr E.J. Fitzsimons and Mr M.P. Jackson replaced Dr Fleming as the Department of Health's representatives in April 1979 when Dr Fleming retired from the Public Service. Mr S. Medza (Department of Primary Industry) was the Group's Secretary until January 1979. Terms of reference of the Working Group were as laid down in paragraph 4 of Council's resolution (above). Working Group meetings were normally also attended by Mr C. Keating (D.P.I.) and, during the planning stage, a representative from the Australian Bureau of Statistics. Mr Keating also acted as Convenor of a Consumer Survey Steering Committee which included representatives from the Department of Health, Bureau of Statistics, Department of Primary Industry, Public Service Board and Consultants undertaking the Fish Consumption Survey.

On the recommendation of the Working Group, two complementary studies were approved for financing from the Fishing Industry Research Trust Account during the financial year 1976/77. The first was entitled, "Survey of the pattern of fish and shellfish consumption in Australia", to be undertaken by P.A. Consulting Services Pty Ltd, and the second, "Dietary study of Australians consuming significant amounts of fish products", was under the direction of Mrs Ruth English of the Commonwealth Department of Health. Mrs English reported to, and advised, both the Working Group and its Steering Committee on a regular basis.

In addition, relevant data on mercury in fish and fish products in Australia were examined and recommendations made for additional analyses needed to complement the findings of the fish consumption studies. In anticipation of the possible need for pooling results from different analytical sources, the Working Group sponsored an inter-calibration analytical workshop on total mercury in fish tissues, which was organised in July 1977 by the Joint Technical Working Group on Marine Pollution supported by a special grant from the Fishing Industry Research Trust Account. Attention was subsequently directed towards the analysis of methylmercury in fish, mercury in hair and other relevant metals.

## 2. BACKGROUND

### 2.1 The NH & MRC Recommendation

The NH & MRC recommendation in 1971 (NH & MRC 1971b) arose from a request by the New South Wales Department of Health to the Food Standards Committee of the NH & MRC to review its recommendation, which New South Wales had adopted, that foods shall contain not more than 0.03 mg/kg of mercury calculated as the metal. This request was initiated by the fact that the USA had prescribed a limit of 0.5 mg/kg for fish. After examination of published data, available at that time, the food committees of the NH & MRC agreed that the "figure of 0.5 ppm for mercury in fish ... would appear to be a sound basis for protection of the consumer at present, but they could see no justification for a change in the level of 0.03 ppm for other foods at present".

In the same report:

> "Council noted that there is a proven hazard to human health from seafoods which contain high levels of mercury and considered that further mercury contamination of oceans and inland waters is likely to occur and increase this hazard.
>
> Council recommended that the appropriate authorities throughout Australia should be requested to monitor the levels of mercury in inland waters and oceans regularly where this is not already being done. Council also recommended that, if the results of this monitoring show high or increasing levels of mercury, authorities should take action to reduce the emission of mercury at its source."

In May 1972 at its Seventy-fourth Session, the NH & MRC:

> "noted that there was a need to closely examine the question of residue levels of heavy metals in seafoods. Council, therefore, decided to establish an *ad hoc* Subcommittee on Metallic Contamination of Seafoods whose membership and terms of reference are .... To report to the Environmental Health Committee on the health aspects related to the contamination by metals of seafoods and their products."

The ad hoc Sub-committee presented its report to the Seventy-fifth Session of the NH & MRC in November 1972 and Council reported as follows:

> "Methylmercury in Fish - Effects on Human Health.

Council noted the view that its recommendation for a permissible level of 0.5 parts per million for mercury in fish may be too stringent for Australian conditions. Council gave further consideration to currently available evidence in this matter and, in particular, noted the following:

(i) the epidemics of poisoning which have occurred in Japan;

(ii) the occurrence among other fish consumers of mercury levels in blood and hair approaching those associated with symptoms of poisoning;

(iii) the high sensitivity of the foetus to mercury;

(iv) a correlation in man between exposure to mercury contamination in fish and the incidence of chromosome breaks in circulating lymphocytes.

In the light of all the evidence currently available, Council reaffirmed its previous recommendation, made at its Seventy-third Session, that the maximum permissible level for mercury in fish, crustaceans, molluscs and the fish content of canned fish, be 0.5 parts per million.

However, Council noted that there were deficiencies in knowledge of the effects of mercury in the environment and, in particular, the effects of methylmercury on human health in relation to fish consumption patterns. Council endorsed the document - "Methylmercury in Fish - Effects on Human Health" - shown in Appendix XI of this report, as a valid resume of available data on the subject and recommended that it be reproduced and distributed widely.

Council approved a grant of $16,500 for a survey of the consequences of methylmercury ingestion from fish in selected Victorian population groups, to be conducted by Professor D. Penington."

In its document "Methylmercury in Fish - Effects on Human Health" (1973) Council pointed out, amongst other things:

"Since there is no effective therapy for methylmercury poisoning, prevention as the only means of control must be emphasised. Such means should be directed at the maximal reduction of controllable sources of mercury emissions to the environment and the provision of adequate regulations that minimise exposure of vulnerable sub-groups to contaminated fish.

The results of all available mercury determinations on marine products taken from different areas in Australia has indicated that levels of 0.5 ppm were being exceeded. This data, together with that provided by overseas studies on the toxicology of mercury residues in food and tolerance for mercury in fish set by overseas authorities, have been considered by the National Health and Medical Research Council."

The document concluded:

"Methylmercury poisoning has not been reported in Australia. However the potential for toxicological effects in population subgroups with dietary patterns that include large amounts of contaminated fish cannot be excluded. There is need for increased knowledge concerning the effects of methylmercury on human health. Meanwhile it behoves society to err on the side of caution by ensuring that human exposure is kept minimal, at least within the limits of a reasonable safety."

## 2.2 History of Regulatory Action in Australia

In December 1971, the then Commonwealth Department of Customs and Excise, under Regulation 4 of the Customs (Prohibited Imports) regulations prohibited the import of fish, crustaceans and molluscs with a mercury content in excess of 0.5 mg/kg.

In mid-1972 the New South Wales and Victorian Health authorities adopted the NH & MRC recommendation. The Health Authorities in Western Australia and Tasmania followed in December 1972 and Queensland in May 1973. South Australia subsequently adopted a level of 1.0 mg/kg in May 1975 (South Australia 1975), subject to a review of the situation after two years. This level was confirmed by a regulation proclaimed in December 1978.

Early in 1972 a consignment of shark fillets from New Zealand was examined by the Government Analyst on behalf of the Department of Customs and Excise and found to have mercury levels in excess of 0.5 mg/kg. This consignment was confiscated and subsequently returned to New Zealand. Recognising that the New Zealand shark catch included the same species as are landed in the south east Australian shark fishery, it was accepted that levels in locally caught shark required examination.

A collaborative study was instigated within Victoria by the State's Fisheries and Wildlife Division and Department of Health. This study was completed in mid 1972 and revealed that the two species, school and gummy, which predominated in Victorian shark landings both included individuals whose flesh contained in excess of 0.5 mg/kg mercury (Walker 1976). In the case of the school shark, it was estimated that the average mercury level in the Victorian landings was almost double the maximum permissible level, while for gummy shark the average was less than 0.5 mg/kg.

The above discovery led to Regulations being introduced in September 1972 under the authority of Victoria's Fisheries Act 1968 making it an offence to land, consign or bring into Victoria school shark exceeding 41 inches (104 cm) in total length. Shark other than in carcass form (e.g. fillets) were initially precluded entry into Victoria. However an amendment was made in April 1973 to allow the entry of filletted shark into Victoria provided it was appropriately certified by a Health Officer as coming from individual fish complying with the Victorian length requirements. These Regulations were again amended in August 1976 when the school shark maximum length was increased to the partial length equivalent of 112 cm total length and in January 1977 when Victoria reverted to allowing only shark in the carcass form to be landed, consigned or brought into the State.

In September 1974, in a joint statement the Federal Ministers for Health, Science and Primary Industry released the results of a spot check of fish fillets sold in Melbourne, which was part of a continuing survey being conducted by the NH & MRC and the Australian Government Analytical Laboratories into heavy metals in food stuff. The survey showed that 60 percent of the samples had mercury above 0.5 mg/kg and the Ministers concluded that the existing State laws and the way they were enforced provided inadequate protection for the consumer. Shortly afterwards, the Attorney-General proposed a Regulation under the Trade Practices Act (see Section 1).

In September 1975, in consideration of a survey of mercury concentrations in shark species marketed in Western Australia (Hancock 1976, Hancock et al 1977), the W.A. Public Health Department commenced inspections of shark sold at metropolitan markets. As a measure to reduce the average mercury concentration in shark reaching the consumer, a prohibition was placed on the sale of any shark exceeding 18 kg dressed weight which, on analysis, contained in excess of 0.5 mg/kg of mercury.

Studies of mercury concentrations in New South Wales fish demonstrated that marlin contain high levels of mercury (Mackay et al 1975a). Coincidentally, a prohibition was placed on the sale of marlin with the objective of reserving the exploitation of these species for the amateur fishermen. This would also have had the effect of removing this fish from retail outlets.

State Health regulations prohibiting the general sale of fish with excessive mercury, in themselves appear to have had little direct effect on the fishing industry, though the consequent feelings of insecurity throughout the industry cannot be underestimated. Where, however, additional regulatory measures were introduced, as in Victoria and Western Australia, the consequences were more apparent. For example the Victorian Regulation making it an offence to land, consign or bring into Victoria school shark exceeding the legal maximum length had a number of major consequences. The character of the south-east Australian shark landings changed dramatically. These landings were reduced to some 40% less than immediately prior to the Regulation coming into force while the species composition changed, with fishermen giving more attention to catching gummy shark than previously. The gummy shark grounds are predominantly in eastern Bass Strait and hence fishermen operating in that area were little affected. The shark available for capture off western Victoria, South Australia and much of Tasmania are predominantly large school shark and hence shark fishing has declined very significantly off these areas.

Traditionally, Melbourne has been the centre of distribution and consumption of shark and as a consequence of a shortfall in supplies following the Regulation, prices for shark have risen and this in turn increased the incentive for people to illegally import over-sized shark into Victoria from adjacent States. This was recognised as a serious and continuing problem and a number of the regulatory changes mentioned earlier were designed to minimise this trade.

Another consequence arose from the concern that the Regulation might seriously affect the viability of shark fishing off southeast Australia. A number of programmes were instituted with the objective of assisting the fishermen to diversify into other fisheries. Money from both State and Commonwealth sources was made available to charter shark fishing boats equipped with different types of fishing gear with the objective of investigating the feasibility of alternative fishing methods. In addition, Victorian shark fishermen were assisted through the Rural Finance and Settlement Commission which made special low-interest loans available for those who were seeking to diversify.

In Western Australia concern for the future of the industry, and market controls on the sale of shark, led to some shark fishermen changing to other fisheries. The subsequent rise in price of shark to some extent compensated for the reduced quantity sold through metropolitan markets.

In some States pending, or in lieu of, the announcement of additional regulatory measures, warnings have been issued through the media advising the public to restrict consumption of fish. Such warnings, by various Government Authorities, usually followed disclosure of high mercury levels in one or more species. In some cases they were followed by assurances that there was in fact no risk.

The Tasmanian Minister for Agriculture and Fisheries, on 12 November, 1973, advised Hobart residents not to eat fish from the polluted Derwent Estuary, following the release of preliminary data from mercury analyses carried out by CSIRO. A month later, the then Tasmanian Minister for the Environment advised that most of the common edible fish in the Derwent were safe to eat. The discovery in Hobart of a cat suspected of suffering mercury poisoning (Gruber et al 1978), led to a statement by the Minister for the Environment (19 July 1976) warning the public not to eat fish from the Derwent more than once a week. No warnings however, have been issued by Tasmanian Health authorities.

The Western Australian Health Minister in September 1974 advised persons there not to eat more than six pieces of shark a week. Pregnant women were advised not to eat W.A. shark at all. This warning resulted from a report which showed that the average level of mercury in Western Australian shark exceeded the NH & MRC recommended level of 0.5 mg/kg.

At the Federal level, a joint statement by the Commonwealth Ministers for Health, Science and Primary Industry on 21 September 1974 revealed that a spot check of fish fillets in Melbourne during the continuing NH & MRC survey showed that "many of the samples contained enough mercury to constitute a serious health hazard to children". On the basis of the results the Ministers stated that present regulations and their enforcement provided inadequate protection to the consumer. Accordingly they advised that at a mercury level of 0.5 mg/kg an average sized man should not eat more than 410 g (about 15 ounces) of such fish per week, and at the maximum mercury levels detected, the recommended limit would fall to 70 g (2½ ounces) per week.

The Victorian Government, by banning the sale of large shark in 1972, obviated the need for warnings on their consumption. However, black-market large shark from South Australia began to offset this situation, and towards the end of 1974, the Victorian Health Minister advised pregnant women not to eat South Australian shark. In October, 1977, the Health Minister warned persons not to eat more than three meals per week of flathead from Port Philip Bay, following the findings of high-mercury levels in these fish. At the same time pregnant women were advised to eat no more than two flathead meals per week.

In December 1978, after amateur fishermen were said to be ignoring his advice, the Victorian Health Minister again warned that mercury levels in flathead in the northern part of Port Phillip Bay were above safe readings, and that people who ate the fish more than three times a week were placing themselves at risk.

In April 1978, the New South Wales Minister for Health warned that people could be risking their health by eating more than one meal a week of big sharks, swordfish or marlin caught by amateur fishermen and announced that his Government was preparing new regulations to control the marketing of shark in New South Wales.

Meanwhile the Australian Government Environment Council has adopted a National policy on mercury discharges designed to promote actions to achieve the reduction of all man-made emissions of mercury to the environment to the lowest possible level. This will be referred to in a later section of this report.

## 2.3 Situation in other countries

Awareness of the hazards of the ingestion of mercury by humans was brought into focus by the tragedies which occurred, for instance, in Minamata, Japan and Iraq. These and other occurrences obliged government administrators to initiate serious and intensive efforts -

(1) to define the sources and levels of mercury in the environment, particularly as related to contamination of food; and

(2) to establish regulatory action providing for the control of mercury in the environment as a health measure.

Numerous studies throughout the world served to demonstrate that certain areas and certain foods were likely to contain levels of mercury which could be considered harmful when related to data based on serious outbreaks. Fish and fish products were shown to be most commonly involved.

Because present knowledge of the effects of the presence of mercury in the physical environment and in living organisms is still somewhat limited, regulations have had to be based on a generous safety margin to ensure the protection of human health. The regulatory approach to the problem has been to limit firstly ingestion of mercury and secondly emission of mercury into the environment.

### 2.3(i) History of International Attitudes

The Food and Agriculture Organization of the United Nations, the World Health Organization and the OECD have the subject of mercury, its occurrence, impact and control under continuous review.

In 1967 the Joint FAO/WHO Expert Committee on Food Additives first considered the problem and recommended that "any use of mercury compounds that increases the level of mercury in food should be strongly discouraged." In April 1972, this Committee met again and recommended a provisional tolerable weekly intake of 0.3 mg total mercury per person, of which no more than 0.2 mg should be present as methylmercury (expressed as weight of mercury) (Joint FAO/WHO Expert Committee on Food Additives 1972).

The United Nations Conference on the Human Environment held in Stockholm in 1972, while not speaking specifically to the subject of mercury, recommended to the General Assembly of the United Nations that:

"Government use the best practical means available to minimise the release to the environment of dangerous or toxic substances, especially if they are persistent substances such as heavy metals and organochlorine compounds, until it has been demonstrated that their release will not give rise to unacceptable risks or unless their use is essential for human health or food production, in which case appropriate control measures should be applied."

In 1973, the Council of the OECD, "considering the use of and hazards of mercury, as well as the possibilities for emission control and the contingent economic effects" recommended that Governments of Member countries should adopt measures:

"(a) to reduce all man-made emissions of mercury to the environment to the lowest possible levels, with particular attention to:

(i) the elimination of alkylmercury compounds from all uses that allow this material to reach the environment in any way;

(ii) the maximum possible reduction of mercury in discharges from all industrial plants using or manufacturing products containing mercury chemicals;

(b) for which immediate targets should be:

(i) the elimination of alkylmercury compounds in agriculture;

(ii) the elimination of all mercury compounds from use in the pulp and paper industry;

(iii) the maximum possible reduction in the discharges of mercury from mercury-cell chloralkali plants."

The OECD then, in 1974, published an extensive document entitled "Studies of Mercury Uses, Emissions, Biological Impact and Control" prepared by a group of experts from Canada, Japan, Sweden and the United States.

A general set of guidelines was presented in Mercury and the Environment, Organisation for Economic Co-operation and Development (OECD 1974):

"It is necessary to proceed as far as is practical by:

(a) identifying all significant emission sources with respect of their amounts, chemical nature and concentration,

(b) bringing together of all relevant information of technical, economical and administrative importance available on the substance of its uses,

(c) maintaining a public informed as far as possible concerning the pollution and its abatement,

(d) giving industrial and commercial interests, in the interests of fairness, a reasonable opportunity to state their point of view, and by

(e) subjecting known and controllable sources to control (where this is considered appropriate), despite the fact that some sources may not at that time be controllable, and others may not be identifiable."

In the establishment of controls, however, consideration has been given to risk associated with the use of a particular mercury compound balanced against the nature and magnitude of the benefit conferred directly and indirectly by the use of the given compound (OECD 1974 p.99).

The World Health Organization similarly has published a very comprehensive review "Environmental Health Criteria 1. Mercury, Geneva 1976" which summarizes available data to the date of publication and defines areas of future research.

The realization of the involvement of fish in the Minamata disaster caused authorities to look closely at fish as a potential source of mercury, particularly methylmercury.

Surveys of other foodstuffs which have continued now for some years have failed, with a few exceptions such as Japanese rice, to present evidence that foods other than fish contain potentially harmful concentrations of mercury (Joint FAO/WHO Expert Committee on Food Additives 1972). Table 1 summarizes some data from various regions on the mercury content of a number of foods.

In investigating the need for setting maximum levels for mercury in food, a number of countries conducted surveys of the dietary intakes of their populations to determine the extent of the health risk from ingestion of mercury in food (see Section 2.5). On a broader scale data on annual per capita consumption of fish and fish products are available for most countries (Table 2). The average world consumption is 6.7kg annual per capita consumption, (range 0.1 - 39.1), compared with Australia's annual per capita consumption of 5.2kg, which puts it amongst the lower fish consuming countries.

## TABLE 1

## MERCURY IN FOODS

| Food | Country | mg/kg - Range |
|---|---|---|
| Haddock | United States | .017 - .023 |
| Herring | Baltic States | .026 - .041 |
| Apples | United Kingdom | .020 - .120 |
| Apples | New Zealand | .011 - .135 |
| Pears | Australia | .040 - .260 |
| Tomatoes | United Kingdom | .012 - .110 |
| Potatoes | United Kingdom | .005 - .032 |
| Wheat | Sweden | .008 - .012 |
| Rice | Japan | .227 -1.000 |
| Rice | United Kingdom (imports) | .005 - .015 |
| Carrots | United States | .020 |
| White Bread | United States | .004 - .008 |
| Whole Milk | United States | .003 - .010 |
| Beer | United States | .004 |

Source: USA Department of Health, Education and Welfare (1970)

TABLE 2

ANNUAL PER CAPITA CONSUMPTION OF FISH AND SHELLFISH, BY REGION AND COUNTRY

| Region and country | Period | Estimated edible weight (kg) |
|---|---|---|
| North America: | | |
| United States | 1975 | 5.5 |
| Canada | 1973 | 5.9 |
| Latin America: | | |
| Argentina | 1970 | 2.5 |
| Barbados | 1970 | 14.3 |
| Bolivia | 1970 | 0.7 |
| Brazil | 1970 | 2.6 |
| Chile | 1970 | 6.6 |
| Columbia | 1970 | 1.8 |
| Costa Rica | 1970 | 2.2 |
| Cuba | 1970 | 7.4 |
| Dominican Republic | 1970 | 3.8 |
| Ecuador | 1970 | 1.8 |
| El Salvador | 1970 | 1.5 |
| Guatemala | 1970 | 0.4 |
| Guyana | 1970 | 11.7 |
| Haiti | 1970 | 0.4 |
| Honduras | 1970 | 0.7 |
| Jamaica | 1970 | 12.1 |
| Mexico | 1970 | 2.1 |
| Nicaragua | 1970 | 1.1 |
| Panama | 1973 | 9.4 |
| Paraguay | 1970 | 0.4 |
| Peru | 1970 | 9.0 |
| Puerto Rico | 1964-66 | 3.6 |
| Surinam | 1970 | 8.5 |
| Trinidad and Tobago | 1970 | 7.0 |
| Uruguay | 1970 | 1.8 |
| Venezuela | 1970 | 4.7 |
| Europe: | | |
| Albania | 1970 | 1.1 |
| Austria | 1973 | 3.9 |
| Belgium and Luxembourg | 1973 | 8.2 |
| Bulgaria | 1970 | 5.0 |
| Czechoslovakia | 1970 | 3.4 |
| Denmark | 1973 | 35.5 |

| Region and country | Period | Estimated edible weight (kg) |
|---|---|---|
| Europe continued. | | |
| Finland | 1973 | 13.2 |
| France | 1973 | 7.9 |
| Germany, East | 1964-66 | 8.4 |
| Germany, Federal Republic of | 1973 | 3.9 |
| Greece | 1970 | 9.1 |
| Hungary | 1970 | 2.2 |
| Iceland | 1964-66 | 39.1 |
| Ireland | 1973 | 4.9 |
| Italy | 1973 | 6.1 |
| Malta | 1964-66 | 3.3 |
| Netherlands | 1973 | 6.4 |
| Norway | 1973 | 11.5 |
| Poland | 1970 | 6.4 |
| Portugal | 1973 | 22.8 |
| Romania | 1970 | 2.8 |
| Spain | 1972 | 17.0 |
| Sweden | 1973 | 20.8 |
| Switzerland | 1972 | 4.9 |
| United Kingdom | 1973 | 8.2 |
| Yugoslavia | 1973 | 1.5 |
| Union of Soviet Socialist Republics | 1964-66 | 10.2 |
| Near East: | | |
| Afghanistan | 1970 | 0.1 |
| Cyprus | 1970 | 2.6 |
| Egypt | 1970 | 1.3 |
| Iran | 1970 | 0.6 |
| Iraq | 1970 | 2.5 |
| Israel | 1969-70 | 6.6 |
| Jordan | 1970 | 0.7 |
| Lebanon | 1970 | 2.0 |
| Libya | 1970 | 2.9 |
| Saudi Arabia | 1970 | 1.9 |
| Sudan | 1970 | 0.9 |
| Syria | 1970 | 0.7 |
| Turkey | 1970 | 2.5 |
| Yemen Arab Republic | 1970 | 0.4 |
| Yemen (Aden) | 1970 | 12.0 |
| Far East: | | |
| Bangladesh | 1970 | 6.5 |
| Burma | 1970 | 5.4 |
| Sri Lanka (Ceylon) | 1970 | 6.2 |
| China, Peoples Republic of (Peking) | 1064-66 | 3.6 |
| China, Republic of (Taiwan) | 1969 | 15.0 |

| Region and country | Period | Estimated edible weight (kg) |
|---|---|---|
| Far East continued. | | |
| Hong Kong | 1964-66 | 21.2 |
| India | 1970 | 1.1 |
| Indonesia | 1970 | 4.0 |
| Japan | 1973 | 36.4 |
| Cambodia (Khmer Republic) | 1970 | 20.1 |
| Korea, North | 1964-66 | 7.3 |
| Korea, Republic of | 1970 | 9.8 |
| Laos | 1970 | 6.0 |
| Malaysia: | | |
| Sabah | 1970 | 21.0 |
| Sarawak | 1970 | 14.3 |
| West Malaysia | 1970 | 11.0 |
| Nepal | 1970 | 0.4 |
| Pakistan | 1970 | 1.0 |
| Philippines | 1970 | 19.5 |
| Singapore | 1970 | 23.2 |
| Thailand | 1970 | 15.5 |
| Vietnam, North | 1964-66 | 5.5 |
| Vietnma, South | 1970 | 14.4 |
| Africa: | | |
| Algeria | 1970 | 0.6 |
| Angola | 1970 | 4.8 |
| Burundi | 1970 | 1.5 |
| Cameroon | 1970 | 5.3 |
| Central African Republic | 1964-66 | 3.6 |
| Chad | 1970 | 7.5 |
| Congo (Brazzaville) | 1964-66 | 11.3 |
| Dahomey | 1970 | 4.4 |
| Ethiopia | 1970 | 0.2 |
| Gabon | 1970 | 11.0 |
| Gambia | 1970 | 7.3 |
| Ghana | 1970 | 8.6 |
| Guinea | 1970 | 1.5 |
| Ivory Coast | 1970 | 7.0 |
| Kenya | 1970 | 1.5 |
| Liberia | 1970 | 7.0 |
| Madagascar | 1970 | 3.6 |
| Malawi | 1970 | 1.8 |
| Mali | 1970 | 3.0 |
| Mauritania | 1964-66 | 6.2 |
| Mauritius | 1970 | 5.1 |
| Morocco | 1970 | 1.4 |
| Mozambique | 1970 | 1.5 |
| Niger | 1970 | 0.4 |
| Nigeria | 1970 | 5.6 |

| Region and country | Period | Estimated edible weight (kg) |
|---|---|---|
| Africa continued. | | |
| Rhodesia | 1964-66 | 1.1 |
| Senegal | 1970 | 15.0 |
| Sierra Leone | 1970 | 7.7 |
| Somalia | 1970 | 0.5 |
| South Africa, Republic of | 1964-66 | 4.4 |
| Tanzania | 1970 | 3.6 |
| Togo | 1970 | 3.3 |
| Tunisia | 1970 | 2.2 |
| Uganda | 1970 | 8.4 |
| Upper Volta | 1970 | 0.8 |
| Zaire | 1970 | 4.1 |
| Zambia | 1970 | 5.7 |
| Oceania: | | |
| * Australia | 1972 | 5.2 |
| New Zealand | 1972 | 5.2 |
| * Australia | 1975-76 | 6.6 |
| | 1976-77 | 7.0 |
| | 1977-78 | 6.9 |

Note: Data are preliminary.

Source: Food and Agriculture Organization of the United Nations (FAO).

From: (USA, NMFS 1976)

2.3(ii) Current National Controls on Ingestion

Some countries, such as the United Kingdom, have elected to effect control of ingestion of mercury by a continuing monitoring program. Surveys in the UK in 1971-1973 did not produce figures considered to be alarming as to concentrations of mercury in fish, per capita consumption of fish and average amounts of mercury ingested. Many countries have considered controls, but have as yet not instigated any action. Most countries which make regulations place an overall limit on mercury concentrations in fish.

Table 3 presents a summary of current (as of July 1978) permissible levels of mercury in fish in the 15 countries which have introduced controls.

The Netherlands has a "silent norm" (i.e. an unofficial guideline) whereby freshwater fish with concentrations exceeding 1 mg/kg and marine fish with concentrations exceeding 0.5 mg/kg are withdrawn from sale.

In the USA the previous action level of 0.5 mg/kg set by the Food and Drug Administration was raised on 25 May 1978 to 1.0 mg/kg following a District Court ruling and evidence from the National Marine Fisheries Service presented to it.

In Japan there is a provisional guideline of 0.4 mg/kg total mercury. However certain fish species, such as shark and tuna which are stated to have naturally high levels of mercury, are exempted from the regulation.

Some countries such as Finland, Sweden, Norway and West Germany have banned the taking of fish from specified areas, while others, such as Norway, have limited their action to warnings.

Most countries do not attempt to directly control the methylmercury component in fish. Japan has set a separate standard for methylmercury while the U.S. National Marine Fisheries Service, in a 1978 submission to the court case previously referred to, assumed a 90% level of methylmercury. Sweden and most other countries assume a methylmercury fraction close to 100%.

TABLE 3

SUMMARY OF SOME CURRENT PERMISSIBLE LEVELS OF MERCURY IN FISH

| Country | Maximum Permissible Mercury level in mg/kg (ppm) | Remarks |
|---|---|---|
| AUSTRALIA | 0.5 | NH & MRC Recommendation 28.10.71 |
| NSW | 0.5 | Incorporated into the legislation on 21.1.72 |
| QLD | 0.5 | " " " " " 19.5.73 |
| S.A. | 1.0 | " " " " " 22.5.75 |
| TAS. | 0.5 | " " " " " 20.12.72 |
| VIC. | 0.5 | " " " " " 15.3.72 |
| W.A. | 0.5 | " " " " " 1.12.72 |
| BELGIUM | | No specific legislation but a general law states that food should not contain harmful products. Occasionally fish significantly exceeding 0.5 mg/kg are withdrawn from the market. |
| CANADA | 0.5 | Administrative Guideline administered under Food & Drug Act and the Fisheries Act. |
| DENMARK | 1.0 | (a) If fish containing more than 1 mg/kg of mercury are caught in a certain area then the people living in the surrounding district are warned against eating fish more than once per week.<br>(b) The Grindsted-Varde River in Jutland is the only place where there is a prohibition. Here sports fishermen are allowed to fish but not to eat the catch.<br>(c) In the Karrebacksminde fjord district (south west Sjaelland) the local inhabitants have been advised to restrict their fish eating to once per week.<br>(d) Imported tinned fish are limited to 0.5 mg/kg. |
| EUROPEAN ECONOMIC COMMUNITY | | The Scientific Committee of the EEC agrees with the WHO recommendation of a provisional tolerable weekly intake of 0.3 mg of mercury of which no more than 0.2 mg should be methyl mercury. The Committee is not able to lay down limits for mercury in foodstuffs for these reasons:<br>(a) It is not possible to set a limit which could relate widely fluctuating consumptions to a fixed acceptable intake.<br>(b) Since populations and individuals differ greatly in their fish eating habits and the species of fish involved greatly affect the ingestion of mercury, the problem is essentially a local one which should be resolved at a local level.<br>(c) The problem is made more difficult when one considers the importance of fish as a source of protein and any choice of a mercury level is complicated by risk - benefit calculations in the field of nutrition. |

| Country | Maximum Permissible Mercury level in mg/kg (ppm) | Remarks |
|---|---|---|
| FEDERAL REPUBLIC OF GERMANY | 1.0 | A Regulation of 6.2.75 relates to fish, crustaceans and molluscs (fresh weight). Prohibitions on particular fishing areas lie within the competence of the eleven States. |
| FINLAND | 1.0 | (a) There are at present 15 fishing areas that are blacklisted (since 1970). However these areas may soon be taken off the black list as they are considered to be free from mercury.<br>(b) Imported tinned fish 0.5 mg/kg. |
| FRANCE | 0.7 | (a) This limit is for fish expected to have a high level (e.g. tuna). For other fish 0.5 mg/kg applies.<br>(b) There is no legislation in force but random tests are made on imported fish and fish exceeding these limits are barred from the market. |
| GREECE | 0.7 | (a) This is the limit for all seafood caught in Greek waters or imported and intended for local consumption. Legislation is still being drafted and the intention is to change the limit to 0.5 mg/kg.<br>(b) The General State Laboratory is studying the Mediterranean in co-operation with UNEP and FAO with the idea of specifying the mercury pollution and content of fish and shellfish. |
| HOLLAND | | There is no legislation relating to mercury in fish but an unofficial guideline of 1 mg/kg for freshwater fish and 0.5 mg/kg for saltwater fish is applied. Fish exceeding these values are removed from the market. |
| ISRAEL | 0.5 | (a) Both domestic and imported fish have a limit of 0.5 mg/kg applied to them; tuna receive particular attention.<br>(b) A number of samples are taken from any load of fish and, although the reading from any one fish may be up to 1.0 mg/kg, the average must be less than 0.5 mg/kg.<br>(c) No species or areas are prohibited.<br>(d) New legislation is being prepared. |
| ICELAND | 1.0 | (a) The mercury problem is unknown in Iceland.<br>(b) There is very little importation of fish; most is from Scandinavia and is usually tinned fish. |

| Country | Maximum Permissible Mercury level in mg/kg (ppm) | Remarks |
|---|---|---|
| ITALY | 0.7 | (a) There are no recommendations made regarding sizes and quantities per head per week.<br>(b) There are no fishing locale prohibitions. |
| JAPAN | 0.4 total mercury<br>0.3 methyl mercury | (a) Provisional Guideline<br>(b) Tolerable weekly intake of methyl-mercury - 170 microgram for average adult weighing 50kg. Pregnant women and children's diets should be more strictly controlled than this.<br>(c) Fishing is prohibited in the following areas:<br>Tokuyama Bay, Yamaguichi Prefecture<br>Minamata Bay, Kumamato Prefecture<br>Kinko Bay, Kagoshima Prefecture<br>(d) Certain fish species with naturally high mercury levels are exempt from the guideline. |
| KOREA | 0.5 | There is no legislation but this could be rectified at the late 1978 session of the National Assembly. |
| NEW ZEALAND | 0.5 | |
| NORWAY | | (a) Adheres to WHO Standards. "... a provisional tolerable weekly intake of 0.3 mg of total mercury per person of which not more than 0.2 mg should be present as methylmercury (expressed as mercury)..."<br>(b) People are warned against eating fish from Sorfjorden.<br>(c) No lakes in Norway are blacklisted. |
| POLAND | | There is no specific legislation but decisions are made on a case by case basis. The Ministry of Health regards 0.5 mg/kg to be acceptable in fish. |
| PORTUGAL | | (a) There are no specific prohibitions or regulations for domestic use.<br>(b) Exports are regulated according to legislation in force in the importing country. The authorities work to the 1972 FAO standard of 0.5 mg/kg.<br>(c) No legislation is contemplated but EEC standards will presumably apply when Portugal becomes a full member. |
| SPAIN | 0.5 | |

| Country | Maximum Permissible Mercury level in mg/kg (ppm) | Remarks |
| --- | --- | --- |
| SWEDEN | 1.0 | (a) Those fish which should not be eaten are listed as are those fish which may be eaten daily or weekly only.<br>(b) Species containing between 0.2 and 1.0 mg/kg should only be eaten once a week.<br>(c) "The National Swedish Food Administration's Code of Statutes" sets out numerous lakes and rivers throughout Sweden which are blacklisted on account of mercury contamination.<br>(d) Imported tinned tuna fish are subject to a 0.5 mg/kg limit. |
| SWITZERLAND | 0.5 | |
| THAILAND | 0.5 | (a) The Department of Fishery is studying mercury in fish in order to propose laws relating to mercury in fish.<br>(b) The Department of Industrial Works controls industrial effluent which must not exceed 1 mg/kg.<br>(c) The National Environment Board is conducting a survey on the impact on water resources of mercury discharges.<br>(d) The Food & Drug Administration controls food packed in metal containers and requires that mercury in seafood does not exceed 0.5 mg/kg. |
| USA | 1.0 | The Food and Drug Administration issued a new Administrative Guideline on 25 May 1978 which raised the action level for mercury in fish from 0.5 mg/kg to 1.0 mg/kg. |
| U.S.S.R. | 0.2 | (a) River fish. |
| | 0.3 | (b) Tinned fish and fish products from river fish. |
| | 0.5 | (c) Fresh fish, tinned fish and fish products from sea and ocean fish. |
| | 0.7 | (d) Fresh tuna. |
| | 1.0 | (e) Tinned tuna. |

## 2.3(iii) Controls on emission of mercury

It is widely recognized that some human intake of mercury is inevitable due to its widespread natural occurrence but that nevertheless, this intake must be limited in every practical way. One obvious mode of action is the restriction of the use and/or discharge of mercury into the environment. Various countries have applied systems of control based on the view that discharges of mercury should be restricted to the lowest possible quantities and that the initial obligation rests with the persons or industries responsible for the disturbance. Ideally, regulatory action should precede any damage which might occur.

The European Economic Community has recommended the adoption by member countries of uniform emission standards for their industries. Not all members, for example the UK, favoured this approach, and instead the alternative of Environmental Quality Objectives (EQO) was proposed. With reference to mercury, man being likely to be the most sensitive target organism and fish one of the major routes of uptake, it was proposed that the EQO be set so that fish are acceptable as food for human consumption. This objective has provided the basis for epidemological studies of extreme fish eaters from UK coastal areas known to be polluted by mercury (Lindsay in press; see Section 2.5 of this report) and the results are being submitted to the EEC.

## 2.4 Accumulation of mercury in fish

### 2.4.(i) Sources of mercury

The total global amount of mercury is, clearly, fixed. However, several distinguishing properties of mercury provide sufficient reason for continuing assessment of mercury as a potential contaminant and, therefore, as a health risk. They are: its local concentration, its occurrence in physical forms which can be transported in the environment, and its transformation in the environment from inorganic to more toxic forms (OECD 1974 p.131).

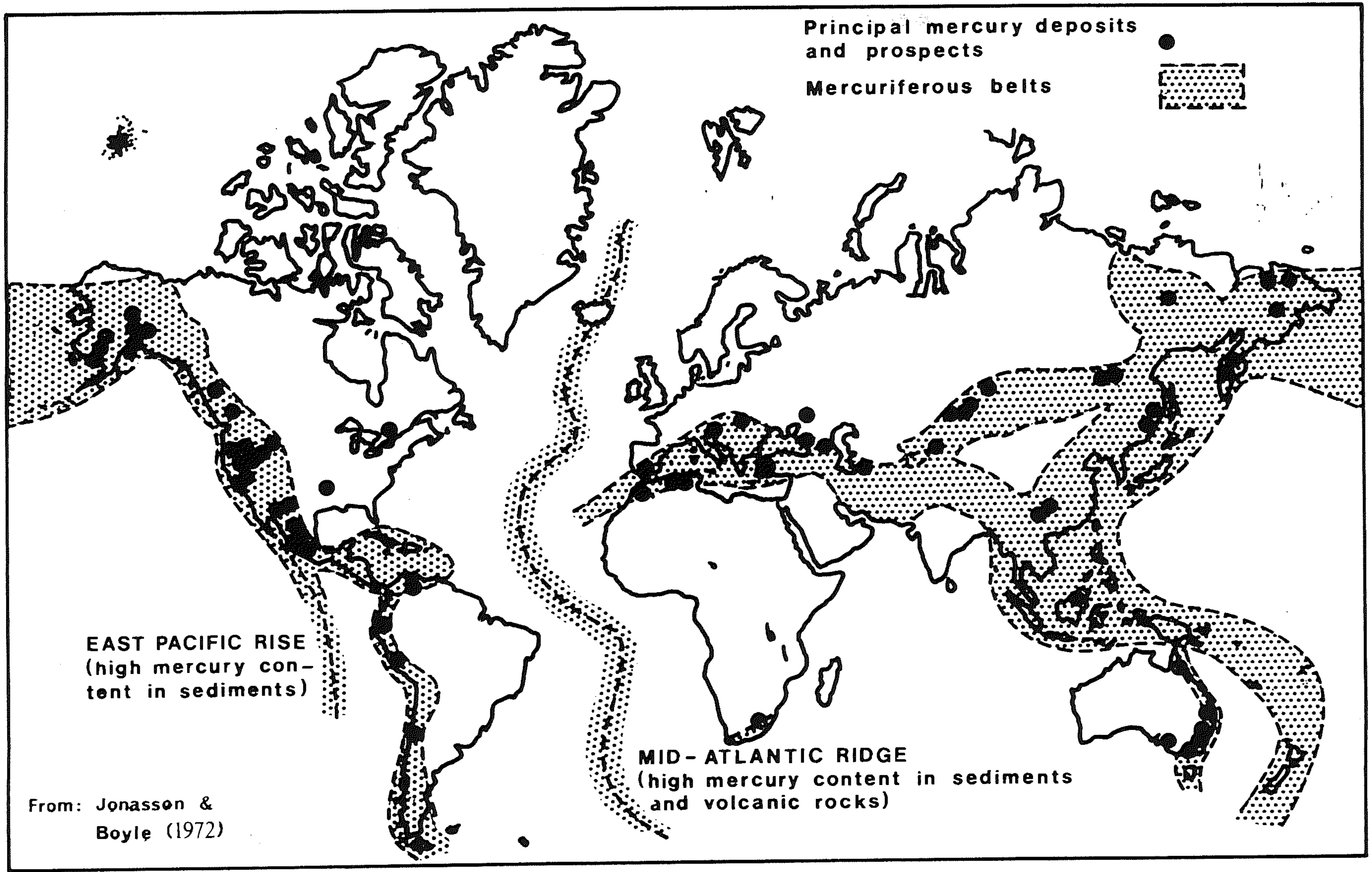
Mercury occurs naturally in the environment, concentrated in geographical belts. A generalized map of the mercuriferous belts of the earth in which most of the major mercury deposits and prospects are located is presented in Figure 1. Clear areas do not necessarily denote areas free of mercury, but simply that at present no published data are available. Implementation of international programs, such as the Global Investigation of Pollution in the Marine Environment (GIPME) by the Intergovernmental Oceanographic Commission, in which Australia is participating, will in future years provide additional data for these areas.

Geological cycling has distributed the element in all strata of the earth where it is in a constant state of transport and distribution. Degassing of the earth's crust alone can result in a circulation of 25,000 to 125,000 tonnes per year (WHO 1976 p.19).

Natural concentrations of mercury are approximately 100 ng/kg (ppb) in soil, 60 ng/kg in fresh water, 0.003-0.009 mcg/$m^3$ in air and 10-30 ng/kg in sea water (Hugunin and Bradley 1975). It is estimated that the total mercury content in the oceans is at least 70 million tonnes. Annual atmospheric circulation of elemental mercury vapour resulting from erosion and weathering contributes some 5000 tonnes to the sea, but these losses together with those resulting from man's activities do not significantly affect the oceans' level of mercury (WHO 1976 p.19). Indeed, recent measurements on the Greenland ice cap indicate that there has been no increase in mercury levels in historical times (Applequist et al 1978).

Some recent papers suggest that differences in estimates of mercury in various ocean waters have significance. When comparing levels in North East Pacific and South Polar Seas, the former have an average surface concentration of mercury of 24 ng/kg (Williams et al 1974), while a transect south of New Zealand to the Ross Sea gave surface levels ranging from 53 to 112 ng/kg. The high levels in the Polar area are thought to be due to active volcanism in that area. Other studies on the other hand, using highly sensitive techniques, have found higher values in northern

FIGURE 1




GENERALIZED MAP SHOWING THE MERCURIFEROUS BELTS OF THE EARTH.

hemisphere waters, up to 33.5 ng/kg, and down to 11.2 ng/kg in the southern hemisphere, in the Indian Ocean (Gardner 1975). This suggested that a true background or base level in the oceans might be around 11.2 ng/kg, while higher values for (near) surface mercury can be attributed to atmospheric fallout from industrial pollution transported via the jet streams. The measurements obtained certainly support that hypothesis.

The importance of mercury concentrations in the ocean was demonstrated in a later study (Gardner 1978). A linear relationship was found between mercury concentrations in fish and in the waters adjacent to the UK. Surface water mercury concentrations ranged from 0 to 443 ng/kg and mean values from 16.6 to 57.8 ng/kg.

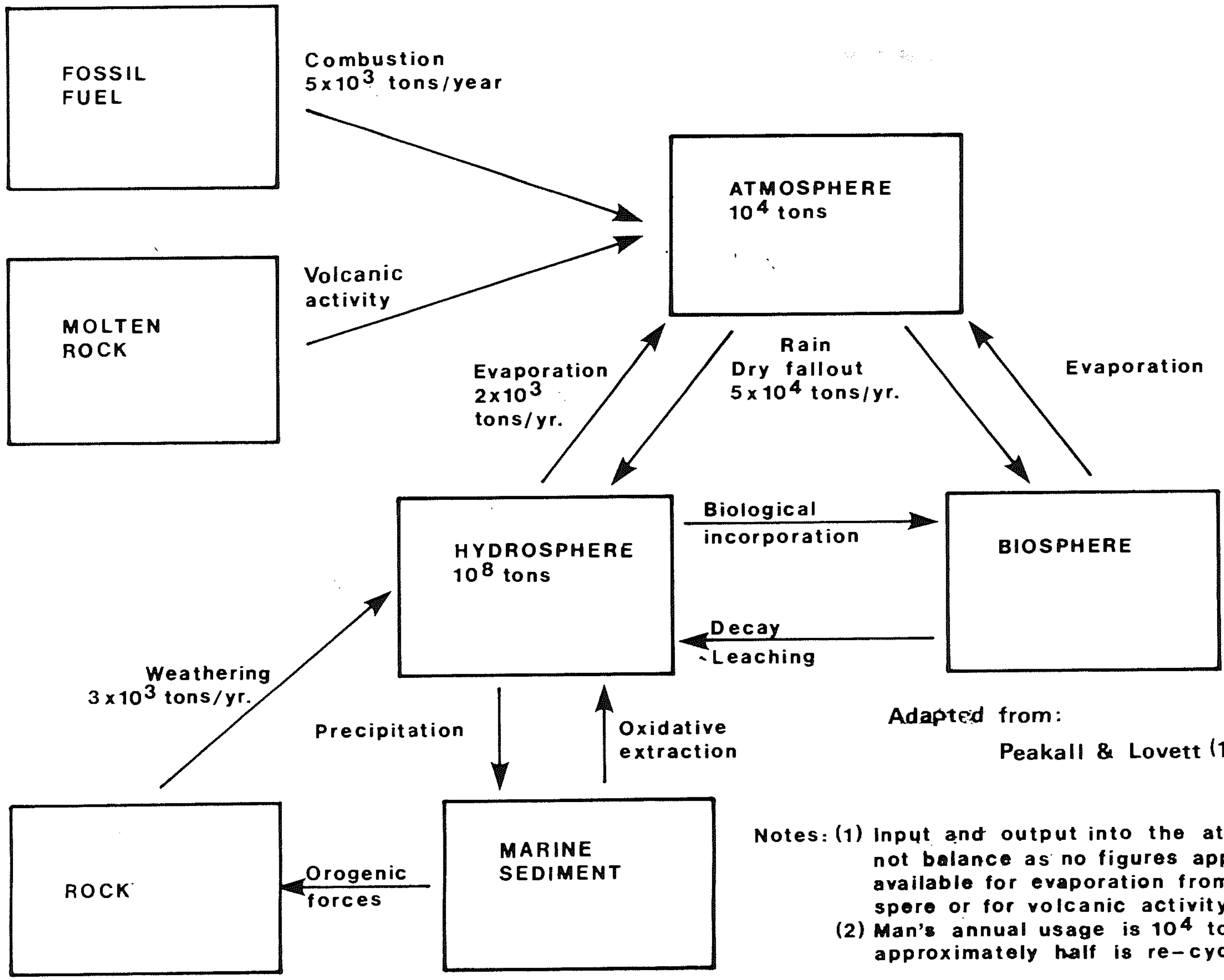
In 1973, world mining and smelting production of mercury was estimated at 10,000 tonnes and has been increasing by an annual rate of about 2%. Mercury is used widely in the chloralkali, electrical equipment (especially fluorescent light manufacture) and paint industries and also finds other applications in agriculture, the pulp and paper industry, medicine and dentistry. Processes for recovering, reclaiming and repurifying mercury from boilers, electrical apparatus, dental amalgams, batteries and catalyst processes have been developed however, and secondary mercury production is expected to significantly reduce this figure (Hugunin and Bradley 1975).

Supplementary activities also account for a substantial release of mercury into the environment. These include the burning of fossil fuels, the production of steel, cement and phosphate, and the smelting and extraction of metals from, for example, their sulphide ores (WHO 1976). Part of the emissions at least are dispersed broadly into the oceans (Gardner 1975, 1978).

Dependent upon these distributions, mercury then finds its way into the food chain due to methylation of inorganic mercury in the sediments of lakes, rivers and other waterways and in the oceans. Methylmercury accumulates in aquatic organisms according to trophic level and the highest concentrations are found in the large carnivorous fish. (See Section 2.4(iii)).

A schematic diagram of the overall global cycling and distribution of mercury is presented in Figure 2. The system of natural mercury transport and distribution is still, however, not well understood. Similarly, the movement of natural and man-made sources in waterways and the transformation of mercury in sediments require further clarification.

## ƆVERALL GLOBAL CYCLING OF ˎ .RCURY.




Adapted from:

Peakall & Lovett (1972)

Notes: (1) Input and output into the atmosphere do not balance as no figures appear to be available for evaporation from the bio-spere or for volcanic activity.

(2) Man's annual usage is $10^4$ tons of which approximately half is re-cycled.

FIGURE 2

### 2.4 (ii) Mechanisms of accumulation of mercury in fish

The mobilization of mercury in the environment is of primary importance when considering its uptake by aquatic organisms. Most interest has centred on the methylation of elemental mercury, as it is in the methylated form that mercury is considered to be most frequently taken up (Fagerstom and Asell 1973).

Most work has been undertaken in freshwater and estuarine systems. Elemental mercury is methylated by chemical means (a non-enzymatic process mediated by methylcobalamin) and by sediment micro-organisms such as bacteria and fungi (Mason et al 1979) in both aerobic and anaerobic conditions (Jensen and Jernelov 1969) and is then readily released into the water mass (Fagerstom and Jernelov 1974). The rate of methylation is dependent on the particular micro-organisms present (Hartung, 1973) and various physico-chemical factors. Methylation is promoted when there is an alkaline pH and a high organic content in the sediment (Matsumura et al 1972), and also when the temperature is elevated (Jernelov 1972a).

In many polluted areas the level of methylmercury has been below detectable limits due either to its rapid mobilization or possible competing processes such as demethylation and the presence of methylation-inhibiting methogenic bacteria (Aston et al 1972). For example, methylmercury in the sediments and vegetation of a polluted saltmarsh ecosystem were undetectable, although elevated levels were found in the primary producers (Windom et al 1976). An annual production of 50 micrograms of methylmercury per gram of total mercury in the sediment was established. A wide range of bacteria appear to be capable of demethylation, although all are anaerobes and *Pseudomonas* species appear to predominate (Shariat et al 1979).

There are two possible pathways for uptake of available mercury by aquatic organisms; firstly via the food web and secondly by direct extraction of methylmercury from the aqueous medium.

Bacteria compete very effectively with sediment in accumulating mercuric ions from river water. They therefore have a significant effect on the mobilization of mercury from the sediment sink into the food chain (Ramamoorthy et al 1977). However mercury can also be taken up higher in the food chain through ingestion of organic detritus complexed with mercury. Uptake direct by filter feeders such as oysters, barnacles and clams appears common (Guthrie et al 1979).

The complexity of the food web is a major limiting factor on the amount of mercury accumulated (Peterson et al 1973) and the organisms at higher trophic levels tend to accumulate more mercury. It has been suggested that the food web will contribute mercury to fish to a certain base level, and above this level mercury is accumulated directly from the water body (Jernelov 1972b).

Direct extraction of mercury from the water body is possible by its affinity for anionic groups, especially the sulphydryl groups of proteins (Lofroth 1970). Uptake could be either directly through the skin or via the gills. In trout at least, uptake is primarily via the gills as the skin has been demonstrated to be relatively impermeable (Olson et al 1973).

The rate of uptake is probably a function of both the concentration of mercury in the water body, its form and the metabolic rate of the fish concerned. For example, increasing temperature increases the accumulation rate in trout, as does increasing concentration (Reinert et al 1974). A study with labelled mercury compounds indicated a wide variation in rate of uptake, with methylmercury being the most readily accumulated (Hannerz 1968), while mercuric chloride uptake is much more rapid than mercuric sulphate uptake (Gillespie and Scott 1971). Tracer studies (Pentreath 1976) have also been made using marine fish (plaice and thornback ray) from which it was concluded that both inorganic and organic mercury are readily absorbed from seawater. Retention of the two forms from food was dissimilar in that methylmercury, in contrast to inorganic mercury, is only slowly eliminated. No evidence was obtained for methylation of the tracer in inorganic mercury obtained from seawater.

Some attempts have been made to model the uptake of methylmercury in, for example, a simple three stage system (chironomids-roach-pike) in a Swedish fresh water body (Fagerstrom and Asell 1973). The main result was the pin-pointing of direct uptake of methylmercury from the water as the most important subject for further study.

Once taken up into the blood stream mercury is then differentially distributed within the body (See Section 2.4(iv)).

## 2.4 (iii) Concentrations of Total Mercury in Fish

### (a) Information from other countries

The following summary of a WHO (1976) review provides a useful indicator of the global situation:*

### (1) GLOBAL SUMMARY

#### a. Freshwater

The earliest reported mercury levels in freshwater fish ranged from 0.03 to 0.18 mg/kg wet weight (Stock and Cucuel 1934, Raeder and Snekvik 1949). Upper limits in uncontaminated waters have been quoted at 0.2 mg/kg for Sweden (Lofroth 1970), 0.15 mg/kg for Canada (Sprague and Carson 1970), and 0.10 mg/kg for Japan (Ui 1969, WHO Regional Office for Europe 1973). References from Europe indicated that fish in contaminated freshwater areas may have values of 0.2 to 0.5 mg/kg, and in heavy pollution, as high as 20 mg/kg (WHO Regional Office for Europe 1973).

Freshwater fish in Western Europe ranged from 0 to 1.0 mg/kg with most values between 0.2 and 0.4 mg/kg (Bouquiaux 1974). Pike from contaminated waters in Finland and Sweden had "natural" background levels of 0.05-0.2 mg/kg. In areas of low contamination levels were in the region of 0.5 mg/kg. However in some 1% of the central Swedish lakes mercury levels from 1.0 to 5.0 mg/kg have been found (Swedish Expert Group 1971).

#### b. Marine

The concentration of mercury in marine fish also shows marked variations. Not all the factors responsible for these variations are understood but it is generally recognised that the species of fish, the geographical location, and the age and weight of the fish are important. The highest values of mercury are usually seen in those fish at the end of a long food-chain such as the large carnivorous species.

Canned tuna from Western Europe contained mercury in the range 0.2 - 0.5 mg/kg. Other canned species from that area also contained up to 0.5 mg/kg. Salmon appears to have low levels of mercury - measurements of some 260 samples of Atlantic Ocean, Canadian and Baltic Sea salmon had mercury levels ranging up to 0.15 mg/kg with most values being close to 0.05 mg/kg.

Recent reports (Peterson et al 1973, Bouquiaux 1974) indicate that mercury levels in most oceanic fish fall in the range 0 - 0.5 mg/kg, with most values close to 0.15 mg/kg wet weight (1,600 samples).

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* Mercury values given in mg/kg rather than ng/kg.

The most important exceptions to this rule are swordfish, tuna fish and halibut, whose values usually range from 0.2 to 1.50 mg/kg (reviewed by the Joint FAO/WHO Expert Committee on Food Additives 1972). Skipjack, white tuna, and yellowfin tuna (911 samples) ranged from 0 to 1.0 mg/kg with most values ranging from 0.2 to 0.3 mg/kg. These samples were caught in the Atlantic, Pacific and Indian Oceans. Bluefin tuna from the Bay of Biscay (285 samples) ranged from 0.2 to 0.8 mg/kg with most values close to 0.5 mg/kg. The same species caught in the Mediterannean Sea (136 samples) ranged from 0.5 to 2.5 mg/kg with most values close to 1.10 mg/kg. Big eye tuna (20 samples from various origins) had mercury values ranging from 0.4 to 1.0 mg/kg. Over 5,200 samples of tuna, variety not specified but originating from Italy, had levels in the range of 0 - 1.75 mg/kg with most values ranging from 0.3 to 0.5 mg/kg wet weight.

Swordfish caught in the western Atlantic (210 samples) had mercury values ranging from 0.05 to 4.9 mg/kg with a mean value of 1.15 mg/kg. 40 samples of swordfish, originating near Italy, had values ranging from 0.65 to 1.75 mg/kg with most values close to 1.10 mg/kg wet weight.

Certain countries are of particular interest with regard to mercury in fish - Japan, the site of the first poisonings, and its present mercury standard for most species of 0.4 mg/kg; Canada, in view of the discovery of possible poisonings in Indian communities; the USA, where the "action" level for mercury has been increased from 0.5 to 1.0 mg/kg; the UK where no domestic mercury limit has been found necessary; New Zealand in view of its proximity.

More detailed data on mercury levels in fish from these countries appear below:

'ˆ) JAPAN

a. Freshwater

The few mercury data available from the Tokyo fish market for trout, salmon, eels and carp were all below 0.10 mg/kg (Amemiya et al 1975, 1976).

b. Marine

Analyses of a broad cross section of fish species marketed in Tokyo showed that deep sea fishes had higher mercury concentrations than fishes of the continental shelf (Amemiya et al 1975, 1976). Mean mercury concentrations ranged from 0.03 to 0.60 mg/kg, but sample numbers were mostly very small. The majority of results were less than 0.10 mg/kg mercury. However high mean levels were recorded for shark, 0.89 mg/kg (2 samples) and tuna 0.93 mg/kg (2 samples).

Other researchers have studied individual species more thoroughly and found that yellowfin tuna had a mean mercury level of 0.20 mg/kg in fish of weights between 4.2 and 65.4 kg (Ueda and Takeda 1977). Other studies (Nishigaki et al 1973) have found tunas, apart from big eye tuna, to have levels between 0.07 and 1.25 and big-eye to be up to a concentration of 2.31 mg/kg. Marlin ranged from 0.03 to 13.02 mg/kg mercury.

Fish from Minamata Bay, at the time of the outbreaks of poisoning, ranged in mercury concentration from 1 to 36 mg/kg. Outside the Bay the range was 1 to 13.5 mg/kg while in uncontaminated waters around Japan the same species always contained less than 1.0 mg/kg mercury (Takeuchi 1972).

(3) CANADA

a. Freshwater

Levels between 0.05 and 1.54 mg/kg have been found depending on species and area of sampling (Jervis et al 1970). Clear differences in mercury levels in fish have been found at different sites below a chlor-alkali plant in the Saskatchewan river system (Sumner et al 1972). Mercury in pike from areas of no known pollution had a mean mercury level of 0.24 mg/kg, 300 miles below the plant the level was 1.94 mg/kg and near the plant itself 4.80 mg/kg. Other species from lakes without any known source of mercury contained mercury levels up to 1.13 mg/kg. Mercury concentrations were found to vary between areas such that it was recommended that each population must be treated as a separate entity when making investigations (Scott and Armstrong 1972). Populations of American eels in Canadian waters ranged from 0.11 - 1.60 mg/kg total mercury in one study (Freeman and Horne 1973a) and 0.07 to 2.08 mg/kg methyl mercury in another (Zitko et al 1971). Samples of fifteen species in the Great Lakes had levels of 0.03 to 0.15 mg/kg (Brown and Chow 1977).

b. Marine

Levels of 0.04 to 0.31 mg/kg were found in individual samples of 10 Canadian marine species (Jervis et al 1970). Atlantic coast fish species ranged from 0.05 mg/kg (clupeoids) to 0.41 mg/kg (skate) (Freeman et al 1974). Bay of Fundy fish were almost all below 0.10 mg/kg except skate, which ranged up to 0.24 mg/kg (Zitko et al 1971). The high levels found in swordfish (Xiphias gladius) (mean landed levels in excess of 1mg/kg) off the Canadian Atlantic coast forced the closure of the fishery for that species in 1971 (Caddy 1976). It was suggested that landings with mean mercury content of less than 0.5mg/kg could have been attained if fishing had been resumed at a high (1971) intensity, although cost per unit effort would also be high. Dogfish from the Strait of Georgia, British Columbia were found to have a mercury content in excess of 0.5 mg/kg at 72 cm for the males and 77 cm for the females (Forrester et al 1972). Values ranged from 0.05 mg/kg in embryos up to 2.0 mg/kg in large (120 cm) females, while samples taken from the Fraser River estuary had higher mercury levels at specified lengths than other areas sampled.

(4) USA

a. Freshwater

The results of a very comprehensive survey of mercury levels found in freshwater fish within the major American river systems are summarized in Table 4a (Henderson et al 1972). With few exceptions, highest levels were found in top predators.

b. Marine

Some of the results of large samples of ocean fish mercury determinations by a number of authors are summarised in Table 4b.

The National Marine Fisheries Service has been conducting a survey of heavy metals in seafoods since 1970. Results of a preliminary survey (Zook et al 1976) for 13 marine fish species showed two with mean mercury levels exceeding the then USA "guideline" maximum of 0.5 mg/kg - a snapper (*Lutjanus compechanus*) and a rockfish. Mean values for the remainder were 0.33 mg/kg and lower. A later, more comprehensive listing of data from this survey (Hall et al 1978) measured a wide range of trace elements in 204 species of finfish, Mollusca and Crustacea from 198 sites around the US coast, representing 93% by volume of that countries commercial and sportfish catch. A mean mercury level in excess of 0.5 mg/kg was found in only 2% of the catch intended for human consumption. The species containing these levels were those mentioned above, gether with the Pacific halibut *Hippoglossus stenolepis*.

(5) UNITED KINGDOM

a. Freshwater

A United Kingdom Working Party (The Working Party on the Monitoring of Foodstuffs for Mercury and Other Heavy Metals 1971) gave a range of means from 0.08 to 0.47 mg/kg for twelve freshwater fish. Pike had the highest average and maximum (1.6 mg/kg) levels. These results were confirmed in a Supplementary Report by the Working Party (Supplementary Report by the Working Party on the Monitoring of Foodstuffs for Mercury and Other Heavy Metals 1973), (Table 5a). A number of freshwater fish species were sampled and the results were similar to those for Sweden where pike had mean concentrations in excess of 0.5 mg/kg. Other concentrations were much lower.

The latter report also included a survey of trout and grayling in an area of localised contamination (site of an organomercury dip for seed potatoes). The results are reproduced in Table 5b. It was noted that only a small proportion of mercury in the contaminated fish was methyl mercury. Bans on fishing in this area have now been lifted as concentrations are now similar to those found in other freshwater areas (Supplementary Report by Working Party 1973).

b. Marine

The Working Party described above, in its 1971 report, compared mercury levels in commercial fish taken in various waters adjacent to the UK.

The means for fish from several distant water fishing grounds (Greenland, Ireland, Norway and the Barents Sea) ranged from 0.05 to 0.1 mg/kg. For middle distance waters (the North Sea) it was a mean value of 0.11 mg/kg and for coastal waters of the United Kingdom it was a mean value of 0.21 mg/kg. The average for the total catch was estimated to be 0.08 mg/kg. None of the fish from the middle and distant waters, when analysed, had levels exceeding 0.5 mg/kg. Mercury in fish from coastal waters ranged up to 2.5 mg/kg.

Mean mercury levels in cod, haddock and plaice, the main species landed, were 0.08, 0.07 and 0.11 mg/kg respectively, again with slightly higher levels from coastal fishing grounds.

The 1973 Supplementary Report found the mean levels of mercury in fish and shellfish virtually unchanged from those quoted in the first report of the Working Party.

(6) NEW ZEALAND

a. Freshwater

The only data published relate to trout (Brooks et al 1976). In most lakes studied some fish exceeded the 0.5 mg/kg limit applicable in New Zealand. Geothermal activity accounted for most of the elevated levels which ranged up to 3.0 mg/kg in fish muscle.

b. Marine

Snapper (the species which also occurs in eastern Australia) is the only species for which specific data have been published (Robertson et al 1975). Average levels in commercial fish catches were found to be 0.25 mg/kg with a range from 0.12 to 0.57 mg/kg. In larger snapper, said to be rarely seen in the market, mercury levels ranged up to 1.30 mg/kg.

## TABLE 4

### SUMMARY OF MERCURY LEVELS IN FISH IN USA

(a) Freshwater

| River System | Mercury Ranges (mg/kg) |
|---|---|
| Atlantic Coastal Streams | 0.05 - 1.80 |
| Gulf Coastal Streams | 0.05 - 0.92 |
| Great Lakes Drainage | 0.05 - 1.30 |
| Mississippi River System | 0.13 - 0.60 |
| Colorado River System | 0.05 - 0.27 |
| Interior Basins System | 0.05 - 0.65 |
| California Streams | 0.09 - 0.23 |
| Columbia River System | 0.07 - 1.70 |
| Pacific Coastal Streams | 0.14 - 0.47 |
| Alaskan Streams | 0.05 - 0.26 |
| Hawaiian Stream | 0.06 - 0.43 |

Source: Henderson et al (1972)

(b) Marine

| Species | Mercury Content (mg/kg) | |
|---|---|---|
| | means | range |
| Yellowfin tuna | 0.13 - 0.47 | 0.06 - 1.32 |
| Skipjack tuna | 0.15 - 0.31 | 0.11 - 0.64 |
| Albacore | 0.16 - 0.20 | 0.13 - 0.27 |
| Bluefin tuna | 0.21 - 0.68 | 0.04 - 0.91 |
| Blue marlin | 3.57 - 4.78 | 0.35 - 14.0 |
| Red snapper | 0.32 - 0.48 | 0.11 - 0.86 |
| Salmon | 0.02 - 0.07 | 0.00 - 0.24 |
| Mackerels | 0.11 - 0.31 | 0.00 - 1.33 |
| Swordfish | 0.88 - 1.15 | 0.05 - 4.90 |
| S rks | 0.46 - 0.62 | 0.06 - 1.56 |
| Flounders & Soles | 0.09 - 0.24 | 0.00 - 0.50 |
| Haddock | 0.04 - 0.10 | 0.00 - 0.18 |
| Halibut | 0.25 | 0.02 - 1.52 |
| Cod | 0.17 | 0.04 - 0.40 |

Source: Zook et al (1976)

## TABLE 5

## MERCURY LEVELS IN FISH IN THE UNITED KINGDOM

(a) Mercury in freshwater fish
(expressed as mg total mercury per kg)

| Species | Number | Mean | Range |
|---|---|---|---|
| Pike | 25 | 0.52 | 0.06-1.3 |
| Brown trout | 167 | 0.09 | 0.02-0.26 |
| Rainbow trout (fish farms) | 29 | 0.03 | 0.02-0.08 |
| Sea trout | 47 | 0.04 | 0.01-0.12 |
| Roach | 4 | 0.24 | 0.11-0.35 |
| Eel | 40 | 0.16 | 0.07-0.30 |
| Tench | 9 | 0.28 | 0.19-0.37 |
| Perch | 6 | 0.20 | 0.09-0.34 |

(b) Mercury in freshwater fish taken from an area of localised contamination
(expressed as mg total mercury per kg)

| Sampling area and species | | Number | Mean | Range |
|---|---|---|---|---|
| In stream at source of contamination: | | | | |
| | Trout | 4 | 11 | 3.4 - 20 |
| | Grayling | 6 | 8.6 | 6.1 - 12 |
| In stream below source of contamination (up to 1,000 yards): | | | | |
| | Trout | 20 | 2.8 | 0.10 - 9.0 |
| | Grayling | 4 | 1.8 | 0.16 - 4.7 |
| At confluence with river: | | | | |
| | Trout | 14 | 1.3 | 0.12 - 5.8 |
| | Grayling | 15 | 0.39 | 0.12 - 0.61 |
| In river approximately 2 miles downstream: | | | | |
| | Trout | 5 | 0.23 | 0.17 - 0.32 |
| | Grayling | 8 | 0.24 | 0.15 - 0.39 |

Source: Working Party on the Monitoring of Foodstuffs for Mercury and other Heavy Metals (1973).

The Ministry of Agriculture and Fisheries monitors mercury levels regularly and provides a list of marine fish which qualify for mercury status certificates. The certificate indicates that mercury levels in the consignment are less than 0.5 mg/kg. The most recent list (Anonymous 1977) included 29 marine species, with mean mercury levels ranging from 0.01 mg/kg (lemon sole) to 0.33 mg/kg (snapper, kahawai = Australian salmon and kingfish). No shipments of ling may be certified if any fish in the shipment exceeds 120 cm whole length.

(b) Relation between Accumulation of Mercury with Size, Age and Locality of Fish

In some migratory predatory fish, mercury levels tend to increase with size, as for example swordfish in the western Atlantic (Beckett and Freeman 1974). Blue marlin off Hawaii and southern California also showed this trend, but striped marlin from the same areas did not (Shomura and Craig 1974).

While "trend" means a positive correlation between the two parameters, it is often a very loose one, and individual data exhibit a wide scatter in many instances. This may be due to changes in mercury uptake during the annual migratory cycle, e.g. of swordfish (Beckett and Freeman 1974) or age and sex differences, e.g. of tuna (Peterson et al 1973) or geographic variation, e.g. Australian gummy shark (Walker 1976).

In other cases no relationship between mercury level and size can be found statistically, because, for example, of the wide scatter.

The variation in mercury level between catches of fish of the same species from different areas can be particularly marked. In North Atlantic halibut differences in the mercury content of prey species in different areas was attributed to the availability of large prey species which contained high vels of mercury (Topping and Graham 1977).

For North Pacific halibut a significant difference in mercury content of fish from different areas is exhibited from north to south across the species range (Hall et al 1976). However in other North Atlantic trawl species such as ling, dogfish and blue whiting, only dogfish exhibited a significant variation of mercury level with catch area (Topping and Graham 1978). This is similar to the situation for dogfish from the Straits of Georgia, British Columbia, where there is a significant difference in mercury levels of similar sized fish caught within short distances of each other (Forrester et al 1972).

A significant correlation has been found between mean mercury content of fish landed in the United Kingdom and the mean mercury content of the water body in which the fish were caught. Concentration factors have been found to range from $29 \times 10^3$ in distant (Atlantic) waters to $10.6 \times 10^3$ in the adjacent Irish Sea (Gardner 1978). These higher levels were attributed to land based sources of both natural and human origin. A similar variation of mercury level with area has also been found in New Zealand snapper, with higher levels attributed to volcanic activity in the vicinity of the fishing ground (Robertson et al 1975).

Mercury accumulation in northern pike in Sweden was adequately described by a model of three variables; weight, growth rate and body burden (Fagestrom et al 1973, 1974). Swedish northern pike have been found to take up more than 20% of mercury in their diet (Peterson et al 1973, quoting Jernelov). Other studies with northern pike however (Olsson 1976) have found that only length is adequately correlated with mercury content as weight is too variable to accurately reflect turnover of mercury. This was attributed to the variable (seasonal) nature of the fish's food supply (and hence weight), while the length of a fish seldom decreases. Indeed, the size of fish and the correlated metabolic turnover was more important than age or exposure in determining mercury concentration in the fish (Olsson 1976). A successfully predictive model of mercury uptake in Canadian yellow perch has also been produced (Norstrom et al 1976), based on caloric requirements for respiration and growth, concentration of pollutant and assimilation efficiency in the diet.

A large number of species have been reported to accumulate significantly more mercury with age, length or weight. Dogfish in some areas of the North Atlantic (Topping and Graham 1978) and the North Pacific (Forrester et al 1972) showed a significant correlation between mercury concentration and length. There was also a significant difference between the accumulation rates of males and females (Forrester et al 1972). A similar correlation between mercury concentration and length has been reported for New Zealand snapper (Robertson et al 1975), and North Atlantic ling (Topping and Graham 1978). In other species correlations have been found between mercury concentration and age in ling and whiting and/or weight in halibut.

An idea of the complexity of mercury - size relationships in freshwater fish is shown in the findings of research on a variety of Canadian species (Scott and Armstrong 1972). Overall, there was a correlation between mercury content and fish length. However the relationship was not consistent even within species, but varied from sample to sample. For some species there was a strong correlation between mercury and length, while for others no correlation, and yet others a negative correlation.

In coho salmon no such correlation was found (Spinelli and Mahnken 1976). Mercury content remained constant during laboratory aquarium tank experiments, suggesting a balanced uptake and loss of mercury.

2.4(iv) Accumulation by different fish tissues

Differential mercury accumulation between tissues reflects both the extent of that tissue's involvement in mercury metabolism and also its importance as a site of final deposition within the body. Table 6 outlines the results of various investigations of differential mercury distribution in fish. The tuna-like fishes exhibit mercury levels in red and white muscle at least as high as those of the organs such as the liver and kidney, both of which play critical roles in normal metabolic processes. In contrast, other fish generally exhibit higher mercury levels in the liver and kidneys.

The muscle tissue appears to act as a reservoir for rcury and methylmercury, and the elimination of the metal from the muscle proceeds at a slower rate than from the other organs (Giblin and Massaro 1973). The relative distribution of mercury in different fish tissues appears to be dependent on such factors as the level of pollution, the relative amount of methylmercury present and whether the body load is increasing or decreasing (Hannerz 1968). At high and moderate pollution levels, the highest mercury concentrations are found in the liver and kidney, while at low levels of pollution the muscle contains the highest concentrations. The muscle tissue probably represents the ultimate site of mercury distribution in the fish, after its passage through the liver and kidney.

The form of the mercury ingested determines its site of first deposition. Methylmercury is more mobile than inorganic mercury and concentrates initially in the liver and kidney. Inorganic mercury ingested directly concentrates initially in the gills (Renfro et al 1974).

Most fish appear to be able to methylate inorganic mercury in the absence of intestinal micro-organisms, an ability which is greater in tuna-like fish. This ability has been attributed to methylcobalamine (Imura et al 1972), but other workers contend that a protein-bound fraction is responsible (Matsumura et al 1975).

The ratio of methylmercury to total mercury in different fish tissues indicates partial physiological control over the form in which mercury is held. For example, in Pacific blue marlin the ratio is between 1:4 and 1:6 (MeHg: Hg) in most organs, but up to 1:35 in the liver (Shultz et al 1976). These ratios imply an ability to demethylate mercury in pelagic fish in particular, as tuna and marlin have a mercury metal content much higher than other fish so far examined.

## TABLE 6

## RELATIVE ACCUMULATION BY DIFFERENT FISH TISSUES

a) Relative accumulation of total mercury and methyl mercury in billfish (in order of decreasing concentration).

| Bonito | | Pacific blue marlin | |
|---|---|---|---|
| Total-Hg | Methyl-Hg | Total-Hg | Methyl-Hg |
| White muscle | White muscle | Liver | Muscle |
| Red muscle | Red muscle | Muscle | Liver |
| Heart | Spleen | Central nervous tissue | Central nervous tissue |
| Kidney | (Heart | Gonad | Gonad |
| (Pyloric caecum | (Pyloric caecum | | |
| (Liver | (Liver | | |
| Spleen | Gonad | | |
| Gonad | (Digestive organs | | |
| Digestive organs | (Kidney | | |
| Blood | Blood | | |
| Gill | Gill | | |
| - Katsuki et al (1975) | | - Shultz et al (1976) | |

( = no significant difference

b) Relative accumulation of mercury in other marine fish (in order of decreasing concentration).

| Sardine | Anchovy | Perch * |
|---|---|---|
| Total - Hg | Total - Hg | Total - Hg |
| Kidney | Kidney | Kidney |
| Liver | Liver | Liver |
| Muscle | Muscle | Heart |
| Digestive tissue | Skin | Muscle |
| Skin | Digestive tissue | Brain |
| Gonads | Gonads | Gonads |
| Gills | Gills | |
| Brain | Brain | |
| - Gilmartin and Revelente (1975) | | - Steinnes et al (1976) |

* *Perca fluviatilis*

There is evidence for in vitro demethylation in other fish also, as the percentage of methylmercury found in bluegill liver and kidney has been found to fall by 90% after fish exposed to mercury were replaced in clean water (Burrows and Krenkel 1973). This loss was over and above the 40% loss in total mercury which took place in the first five days after exposure ceased. In the presence of normal background mercury levels, however, there may be no drop in total mercury load at all, and any decrease in mercury concentration may be attributable solely to fish growth (e.g. Laarman et al 1976).

## 2.4(v) Proportion of organic mercury

The form of organic mercury present in fish is generally believed to be methylmercury. Some authors are more cautious, preferring to use the term organic mercury (e.g. Suzuki et al 1973, 1976b). In an early study it was concluded that shellfish from Minamata Bay had accumulated probably an ethyl or methyl form of organic mercury directly from the water (rukayama et al 1962). The mercury compound which had accumulated in toxic shellfish from Minimata Bay, after the rigorous degradative procedures involved in its isolation, was identified as a methyl, or possibly an ethyl derivative (Uchida et al 1961). The Swedish method of analysis involving acid digestion might synthesize methylmercury (Schroeder 1974, p.71) but Westoo (pers. comm.) does not support this view. Nevertheless "methyl" is the most commonly used expression and is used here.

The Swedish Expert Group (1971) determined that virtually all mercury in Swedish freshwater fish was present as methylmercury. This appears to be true regardless of which mercury compounds were discharged into the water (Westoo 1974). A deal of variation is found between individual Norwegian brown trout, 61-93% (mean 82%) and English perch, 67-100% (means in two samples 79% and 92%) methylmercury (Steinnes et al 1976) . A Canadian population of American eels ' 1 an average of 50% methylmercury (Freeman and Horne 1973a). Lake trout were found to contain 21-35% methylmercury (quoted in WHO 1976).

A number of studies of mercury in marine fish have included determination of the proportion of methylmercury; a selection is summarised in Table 7. Most research seems to have concentrated on species known to contain high mercury levels. Some values exceed 100%, presumably indicating some inaccuracy in analytical methodology. In some of the early Japanese work the extraction procedure was undertaken at too high a pH and not all the methylmercury was released (T. Pearce, pers. comm.)

Most of the marine species examined contained 60-100% methylmercury except blue marlin (10-20% MeHg); note the difference between red and white muscle in tuna species. Differences in the percentage of methylmercury in white muscle from different portions of tuna have also been recorded (Tamura et al 1975).

TABLE 7

PERCENTAGE OF MERCURY IN FISH PRESENT AS METHYLMERCURY

| Types of fish (& Source) | Mean (range) MeHg % | Reference |
|---|---|---|
| Swordfish (USA) | (93-113) | Kamps et al 1972 |
| Canned tuna (USA) | (90-125) | Kamps et al 1972 |
| Canned tuna (UK) | 90 | Working Party on Monitoring of Foodstuffs 1973. |
| Bluefin tuna | | |
| (White muscle) | (80-108) | Tamura et al 1975 |
| (Red muscle) | (42-75) | Tamura et al 1975 |
| Bonito | | |
| (White muscle) | 89 | Katsuki et al 1975 |
| (Red muscle) | 92 | Katsuki et al. 1975 |
| Yellowfin tuna | | |
| (White muscle) | 76.0 | Ueda & Takeda 1977 |
| (Red muscle) | 87.5 | Ueda & Takeda 1977 |
| Bluefin tuna (Japan) | 89 | Nishigaki et al 1973 |
| Southern bluefin tuna (Japan) | 83 | Nishigaki et al 1973 |
| Big eye tuna (Japan) | 79 | Nishigaki et al 1973 |
| Striped marlin (Japan) | 85 | Nishigaki et al 1973 |
| Blue marlin (Japan) | 18 | Nishigaki et al 1973 |
| Blue marlin (USA) | 10 | Shultz et al 1976 |
| Blue marlin (USA) | 19.4 | Rivers et al 1972 |
| Yellowfin tuna (USA) | 88.9 | Rivers et al 1972 |
| Skipjack tuna (USA) | 100 | Rivers et al 1972 |
| Dolphin fish (USA) | 100 | Rivers et al 1972 |
| Salmon, sea trout (Sweden) | 93 | Westoo 1973 |
| Variety marine fish (South China Sea & Northwest Australia) | 94.8 | Suzuki et al 1973 |
| Variety marine fish (Italy) | 90.7 | Galeno 1974 |
| Variety fish species (Tokyo) | (57.5-94.1) | Amemiya et al 1975 & 1976 |

The proportion of methylmercury is usually quite different in tissues other than muscle, ranging from 1.5% (liver) to 38.6% MeHg (gills in blue marlin (Shultz et al 1976). Salmon viscera ranged from 30-63% MeHg while muscle contained an average of 93% (Westoo 1973). In several tuna and other marine fish species the proportion of methylmercury is usually much lower (Katsuki et al 1975, Suzuki et al 1973 and Tamura et al 1975).

In the United Kingdom, fresh fish were found to have an average methylmercury content of 80%, with 90% MeHg in canned tuna (Working Party on Monitoring of Foodstuffs for Heavy Metals 1973). Later work has indicated that the methylmercury content in fish is 95% (Working Party Supplementary Report 1975).

In a recent District Court judgement in the USA, the judge accepted a National Marine Fisheries Service submission that, for regulatory purposes, the methylmercury level be considered to be 90% of total mercury (Anderson Seafoods vs Califano and Kennedy 1978).

2.4(vi) Effects on fish

Acute and sublethal bioassay tests have been the most favoured tool to determine the effects of heavy metals on marine organisms.

A number of criticisms can be made of acute toxicity tests, including the short duration of the tests, lack of sensitivity and use of high trophic level organisms (Gray 1974). Recognition of these limitations has resulted in many workers concentrating more on sublethal effects of heavy metals, because the concentrations necessary to produce these effects are the most commonly encountered in the environment.

Acute toxicity tests are usually reported using the median lethal concentration. The most commonly used symbol is the 96 hr LC50 i.e. the concentration of the test substance in the water body sufficient to kill 50% of the test organisms in 96 hrs. Equivalent terminology used is TL50 and $TL_m$.

A large proportion of the work to date has been undertaken on invertebrate species (including commercial shellfish) because of their known ability to accumulate high metal levels and their ease of handling.

A useful first step has been to investigate the effect of mercury on viability of sperm, since many aquatic animals practice external fertilization. Exposure of steelhead trout (Salmo gairdneri) sperm to levels of 1 mg/litre of methylmercuric chloride prior to mixing with roe produced a significant reduction in the percentage of successfully fertilized eggs (McIntyre 1974). It has been shown that in pike (Esox lucius) for example, there is a 1500 times concentration factor for gonadal tissue and extrapolating from the above, levels of only 7.69 x $10^{-4}$mg/l (0.769 ppb) of mercury are required in the water body to significantly affect fertilization (Hannerz 1968).

The concentrations of mercury required to affect the development of fertilized oyster (Crassostrea virginica) embryos are also low, as 50% did not develop after exposure to only 0.0056 mg/litre mercuric chloride and 100% mortality resulted after exposure to 0.008 mg/litre (Calabrese et al 1973). This may be a feature of invertebrate species however, as 3 mg/litre mercuric chloride was necessary to have a significant effect on European carp (Cyprinus carpio) eggs, although only 4 mg/litre was required to kill all of them (Huckabee and Griffiths 1974). In these series of experiments selenite ($SeO_2$) was found to potentiate mercury toxicity rather than decrease it as is commonly the case. It was suggested that this may be due to mercury and selenium reacting directly with the sulphydryl groups on the egg membranes, rather than first forming a complex of reduced reactivity as they appear to do in vivo.

For ovoviviparous fish such as the Pacific dogfish shark Squalus suckleyi, tissue mercury levels have been found to be between 0.3 and 1.2 mg/kg. The embryo which develops lies free in the uterus, fed by the yolk-sac and with no tissue links with the mother. However, although there is free movement of minerals from the mother to the foetus, there appears to be selective exclusion of mercury, as levels in the foetus are only 10% of the mother's (Childs et al 1973).

Juveniles in general exhibit greater sensitivity to environmental stresses than adults (Kenfo et al 1974) and in particular, to environmental pollutants such as elevated heavy metal levels. In juvenile Bay Scallops (Argopecten irradians) concentration factors of $10^3$ are found, although the juveniles show an ability to rapidly acclimate to high mercury levels (Nelson et al 1976). Another sensitive indicator of mercury pollution is shell growth, and using this technique it is also not necessary to sacrifice the test organism. Significant retardation of shell growth in juvenile oysters (Crassostrea virginica) was found at levels as low as 10 x $10^{-3}$ mg/litre (10 ppb) (Cunningham 1976), although there was complete recovery in 20 days.

Juvenile crustacea may be even more sensitive to low environmental mercury levels than molluscs. Post-larval white shrimp Penaeus setiferus exhibited 30% mortality at 10 ppb and 50% mortality at 17 ppb in 96 hour LC tests. However these organisms exhibited neither mortality nor physiological stress at 1 ppb, thus implying that the critical level lies in a very small range (Green et al 1976). For the brine shrimp, Artemia salina there is a significant reduction in survival at 0.001 mg/litre and no nauplii are produced at concentrations greater than 0.002 mg/litre (Cunningham and Grosch 1978).

The effect of mercury depends also on the stage of development of the juvenile. The respiration of the first zoeal stage of the crab Uca pugilator is depressed when exposed to 1.8 ppb of mercury. However crabs raised to the third zoeal stage at that concentration showed no significant depression of metabolic rate (Vernberg et al 1973).

Although higher metal concentrations are required to affect adults, there are numerous sublethal effects via accumulation in the gills, liver, kidney etc., which are difficult to detect and attempts have been made to monitor physiological activity in adult fish to elucidate them.

There are a number of fish liver enzymes which are either metal-requiring, metal sensitive or are involved in mineral metabolism. In vivo tests of the killifish (Fundulus heteroclitus), have detected decreases in catalase, acid phosphatase and xanthine oxidase activity after exposure to 96 hours LC50 levels of 0.23 mg/litre of mercury. In vitro tests exhibited similar results but the concentrations of mercury required to elicit an effect were very high (eg $10^{-4}$) thus giving rise to the idea that separate pathways are involved in each case (Jackim et al 1970), probably due to homogenation of the tissue (Kenfo et al 1974). However catalase in particular appeared to be a good indicator of sublethal effects, if variations in its level can be adequately isolated from other environmental stresses.

Catfish (Ictalurus punctatus), when injected inter-peritoneally with 15 mg/kg methylmercuric chloride showed deposition of mercury in the liver, with marked necrosis of the liver cells within 72 to 96 hours (Kendall 1977).

At lower levels of mercury, fish metabolism appears to be more readily adaptable, as at $10 \times 10^{-3}$mg/litre (10.0 ppb) the juvenile striped bass Morone saxatilis showed no significant change in enzyme activity (Dawson et al 1977).

Elevated respiration rates appear to be another feature of exposure to mercury at levels as low as $10 \times 10^{-3}$ mg/litre (10 ppb) (Calabrese et al 1975, Dawson et al 1977). This is paralled by reductions in such blood constituents as plasma-protein and haemoglobin. Such physiological responses may also be enhanced by increases in temperature. In trout for example, increasing temperature significantly increases toxicity and decreases the rate of active metabolism, i.e. the combined effect of increased mercury level and temperature more than offsets increased metabolic rates induced by the increased temperature alone (Macleod and Pessah 1973), and such a depression in active metabolism may be a sign of stress not far from a lethal condition.

Among other effects induced by exposure to mercury are ultrastructural changes, especially to the gill epithelia and kidney tubules (Fowler 1972), disruption of sodium ion transport and the osmo-regulatory system of the fish (Kenfo et al 1974), and inhibition of fin regeneration (Weis and Weis 1978).

A number of lethal and sub-lethal effects have been studied among the invertebrates. The crayfish Orconectes limosus exhibits total mortality at 5 mg/litre during a 96 hr LC test, with an LC50 between 0.5 and 1 mg/litre (Doyle et al 1976). Movements become increasingly sluggish with time at all concentrations above 0.25 mg/litre, and mortality would probably be even higher if exposure took place during the moult period.

In the crab, Uca pugilator, long term mercury tolerance was 0.18 mg/litre. At 0.1 mg/litre, in a 96 hr LC test, limb bud growth was not affected, but at 1 mg/litre there was a total inhibition of limb re-growth (Weis 1976). However there was also a 60% mortality at this concentration so inhibition at this level may be an artifact of toxicity.

Behavioural modifications are also important, but less easily studied. With increasing mercury levels the trochid snail Monodonta articulata increased its oxygen consumption and both its length and frequency of emersion. When exposed to high mercury levels (0.8 mg/litre plus) the snail was no longer able to maintain this avoidance activity and retracted into its shell where it died if not removed from the medium (Saliba and Vella 1977). Similar avoidance behaviour has been shown in fish, which swim away from areas with elevated metal levels.

The actual pathological effects appear to be associated with the saturation of metallothionein, the main metal-mediating enzyme in the cytoplasm. The excess metal then appears to spill over into the high molecular weight (enzyme containing) pools and pathological changes arise as a result of structural changes in metalloenzymes (Brown and Parsons 1978).

The effect of a heavy metal pollutant, particularly mercury, on aquatic animals is modified by a range of environmental variables. These include physical modifications such as alteration in pH, temperature, salinity as well as even synergistic effects of other chemicals, natural or un-natural. The organism itself will also vary in its response depending on species, size, development stage and previous exposure to environmental stress.

2.4(vii) Depuration

(a) Natural

In some situations where gross pollution was the obvious or suspected source of elevated mercury levels in fish the pollution source was removed and fish monitored for mercury levels. In some other situations where this was not possible, experiments have been carried out on reducing the mercury content by transplantation to "clean" waters.

The use of mercury in the Swedish paper manufacturing industry was banned in 1967. Northern pike were sampled for mercury in previously polluted waters one and five years after the implementation of the bans. Mercury levels in the pike decreased between 1968 and 1972 but the levels found in the pike were proportional to size rather than age, weight or the exposure time of fish (Olsson 1976).

Reductions in mercury content have been noted at sites downstream from industrial areas after effluent discharge had eased (Westoo 1974). In Baltic herring for example, nearly 40% of fish exceeded 1.0 mg/kg mercury in 1967; by 1972 only 1% exceeded this figure. Mercury levels in fish from the vicinity of chlor-alkali factories did not decrease however, probably due to continued mobilisation of mercury in sediments.

Continued mobilisation of sediment mercury is also implied in a similar situation in Norway (Steinnes et al 1976). After mercury compounds were banned in the paper industry in 1970, perch and brown trout showed rapid decreases in mercury content from around 4 mg/kg to 1 mg/kg in the first year, but stabilised over the next four years at about the latter level, which was still higher than the upstream level of 0.2 mg/kg.

Transplantation studies suggest a half life of methylmercury (initially 100% of total mercury) in northern pike of 750 days at $10^{o}C$. In natural waters of Finland, of an annual temperature $5^{o}C$, the half life is estimated at 3-4 years (Miettinen 1971). This temperature effect has been demonstrated in trout also (Rissanen 1973).

Elimination of mercury is not only influenced by temperature. Half life is also inversely proportional to ambient concentration of mercury. Trout dosed with 0.4 mg/kg methylmercury exhibit a mercury half life of 340 days. If dose is 4.0 mg/kg, the half life is only 170 days (Rissanen 1973).

A successful model used on Canadian yellow perch required that clearance rate of mercury was related to body weight but was independent of metabolic rate, although the latter is dependent on temperature (Norstrom et al 1976).

Body weight as a function of depuration is important. Yellow perch and rock bass were taken from contaminated Lake St Clair (USA) and put in clean water ponds. Significant mercury losses were noted, but all the reduction in terms of concentration of mercury over a period of more than 2 years, was attributable to dilution by growth (Laarman et al 1976). There was no nett loss of mercury from the fish. Studies of losses of mercury from northern pike on transplantation from a contaminated Canadian lake confirmed this (Lockhart et al 1972). During most of the period there was no nett loss of mercury, and after the 12 month study it was considered that growth dilution was as important as elimination in lowering mercury concentration. Further confirmation of the involvement of growth in reduction of mercury levels has been noted in a long term study where northern pike showed increased mercury concentrations in periods of starvation (Olsson et al 1976).

The form of the mercury also influences the biological half-life. Inorganic forms appear to be lost faster by aquatic organisms than organic forms, possibly due to the latter's tighter bonding to, for example, sulphydryl groups in the cells (Hamdy and Prabhu 1978).

(b) Artificial

The possibility of reducing mercury content during processing of fish is of interest particularly in the manufacture of fish concentrates. In the manufacture of fish protein concentrate (FPC), protein levels are increased 4-6 times and mercury content increased correspondingly about fivefold. In other words the concentrating process itself does not eliminate mercury (Archer et al, 1973). In this study it was found that enzymatic proteolytic digestion of FPC produced a 2 to 7 fold increase in the mercury content of the insoluble (enzyme resistant) fraction and a corresponding decrease in the soluble part.

Another suggested method of mercury reduction is the use of an acidified cysteine wash on the extracted concentrate (Yannai and Saltzman 1973, Spinelli et al 1973). Soaking fish slices in 5% cysteine hydrochloride solution at pH 0.5 in a fish:solution ratio of 1:35 for one and a half hours (with stirring) can remove up to 80% of the mercury content (Schab et al 1978) although other studies have claimed similar results with much less vigorous conditions (e.g. 1% cysteine-HCl) (Teeny et al 1974). By repeated use of the extraction solution and periodic removal of the mercury with an organic solvent the process was said to be economically feasible for processed fish products, having no observable effect on odour, taste or storage.

Less efficient reduction of mercury in FPC slurries can be obtained utilizing acidified isopropanyl in the production process. Use of 99% isopropanyl acidified with 37% hydrochloric acid solution (i.e. 2.6% HCl) effectively removed 80%+ of mercury (Regier 1972). Conversely, by using 1.2g of sodium borohydrate for every mg/kg of mercury in 100g of fish protein concentrate, mercury levels can be effectively reduced below 0.5 mg/kg (Cohen and Schrier 1975).

2.4(viii) Associated substances

An interest in selenium has arisen from the apparent protective effect the element has against poisoning from mercury compounds. A number of feeding trials using rats and quail have been undertaken to examine this apparent protective effect of selenium against, and its relationship to, mercury levels in the diet.

The naturally occurring selenium in tuna or swordfish, for example, appears to confer a protective effect against mercury poisoning (death) in quail when added to a base ration contaminated with mercury (Anonymous 1973, Friedman et al 1978). At lower levels of mercury, selenium, either naturally in the ration or added as selenite, can suppress sub-lethal effects in rats such as growth depression (Ganther et al 1973). Addition of sodium selenite to the diet prior to treatment with mercury can also delay the onset of symptoms in Japanese quail (Stoewsand et al 1974).

Selenium levels in fish are generally reported as below 1.0 mg/kg. In Norwegian (i.e. N.E. Atlantic) cod and halibut for example, levels did not exceed 0.15 mg/kg (Egaas and Braekkan 1977a). However, levels in shellfish are generally higher, with values up to 4 mg/kg in lobster and 2 mg/kg in molluscs being reported.

Selenium levels in the large predatory fish such as tuna and swordfish are very high. In swordfish, for example, levels of selenium ranged from 0.79 to 4.84 mg/kg in muscle, with a mean value of 2.18 mg/kg. These values appeared to be related to size and mercury level (Friedman et al 1978).

It has been suggested (H.E. Ganther, pers. comm.) that arsenic and vitamin E also might have a protective role against methylmercury poisoning. In addition it was discovered by Moxon (1938) that arsenic exposure can counteract the toxic effects of selenium. Arsenic is widely distributed in fish, and particularly shellfish, tissues (Hall et al 1978).
A general review of arsenic in the marine environment has been given by Penrose (1974), while other authors give details of the arsenic levels in North Atlantic fish in particular (Windom et al 1973, Egaas and Braekkan 1977b).

The precise relationship of selenium and other substances to the toxicity of methylmercury remains the subject of discussion and experiment. The recent decision by the US FDA to no longer take legal action against the sale of fish containing mercury up to 1.0 ppm, and the court case which preceded it, did not involve any consideration of such protective factors. H.E. Ganther (pers.comm.) believes the best approach to resolving this matter is to identify the form of selenium in fish so that direct studies of its intrinsic nutritional potency and activity in detoxifying methylmercury can be carried out, and he reported substantial progress in this area.

Additional information on this subject may be obtained by reference to Section 2.7 and to the separate contributions to the Working Group by Dr R.H. Fleming, Department of Health, Canberra.

## 2.5 Relevant studies in other countries

This section briefly describes the approaches adopted in some major overseas studies in relating mercury levels and the amount of fish consumed by individuals. The main findings of these are summarised in Table 8.

### 2.5(i) Methylmercury in fish, Sweden, Nordisk Hygienisk Tidskrift. (Swedish Expert Group 1971)

The report found that although fish had more mercury than any other single source of food it was a relatively small item in the Swedish diet. Average consumption in Sweden was about 30g of fish flesh daily.

However there was considerable variation about this average. A few per cent of the population never ate fish whereas some individuals consumed up to 500g per day. About one tenth consumed about 80-100g per day corresponding to a fish meal every second day or more.

It was found that mercury levels in the blood were related to fish consumption. However the relationship between mercury in hair and fish consumption was less clear.

The report identified 'acceptable' levels of mercury in whole blood and blood cells as 0.02 mgHg/kg and 0.04 mgHg/kg respectively and in the hair as about 6 mgHg/kg and these values correspond to an acceptable daily intake through fish of 0.03 mgHg as methyl mercury or about 0.4 mcgHg/kg body weight. These levels include an applied safety factor of 10 which, in the opinion of the Swedish group, gives a sufficient safety margin. The group noted that assessments upon which the safety factor was based were made cautiously and that, should new data become available, the values should be reinvestigated.

By means of the data on fish consumption in the Swedish population and on the relationship between exposure and levels in blood cells, qualified assessments were made of the consequences of different limits for mercury in fish to this population's mercury concentration in the blood. These were:

- a content of 1 mg/kg in fish might result in one third of the population reaching levels above the acceptable level

- with 0.5 mg/kg about one tenth of the population might exceed the acceptable level

- with 0.2 mg/kg with free consumption or 1 mg/kg in combination with a restriction of the consumption of contaminated fish to one meal a week, exposure would be within the acceptable level.

2.5(ii) <u>Consumption of fish and exposure to methylmercury, Sweden.</u> (Jonsson et al 1972)

Fish consumption habits were studied during July 1967 by mailed questionnaire to 179 salt-water and 177 fresh-water fishermen and 357 adult males selected at random from the total population.

The median consumption of fish among salt-water fishermen was 90g per day with 6% of respondents eating more than 200g per day. Fresh-water fishermen had a median consumption level of 50g per day with 3% eating more than 200g per day and for the random sample of males 30g per day and 0.8% respectively.

Where the origin of the fish consumed was known, its mercury content was assumed, the values depending on the various fishing areas around Sweden. Where the origin was not known, the fish was assumed to be uncontaminated.

The estimated exposure to methylmercury through fish consumption was then calculated for the year for each individual. Median exposure was 4mcg mercury/day and 10% of persons ingested over 11 mcg per day. The highest individual exposure was an average 30 mcg per day.

The report noted that there were definite seasonal variations in exposure to mercury. It also acknowledged that the sample sizes were smaller than was desirable.

2.5(iii) <u>Studies on humans exposed to methylmercury, Sweden.</u> (Birke et al 1972)

In Sweden 26 human subjects exposed to methylmercury through the consumption of fish were studied during and after varying degrees of exposure. The study describes the materials and methods of analysis and sampling in some detail.

In 14 subjects having a low to moderate intake of ocean fish (mercury levels 0.01-0.1 mg/kg) methylmercury comprised half or less of total blood cell mercury. The proportion was much higher in heavily exposed subjects.

A positive relationship was found between exposure to methylmercury through fish consumption and the level of mercury in the blood. Twelve subjects eating moderate or high quantities of 'contaminated' fish had total mercury levels in the hair, blood cells and plasma much higher than the 14 low consumers.

A roughly linear relationship between mercury levels in hair and blood was found with hair readings approximately 300 times as high as those of blood.

2.5(iv) Working Party on the Monitoring of Foodstuffs for Mercury and Other Heavy Metals, United Kingdom 1971, 1973

These reports estimated that the average amount of mercury in fish generally available to the consumer was 0.08 mg/kg. Mercury levels were highest in canned tuna and in fish from coastal areas. Average consumption of fish in the UK was approximately 24g per day, this estimate being based on official annual consumption statistics. From the two figures it was calculated that the daily intake of mercury from fish by the average consumer was approximately .002 mg (i.e. 24g x 0.08mg/kg). The actual figure for individuals would vary depending on the amount and kind of fish consumed.

The only indication of variations about the mean were provided by results of an annual National Food Survey. These showed that daily fish consumption ranged from 12g per person on average in poorer households with several children to 34g per person in wholly adult households in the higher income groups. However it was noted that these figures were only an average of groups of households and gave no indication of the differences in consumption within households and between households within the groups.

The report concluded that the only sections of the community which might consistently ingest well above average amounts of mercury in the diet were individuals consuming large amounts of fish taken almost exclusively from certain coastal areas or those eating large amounts of canned tuna.

To assist in assessing the medical significance of such an intake of mercury a small survey was undertaken of the mercury content of blood and hair of fishermen from an area where the consumption of fish was known to be above average. These results were compared with those of a control group.

Owing to the small sample used - 6 heavy fish eaters and 6 controls - no definite conclusions could be drawn from this exercise although it did appear that there were no significant differences between the two groups in hair mercury levels whereas blood samples in the high fish eating group appeared to contain significantly higher quantities of mercury. The average blood mercury level of the control group was 0.005 mg/kg and of the fishermen 0.016 mg/kg.

2.5(v) Mercury intake in UK fishing communities. (Lindsay in press)

More recent studies have been undertaken to provide the basis for prediction of mercury input rates which will allow UK environmental quality objectives for mercury to be met, i.e. that "mercury content of fish is such that no risks are posed to the consumers, and that the safety margin for critical groups (Shepherd 1975) of the most exposed members of the population is as large as possible".

Having concluded that the most critical group of fish consumers in coastal communities is invariably found amongst fishermen and their families, the latter were made the subject of a dietary and epidemiological study along the coast of the N.E. Irish Sea, an area affected by industrial discharge of mercury, and in a control area of the S.W. coast. Daily fish consumption rates for 637 individuals from the two areas gave the log-Gaussian distribution typical of this type of survey (Preston et al 1974). Previous studies had established that the median value for the consumption rates of 30 of the most extreme consumers could be used as a reference level for the time-weighted average consumption level of the most extreme consumer (Shepherd 1975). The reference level for the N.E. Irish Sea was 325g per day of fish and shellfish compared with 358g for the control area. This compared with a national average consumption of fish and shellfish of approximately 20g per day. The mean mercury level in the fish component of the N.E. Irish Sea diet was 0.27 mg/kg, compared with 0.22 mg/kg in the control area. One hundred and seventy four individuals from the two areas took part in a duplicate diet survey, which showed that total weekly mercury intakes varied between .004 and .443 mg per 70 kg body weight for the N.E. Irish Sea compared with .005 to .560 in the controls. Selenium intakes were also calculated. Levels of mercury in whole blood were .0004 to 0.0258 mg/kg (N.E. Irish Sea) and 0.0004 to 0.0121 (controls) and in hair 0.1 to 60 mg/kg. The latter high value for total mercury in hair contained only 2 mg/kg organic mercury and it was concluded that it is preferable to measure organic mercury levels in hair to avoid any difficulties arising from external contamination of hair by inorganic mercury.

Linear regressions between concentrations of total mercury in whole blood and hair gave good agreement with the ratio of 250:1 in hair and blood obtained in other studies. A significant relationship was found between total intake of mercury and blood and hair mercury levels. However, a linear regression of total intake of mercury against blood and hair mercury levels was assumed in order to compare the data with that obtained in other studies where a linear relationship between these variables had been assumed. The data from the UK study showed a regression of blood mercury levels against mercury intake with a lower (ca. 8 times) slope than that based by the FAO/WHO Study Group on metabolic data from tracer studies on human volunteers (Miettinen 1973). However, the UK data did not support the assumption of linearity, but the form of the relationship was too complex to interpret. The data indicated that the consumption of methylmercury at the level of the tolerable weekly intake of 0.2 mg of methylmercury per week recommended by FAO/WHO would not be likely to result in levels in excess of .005 mg/kg whole blood as organic mercury and 2 mg/kg in hair.

On the basis that the most extreme consumer examined in the study had a blood mercury level an order of magnitude below the FAO/WHO toxic threshold of .02 mg/kg for the most sensitive individual, it was concluded that there are no consumers of fish in the United Kingdom who are adversely affected by the current levels of methylmercury present in fish in UK coastal waters.

Similar studies are currently being undertaken (Fishing News 1 September 1978).

2.5(vi) The MECCA Project and subsequent studies (USA)

In 1972 the National Marine Fisheries Service carried out a study known as the MECCA project using a computer model to estimate the mercury intake of US seafood consumers. A further study was undertaken, the results being published in 1978, using a more precise and statistically significant :sion of the MECCA model. Summaries of both these studies follow.

(1) The MECCA Project (Finch 1973).

This program used data collected in a survey of 1500 U.S. families which had been designed to provide information for economic analysis.

A data base was constructed which listed for each family estimates of the total weight of each kind of fish consumed.

A computer model was then employed to scan the data base, using for each run a given set of microconstituent levels for the 52 kinds of fish reported in the data base, and to calculate the average daily intake of the microconstituent for each family, based upon its consumption by species. From this a istribution of the estimated intake levels of all the individuals in the survey was calculated and printed out.

The model was applied to calculate mercury intakes of individuals in the sample on the basis of average levels of mercury from 52 kinds of fish in the data base.

Further computer runs were then made using alternative input mercury levels. These were calculated assuming the effect of different regulatory guidelines upon the mercury levels in the available supply. By comparing results the extent to which different guidelines reduced the intake of mercury was estimated.

The results of the MECCA study suggested that the action level for mercury in fish could be raised to 1.5 mg/kg without compromising public safety.

(2) Further Study Based on the MECCA Concept (USA, NMFS 1978)

The National Marine Fisheries Service noted a number of limitations to the MECCA study:

a. limitations on the accuracy of the survey results, which were based on mailed returns

b. the assumption that all fish purchased are eaten

c. the transposition of common names understood by the consumer to particular species with identified mercury levels could give rise to error

d. available mercury data were limited in some cases, and

e. no allowance was made for groups who by reason of religion, diet, ethnic considerations etc. deviated markedly from the average survey results.

Because of shortcomings in the MECCA project, the National Marine Fisheries Service conducted a more detailed study. This was aimed at determining the statistical chance of United States consumers exceeding the current allowable intake of mercury as a consequence of their seafood diet.

Mercury data were based on the analysis of 18,900 fish and seafood samples covering 135 seafood items. Consumption data were obtained from 24,650 people in 1973/74 and provided information on the species and quantity of fish eaten by all members of the households over a period of a month. One twelfth of respondents filled in a diary for a year.

The then current FDA Allowable Daily Intake (ADI) for mercury was 0.03 mg per day for a 70 kg man and this incorporated a ten-fold safety factor.

In this survey the 'personal' ADI for each respondent was calculated using estimated body weights. The estimated highest possible current mercury intake ('upper limit daily intake') of the individual respondents was then computed, based on their fish intake, both quantity and species.

The model presented results in the form of the percentage of respondents who had an upper limit daily intake of mercury less than their personal ADI at a 95% level of confidence. The data were analysed for three groups of people, namely, all respondents, children, and women of child-bearing age. It was further refined to estimate the percentage of respondents who would not be at risk of exceeding their ADI's should action levels of 1.0 mg/kg and 0.5 mg/kg be imposed on marketed fish at a 75% enforcement level. A 100% enforcement level was considered impractical.

According to the results, with no regulatory control on the mercury content of marketed fish 99.81% of all respondents had an upper limit mercury intake lower than their ADI at a 95% confidence level. When an action level of 1.0 mg/kg mercury was introduced, the percentage rose to 99.87% and with an action level of 0.5 mg/kg was 99.89% .

Further analysis showed that 99.84% of respondents retained a seven-fold or greater level of protection when consuming their highest daily intake level of mercury (ADI being a ten-fold level of protection) and none had less than a two-fold level of protection. The percentage of children retaining a seven-fold or greater protection level was a little lower at 99.86%. The results for women of child-bearing age were similar to those for all respondents at 99.97%.

The conclusion of this section of the report was that mercury in seafood posed little hazard to the overall seafood eating public. The same conclusions were reached with regard to the hazards of eating tuna by itself and of halibut by itself when data on the mercury content and consumption levels of these fish were analysed by the model. Swordfish however, while not regarded as a hazard at the time of the study, was considered to be uniformly high in mercury and regulatory constraint on its supply via an action level of 1.0 mg/kg was recommended. The same recommendation was made for fresh water fish which were particularly subject to local contamination with mercury.

It was recommended in the report that no other action levels be enforced as mercury in seafood generally was not a health hazard. It was also considered that significant economic benefit would accrue to the fishing industry from such a move, and consumer confidence in seafood would also improve. Continued monitoring of mercury levels in fish and consumption patterns was also advised.

Loaves and Fishes, USA. (Marsh et al 1975)

This report used as its fish consumption data base the findings of a survey carried out by the Tuna Research Foundation in the US in 1973-74. The average consumption of seafood was found to be 18.58oz (526g) per month and some 2.9% of respondents ate more than 70 oz (198g) per month with 1.4% consuming over 90 oz (2547g) per month. The survey then concentrated particularly on 'heavy fish eaters', those consuming over 90 oz (2547g) per month, who were asked to keep a further record of fish eaten. A strong tendency to reduce consumption from the previous high levels was revealed with the average monthly seafood intake falling from 124.2 oz (3515g) in the first survey month, to 45 oz (1274g) in the second.

The maximum mean monthly consumption of any individual over the two months was 197 oz (5575g) and it was concluded that it was unlikely that any U.S. consumers consistently eat more than 200 oz (5660g) of seafood per month.

The report went on to relate consumption to mercury in tuna. Some data on mercury levels in canned tuna were available from analyses, made in 1971 before official recognition of the presence of mercury in tuna, and a median nine month mercury intake of 11.485mg (0.0425 mg per day) was calculated for an individual consuming a steady 200 oz (5660g) per month.

No values for the mercury content of other seafood species were available at the time of the report.

The report briefly discussed the theoretical aspects of methylmercury toxicity particularly the 'pulse' effect of ingesting large single doses of mercury and the effect of ingestion pattern on the estimation of blood mercury levels at the onset of symptoms of poisoning. It pointed out that it has not been established that the entry of methylmercury into the brain is linearly related to the blood concentration at all levels; the authors posed the possibility that relatively more mercury enters the brain when the blood concentration is high. Studies by the authors indicated at least two components in the clearance of mercury from the blood - the first rapid and the second the slower and generally accepted 1% of body burden per day. Thus extrapolation back from equilibrium blood levels several days after ingestion of a large dose of mercury may not give an accurate initial blood concentration which may be higher than calculated and more likely to affect the bra .

Also briefly discussed is the interaction of methylmercury with dietary selenium and the results of experiments which appeared to show a reduction of the toxicity of methylmercury and a change in its distribution in the tissues when selenium was included in the diet of laboratory animals. The authors raise the question of the possibility of the presence of a less toxic selenium - methylmercury complex in ocean fish and consider it very important to establish the exact form of the methylmercury and its toxicity.

### 2.5(vii) Fish Consumption and mercury levels in France

A survey by the Scientific and Technical Institute for Marine Fishing on fish consumption and mercury levels found that Frenchmen, on average, eat 14kg of fish per person per year. It was recognised that some groups eat much greater amounts of fish than the average and it was decided that the study would adopt as its minimum standard, the need to safeguard the highest risk group, Mediterranean fishermen, from over-exposure to mercury through fish consumption. Levels of mercury in fish from the Mediterranean are higher than those in ocean fish.

The study concluded that a Mediterranean fisherman would need to consume at the rate of between half and one kg of tuna per day, every day, before the first symptoms of mercury poisoning could be expected.

2.5(viii) Mercury in fish and possible ingestion rate, Italy. (Galeno 1974)

Samples representing 26 families of fish were taken from Turin market (148 samples in total) and were analysed for mercury content. The average level was 0.232 mg/kg with a range of 0.005 mg/kg to 2.4 mg/kg. The average for 'small' fish was 0.165 mg/kg and for large predatory fish, 0.847 mg/kg. Methylmercury was estimated at 90.75% of total rcury.

Calculations of weekly mercury intake were based on an average daily consumption of seawater fish of 9.4g per head as estimated from a 1973 study. The weekly absorption of total mercury was found to be .0152 mg of which .0138 mg was methylmercury. These two values are 20 and 14 times lower than the weekly tolerable intake of mercury of 0.3 mg established by the FAO/OMS Commission. It was concluded that it was possible to exceed the FAO guidelines only by eating two fish meals of 327g each per week, one from a large predatory fish.

2.5(ix) Methylmercury in heavy fish eaters, Peru. (Turner et al 1974)

Two fishing villages and one inland village in northern Peru were studied and a total of 186 persons were surveyed. A dietary survey was conducted in the fishing villages and the average weekly fish consumption found to be 10.1 kg per family and the average family size 6.2 persons. Blood mercury levels lay between 0.011 and 0.275 mg/kg with a mean value of 0.082 mg/kg. Residents of the inland village where fish consumption was much lower at an average of 1.9 kg per family weekly had blood mercury levels averaging 0.0099 mg/kg with a range of 0.0033 to 0.0251 mg/kg.

2.5(x) Methylmercury in heavy fish eaters, American Samoa. (Marsh et al 1974)

Eighty-eight Korean fishermen based at American Samoa and 45 Samoan factory workers were studied. The fishermen were at sea about 47 weeks per year and lived largely on fish and rice consuming an average of 10.4 oz (294g) fish per day. Male shoreworkers ate an average of 7 oz (198g) fish per day and females 3.7 oz (105g). Many types of ocean fish were consumed including tuna and swordfish.

The average blood mercury level of the fishermen was .064 mg/kg and of shoreworkers .035 mg/kg. The highest level recorded was an average .132 mg/kg found in a crew living almost exclusively on big-eye tuna and eating approximately 9 oz (255g) of fish per day. The average hair mercury level of the fishermen was 17 mg/kg (range 3.3-47.8) and of shoreworkers 8.1 mg/kg (range 1.3-24.0).

2.5(xi) Fish Consumption and mercury intake on small islands in Japan (Suzuki et al 1976a)

On the islands studied fish samples and samples of hair and blood from islanders were analysed for mercury. Fish consumption was estimated from a calculation of available fish based on the annual catch. The frequency of consumption of fish was determined at interview.

Analyses showed that two general groups of fish had mercury contents greater than 1 mg/kg, the oceanic Scombridae (wahoo and skipjack) and the carnivorous reef fish.

Consumption of fish varied between islands from an estimated 104g daily per person to 395g and between two and eleven meals per week.

On four islands, the red blood cells of sample residents were analysed for mercury content. Total mercury concentrations ranged between means of .009 mg/kg (range .005 - .016 mg/kg on Oahu Is, Hawaii and .114 mg/kg on Kuchinoshima (range .035 - .210 mg/kg). These two islands also had the lowest and highest respectively averages of mercury levels in the hair of residents, these values lying between an average 3 mg/kg with a range of 1.8 - 43 mg/kg for Oahu Is and 23 mg/kg with range 1.9 - 48.8 mg/kg for Kuchinoshima. The results of hair analyses may have been affected by the sampling method; the tips of the hair were analysed and thus samples were of different ages and seasons.

The report found that, on the small islands studied, mercury levels were closely associated with the frequency of fish consumption of islanders on a collective basis, this association being modified by the species consumed. The frequency of consumption was well correlated with the availability of fish.

## TABLE 8

## SUMMARY OF RESULTS FROM OVERSEAS STUDIES

| Survey | Consumption averages + | Mercury readings + | Other |
|---|---|---|---|
| [E]xpert Group Sweden (1971) | 30g/day* (10% over 80-100g/day) | none | % of consumers reaching highest acceptable level of Hg at action levels of:<br>1 mg/kg - 33%<br>0.5 mg/kg - 10%<br>0.2 mg/kg - 0% |
| [J]onsson et al (1972) [S]weden | - salt-water fishermen 90g/day (6% over 200 g/day)<br>- fresh-water fishermen 50g/day (3% over 200 g/day)<br>- random adult males 30g/day (0.8% over 200 g/day) | none | Median exposure to Hg of random sample .004mg/day with seasonal variation |
| Birke et al (1972) [S]weden | - contaminated - fish consumers 10-300 g/day | - low to moderate ocean-fish consumers<br>.0096 mg/kg red cells<br>.0032 mg/kg plasma<br>1.6 mg/kg (range 0.760-3.000) hair<br>- dentists<br>.022 mg/kg red cells<br>.0062 mg/kg plasma<br>- contaminated fish consumers<br>. range .007-.650mg/kg whole blood<br>. range 2.000-185.000 mg/kg hair | linear relationship between blood and hair Hg |

| Survey | Consumption averages + | Mercury readings + | Other |
|---|---|---|---|
| Working Party (1971, 1973)<br>UK | 24 g/day* | - fish<br>. 0.08 mg/kg<br><br>- blood<br>. heavy fish consumers - 0.016 mg/kg<br>. controls - 0.005 mg/kg<br><br>- hair<br>. heavy fish consumers - 2.4 mg/kg<br>. controls - 2.9 mg/kg | average daily intake .002 mg |
| Shepherd (in press)<br>UK | Extreme consumers<br>NE Irish Sea - 325 g/day<br>SW Coast - 358 g/day | Hg in whole blood:<br>NE Irish Sea 0.0004 to 0.0258 mg/kg<br>SW Coast 0.0004 to 0.0121 mg/kg<br>Hair 0.1 to 60 mg | weekly intake<br>NE Irish Sea: 0.004 to 0.443 mg/70 kg<br>SW Coast 0.005 to 0.560 mg/70kg |
| MECCA<br>Finch(1973)<br>USA, NMFS (1978) | none | none | Action level — % respondents not exceeding personal ADI<br>none — 99.81<br>1 mg/kg — 99.87<br>0.5 mg/kg — 99.89 |
| TRF<br>USA | 17.5 g/day (525g/month)<br>3% over 66 g/day (1981g/month)<br>1.4% over 85 g/day (2547g/month) | none | Median Hg intake of consumers eating 190g tuna /day = .04254 mg |
| France | 38g/day (14 kg/year) | none | |

| Survey | Consumption averages + | Mercury readings + | Other |
|---|---|---|---|
| Galeno 1974) taly | 9.4 g/day* | - fish<br>. 0.232 mg/kg (range 0.005 - 2.4 mg/kg)<br>. large predatory types - 0.847 mg/kg<br>. small and medium - 0.165mg/kg | weekly absorption Hg .0152 mg |
| urner et al (1974) eru | - fishing villagers 232 g/day (10.1 kg/week/family)<br>- inland villagers 44g/day (1.9 kg/week/ family) | blood<br>. fishing villagers - .082 mg/kg (range .011 - .275 mg/kg)<br>. inland villagers - .0099 mg/kg (range .0033 - .0251 mg/kg) | |
| ..arsh et al (1974) amoa | - fishermen<br>. 296 g/day<br>- male shoreworkers<br>. 198 g/day<br>- female shore-workers<br>. 104 g/day | - blood MeHg<br>. fishermen .064 mg/kg<br>. shoreworkers .035 mg/kg<br>- hair organic Hg<br>. fishermen 17 mg/kg<br>. shoreworkers 8.1 mg/kg | |
| uzuki et al .1976a) Japan | 104 - 395 g/day* | - blood cells .009 mg/kg - .114 mg/kg<br>- hair<br>. 3 mg/kg - 23 mg/kg | |

+ All figures are averages of the sample surveyed unless otherwise stated. Sample size is in some studies very small.

* Information not obtained directly from the survey.

## 2.6 Relevant Australian Information

### 2.6(i) Sources of mercury in Australia

#### (a) Natural

Since the east coast of Australia is in a mercuriferous zone (Figure 1) it might be expected that leaching to waterways would create higher background levels of mercury there than in non-mercuriferous areas. For example the Clarence River in NSW flows through cinnabar (Hg) deposits (Andrews 1928)

Research into mercury levels in open oceans suggests that mercury levels in the Southern Pacific ocean may be several times higher than in the northern hemisphere while those in the Indian Ocean may be quite low (see Section 2.4(i)).

#### (b) Industrial

Mercury used industrially in Australia is all imported. The Australian Bureau of Statistics has provided the information contained in Table 9 on imports to Australia for the years 1973-1979.

More specific statistics are, however, required. Many mercury compounds of concern are included in import statistics under headings too broad to be of use - for example, part of "chlorides, other" "sulphides, other" and so on. In other cases, the headings used, while appropriate, are nevertheless too broad; all organo-mercurials other than phenylmercury compounds are listed as "other organo-mercury compounds" and no separate figures for the highly toxic alkylmercury compounds are available.

The import statistics do not indicate the use to which the mercury is being put in each case, or what subsequent alterations in chemical form the compounds undergo. In addition, the State import statistics do not indicate where the mercury is actually used in industry. The Australian Chemicals Guide, 1975, lists six Australian companies as producing mercury compounds. Of these, two market mercury metal only, one markets a single mercury compound, and the remaining three produce a range of mercury pesticides and other compounds.

The pulp and paper industry in the past used considerable amounts of mercury slimicides. Their use, however, has been discontinued following State Government and industry negotiations. However, small amounts of mercury are released during the production of chlorine and caustic soda used in bleaching and pulping, both of which are made by the mercury cell process (Department of EHCD 1977).

TABLE 9

MERCURY IMPORTS IN AUSTRALIA

| Import | | Total kg | Total $ | State sub-totals (kg) NSW | VIC | OTHER* |
|---|---|---|---|---|---|---|
| 1973-74 | Mercury | 102,534 | 274,055 | 72,306 | 29,883 | 345 |
| | Phenylmercury compounds | 3,833 | 37,723 | 3,381 | 202 | 250 |
| | Other organic mercury compounds | 12,070 | 29,906 | 2,063 | 6 | 10,001 |
| 1974-75 | Mercury | 50,197 | 263,532 | 8,768 | 40,738 | 691 |
| | Phenylmercury compounds | 283 | 6,106 | 31 | 2 | 250 |
| | Other organic mercury compounds | 6,049 | 61,971 | 6,021 | 28 | - |
| 1975-76 | Mercury | 61,039 | 155,146 | 43,711 | 16,638 | 345 |
| | Phenylmercury compounds | 4,401 | 35,068 | 4,000 | 401 | - |
| | Other organic mercury compounds | 1,366 | 14,013 | 1,314 | 52 | - |
| 1976-77 | Mercury | 40,291 | 98,929 | 23,359 | 15,674 | 1,250 |
| | Organo-mercury compounds | 8,679 | 75,353 | 7,425 | 1,254 | - |
| 1977-78 | Mercury | 47,870 | 166,298 | 40,179 | 4,890 | 2,801 |
| | Organo-mercury compounds | 12,478 | 50,640 | 11,096 | 1,382 | - |
| July 78 -Jan 79 | Mercury | 56,247 | 186,125 | 50,566 | 4,774 | 907 |
| | Organo-mercury compounds | 13,553 | 20,902 | 13,552 | 1 | - |

* These figures are available in State-by-State breakdowns, but because of their small size it was considered appropriate to group them together.

Mercury compounds have in the past had considerable use in Australia as fungicides for agricultural use. A wide range of different compounds was used - inorganic mercury compounds such as mercuric and mercurous chloride, alkyl - and alkoxy-mercurials, including methoxyethylmercury chloride, and phenylmercury compounds, principally phenylmercuric acetate and phenylmercuric chloride. Table 10 shows the value of mercury compounds produced for agriculture in Australia from 1963 to 1975.

Production of mercurial seed dressings was discontinued early in 1973 and their sale was later prohibited in all States, except for some particular uses on certain ornamental and field crop seeds for which there appeared to be no suitable alternative materials. The statistics indicate there was no further production after June 1973. Alkylmercury compounds, which represent the greatest risk to the environment and human health, have not been used in agriculture for some years. Available information indicates that none are currently registered or marketed.

A range of mercury fungicides is used in small amounts for the control of a variety of diseases in turf. None of the available alternatives appear to be able to control the diseases adequately, and several strains which are resistant to the new fungicides have already developed.

The heaviest remaining use for mercurial fungicides is in the sugar industry where phenyl mercuric acetate is the standard treatment for the control of "pineapple" disease. Under Queensland State legislation designed to protect the industry from the serious losses which once devastated cane fields, the cuttings used for planting new crops of sugar cane (known as setts) must be treated by dipping in a solution of phenyl mercuric acetate. The quantity of fungicide is not known but most of the phenylmercury imports are used for this purpose.

Extensive research has been carried out to evaluate non-mercurial fungicides for pineapple disease control. While there is some indication that several materials might have a potential, it will be a number of years before this work has reached a stage where a clear picture can be presented. The most effective compounds are systemic fungicides but many important pathogens have already developed resistant strains. The industry has therefore been strongly advised not to change from phenyl mercuric acetate until there is adequate evidence that alternative materials will not fail due to the development of resistance.

TABLE 10

VALUE OF MERCURY COMPOUNDS PRODUCED FOR AGRICULTURE IN AUSTRALIA 1963-1975

$'000 (wholesale)

| Year | Mercurial compounds (excluding seed dressings) | Mercurial seed dressings |
|---|---|---|
| 1963 | 133 | ? |
| 1964 | 147 | 74 |
| 1965 | 92 | 66 |
| 1966 | 93 | 60 |
| 1967 | 162 | 73 |
| 1968 | 87 | 138 |
| 1969 | 87 | ? |
| 1970 | 82 | 47 |
| 1971 | n.a. | n.a. |
| 1972 | 99 | 54 |
| 1973 | 115 | 53 |
| 1974 | 209 | - |
| 1975 | 240 | - |

(c) Emissions

There are few data on mercury emission from Australian industry. Australian sources of emission have included agriculture, catalyst preparation, the chloralkali industry, dental preparations, electrical apparatus, general laboratory use, instrument, paint and pharmaceutical manufacture, the pulp and paper industry, acid manufacture and sewage effuent, as well as from mining and refining and combustion processes (coal, oil, gas).

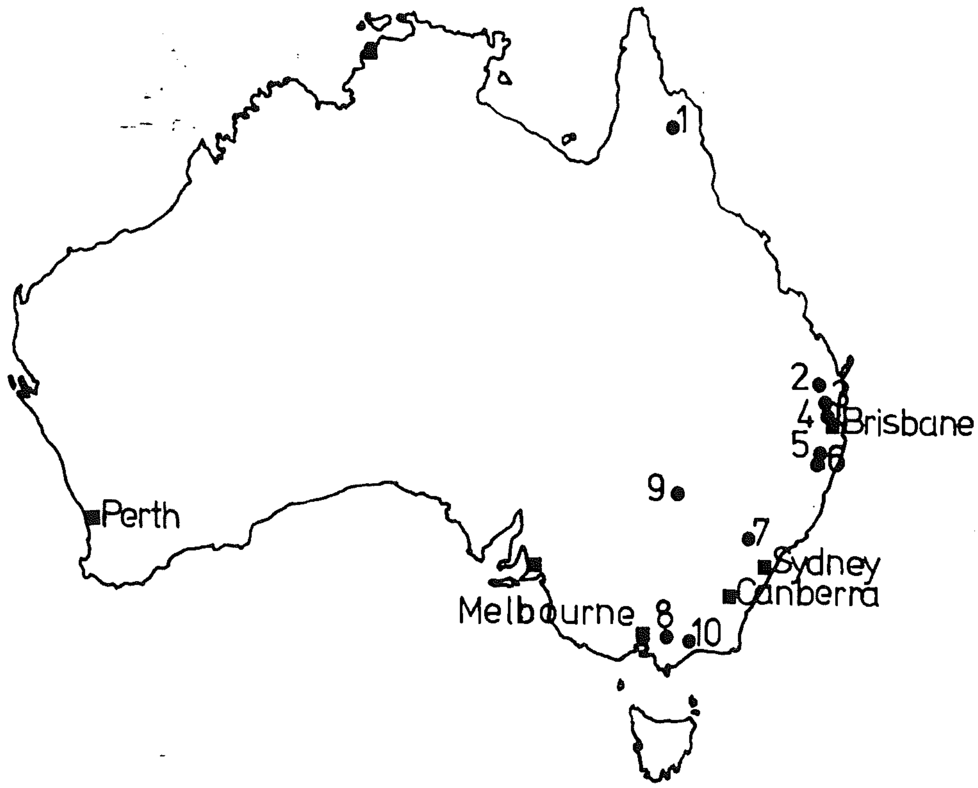
Mercury mining ceased in Australia in 1945. Deposits were near the east coast. Sites of mines are shown in Fig. 3 (Department of National Development, 1965). Total historical production amounted to approximately 13,000 kilograms from mercury mines, while several hundred tonnes have been released into the environment in the course of mining for other metals such as gold.

That mercury was not considered a significant problem in the last decade is evidenced by its absence from the report of the (Australian) Senate Select Committee on Water Pollution (1970). Awareness of the problem in this decade has led to international exchanges of information by member countries of the Organisation for Economic Co-operation and Development (OECD). Australia is a member and its contributions to the annual exchanges of information, although incomplete, constitute the only available data relating to Australian mercury emission (OECD 1976 and 1977).

Australia's apparent consumption of mercury metal in 1975, 56 tonnes, was close to that of Sweden and about half that of Japan. Emission to water in 1975 from the Australian mining and refining industries, which would constitute one of the major sources, was over 6,000 kg.

Mercury emission from pulp and paper manufacturers in Tasmania dropped considerably from 1975 (900 kg) to 1976 (300 kg), as did chloralkali plant emission to air (1000 kg to 150 kg). Emission has now ceased. Between the two years there were several developments designed to reduce mercury emission. These included installation of a filter at a major chloralkali plant, recovery systems installed in the processing line of a major laboratory and the major zinc refinery, and closed water circuits as well as stack cooling and scrubbers in chloralkali plants.

Events such as these and the progressive implementation of the Australian Environment Council's policy on mercury emissions should ensure gradual further decrease in mercury pollution of aquatic ecosystems both by direct emission to water and indirect emission from atmospheric fallout.




1. LITTLE RIVER
2. KILKIVAN DISTRICT
3. MONSILDALE
4. MOUNT MEE
5. TABULAM
6. YULGILBAR PULGANBAR & LIONSVILLE
7. CUDGEGONG
8. COBAR
9. JAMIESON [SILVER CREEK]
10. BULLUMWAAL

Adapted from: Department of National Development [1965]

FIGURE 3

PRINCIPAL LOCALITIES FOR MERCURY IN AUSTRALIA

Few specific instances of the effects of mercury emissions into Australian waterways have been recorded. One study found no difference in mercury levels in oysters from a number of non-industrial and industrial (Georges River and Botany Bay, NSW) estuaries, implying no mercury pollution of the industrialised areas (Hussain and Bleiler 1973). More recently, elevated mercury levels were found in oysters from these areas (Williams et al 1976). Other research (Mackay et al 1975b) showed relatively high levels of other metals in Georges River oysters. It was concluded that the area may pose future problems regarding metallic contaminants. On the basis of small samples of fish, another study concluded that mercury levels in Botany Bay and the Shoalhaven River were higher than the open ocean (Neuhaus et al 1973). Both areas receive industrial pollution.

The most severe metallic contamination in an Australian waterbody has been recorded in the Derwent estuary, Tasmania, which was found to contain up to 1100 mg/kg sediment mercury (Bloom (1975). These levels were only exceeded in upper Minamata Bay in Japan where levels in the range 113 to 2010 mg/kg have been found, in comparison with levels of 0.37 to 0.34 mg/kg outside the Bay and 12.2 to 159.5 in the lower reaches of the Bay (Takeuchi 1972). For comparison, uncontaminated sediments from Bass Strait contained 0.01 to 0.05 mg/kg (Dix and Martin 1973). Mercury levels in plankton, shellfish and fish from the Derwent estuary were correspondingly elevated. Sources of contamination include a zinc refinery, paper-making plant and a chlor-alkali plant in the Derwent river. A detailed comparison of mercury levels in fish from the Derwent and unpolluted estuaries is also available (Dix et al 1975).

### 2.6(ii) Mercury analyses in Australian fish

The number of Australian publications with data on mercury levels in fish is limited, as most such data is still held in unpublished form by the various research organisations. (See Section 3.1(iii).)

The Tasmanian coast has received the most intensive investigation, especially the Derwent River estuary, into which effluents, containing heavy metals enter the river from several industrial sources, resulting in mercury levels in sediments significantly higher than on any other part of the Tasmanian coast. A survey of the estuary was conducted for a range of heavy metals, including mercury in sediments, fish and shellfish (Bloom 1975), which found that most shellfish contained heavy metals in excess of health standards. Shellfish were absent from sites of major discharge. A large number of samples from one year's amateur catch, (which included species not regarded as of commercial significance) contained mercury levels in excess of 0.5 mg/kg.

An investigation of mercury levels in sixteen species of fish found in the Derwent estuary related the levels to the fish's trophic position (Ratkowsky et al 1975). Of the top fish carnivores, 51% had levels in excess of 0.5 mg/kg, while only 7% of the herbivores had levels in excess of that figure.

This agrees with work overseas, the highest concentrations being found in large pelagic carnivores such as swordfish (Freeman and Horne 1973b) and marlin (Shomura and Craig 1974). Similar species are also found off the Australian coast, although they are not currently being utilized for commercial purposes. High mercury levels were found in black marlin caught off Cairns where the average level found was 7.3 ppm in muscle, but with high variation between fish (Mackay et al 1975a). Marlin appear to be unusual in that the proportion of organic to total mercury is low, around 10%. (Shultz and Ito 1979; J.S. Edmonds, pers. comm.)

The sand flathead Platycephalus bassensis appears to be a valuable indicator of heavy metal pollution, as it is a widespread, easily caught non-migratory fish high in the food chain, with a wide possible range of mercury levels and exhibits significantly higher mercury concentrations in sites of known mercury pollution, which clearly demonstrates a site dependence for mercury uptake (Ratkowsky et al 1975). Several sites of major mercury pollution were pinpointed with this species (Dix et al 1975).

The tendency for sand flathead to accumulate mercury has also been demonstrated in Victoria (Walker 1977b). The mean mercury levels in specimens caught in Port Phillip Bay was 0.62 mg/kg, and as a result the public were advised not to eat Port Phillip Bay flathead, whether caught by amateurs or commercially.

Several studies have also been undertaken on New South Wales commercial fish and shellfish. An investigation of the mercury levels in oysters (Crassostrea commercialis) in Botany Bay and a comparison with levels found at other "unpolluted" locations found that in all cases levels were less than 0.5 mg/kg and no significant trend of pollution was found in Botany Bay (Hussain and Bleiler 1973). However, this result was not confirmed by further studies. Somewhat elevated levels of mercury were found in oysters from the Georges River/Botany Bay system, which were attributed to both natural and man-made sources (Williams et al 1976). The mean level of mercury in oysters from this system was 0.069 mg/kg, still well below the limit of 0.5 mg/kg. The study also tended to confirm that mercury is concentrated up the food chain, although all metal levels found in a higher trophic level fish (bream, Acanthopagrus sp.) were still well below 0.5 mg/kg.

Analysis of fresh fish from Botany Bay and the Shoalhaven River found that fish from both sites showed elevated levels in parallel with their "known pollution loads" (Neuhaus et al 1973).

A more extensive survey on New South Wales commercial fish using commercial size ranges from the major fishing grounds was undertaken more recently (Bebbington et al 1977). Again, the top carnivores exhibited the highest mercury levels, and a percentage of the yellowfin tuna (Thunnus albacares) (25%), mulloway (Sciaena antarctica) (19%) and snapper (Chrysophrys auratus) (13%) had levels in excess of 0.5 mg/kg.

A significant amount of work has been undertaken on mercury levels in commercial shark (Walker 1976). An investigation of mercury in school shark (Galeorhinus australis) and gummy shark (Mustelus antarcticus), the two main commercial shark species, found that the mercury concentration increased proportionally to shark length, but school shark showed a higher concentration than gummy shark of the same length. Males exhibited higher levels than females of comparable length in both species, but only male gummy shark had a positive correlation between locality and mercury level. It was hypothesized that the difference between school and gummy shark may be due to either a difference in food chain levels or difference in growth rate or possibly both. The sexual difference in mercury could be attributed to the faster growth rate of the females.

An examination of the Western Australian commercial shark species, in particular the whiskery (Furgaleus ventralis), gummy (Emissola ( = Mustelus) antarctica) and bronze whaler (Carcharinus obscurus) (Hancock et al 1977) found that the weighted average mercury concentration for all three species was approximately 0.75 mg/kg, and that individual mercury concentrations were positively correlated with shark size. Further work on the effects of sex, season and fishing area was suggested.

Fish from the Australian Northwest shelf contribute up to 47% of Taiwan's total fish catch from boats greater than 50 tonnes (Liu 1976). An analysis of fish sold on the Taiwan fresh fish market indicated that only specimens of the species known to have elevated mercury levels, such as shark and marlin, had levels in excess of 0.5 mg/kg (Sun and Chang 1972).

A number of other Australian published articles deal with mercury in fish, but have not provided new data. A composite list of all relevant publications to June 1978 is available from Department of Primary Industry.

2.6(iii) Market Basket Surveys

A limited amount of information on mercury in fish has come from national surveys of trace elements in foodstuffs, carried out by the Commonwealth Department of Health.

The first market basket survey (NH & MRC 1971a) was carried out in 1970, when fish samples were blended with meat samples prior to analysis as a food group.

The 1973 survey (NH & MRC 1974) treated fish separately. All 24 fish samples contained in excess of 0.1 mg/kg with two samples above 0.5 mg/kg. In the next (1974) survey (NH & MRC 1975) six of 24 fish samples were above 0.5 mg/kg, the highest being 0.9 mg/kg. In the 1975 survey (NH & MRC, 1977), the 24 fish samples ranged from 0.005 to 0.34 mg/kg mercury. Thirteen shellfish samples ranged from 0.005 to 0.11 mg/kg. In the 1976 survey (NH & MRC 1978) 24 fish samples ranged from 0.011 to 0.847 mg/kg mercury, and seafood samples (20 oysters and 19 prawns) were all below 0.1 mg/kg. In this survey the fish was analysed "as consumed," that is in batter.

Since the fish samples collected in these surveys are usually mixed, unidentified pieces, the data have little relevance in determining mercury ingestion by any particular person or group. However, the results have so far been the only available guide to average mercury intake by the Australian population. The relative importance of fish to some other foods with respect to mercury ingestion is discussed in Section 2.6(iv).

The data were adequate to estimate weekly mercury intake by age group of population based on the "average" per capita consumption of the various food items. The survey report compared Australian average intake to the relevant FAO/WHO "provisional tolerable weekly intake. Results are shown in Table 11 (from NH & MRC 1978). (See also Section 3.3(vi)).

2.6(iv) Mercury in Foods Other than Fish

Fish makes a minor contribution to total foods in the Australian diet - less than 1% (Australian Bureau of Statistics 1978). For this reason, mercury ingestion from other foods could be of significance.

The market basket surveys referred to above are one of the few sources of data on mercury in other Australian foods. The maximum recommended (NH & MRC) concentration of mercury in "other foods" is 0.03 mg/kg. This figure was not exceeded in the 1971, 1973 and 1974 market basket surveys, but the 1975 survey (NH & MRC 1977) showed some higher results in most of the food groups analysed, including chicken, mutton, pork, beef and lamb liver.

Results of the 1976 survey (NH & MRC 1978) which included a wide variety of foodstuffs showed that some samples of lambs fry (liver), pork, and fish exceeded the recommended maximum levels. However, average mercury content of these commodities was 0.006, 0.005 and 0.201 mg/kg respectively. Fish clearly contained the highest concentrations of mercury.

The preliminary findings of an ongoing survey of heavy metals in meat (Department of Primary Industry 1976) also showed that the 0.03 mg/kg recommendation was being exceeded in the case of beef and mutton, where 9.9% of the 345 beef samples and 6.4% of the 78 mutton samples were higher than 0.03 mg/kg.

A survey of mercury in various cereals and cereals products (eg breakfast cereals) found very low levels (Rakuns and Smythe 1978). Breakfast cereals had levels ranging from 0.003 to 0.008 mg/kg, while cereals had levels of between 0.0042 to 0.0076 mg/kg.

The 1976 Market Basket Survey also included mercury levels in samples (usually 24) of forty-four of the commonest dietary items. Analyses were carried out on all foods "as consumed", ie as prepared and cooked. The results were all very low, around 0.004 mg/kg mercury (except fish and shellfish).

From detailed results in appendices to the report (NH & MRC 1978), fish constitute 25% of mercury intake on average in an adult male, and less for an adult female. Fish appears to be the largest single contributor of mercury in adults and children over the age of 1 year.

The 1975 Market Basket Survey (NH & MRC 1977), included analyses of only 5 meat products and eggs, apart from fish products. Mercury levels presented were higher than those of the 1976 survey and the results suggest mercury intake by adults from fish constituted about 40% of the total from the foods analysed.

It is worth noting that a Swedish Expert Group (1971) reported that methylmercury accounts for well over half the total mercury in samples of pork chop and liver, beef and eggs.

The most significant conclusion however is that the average Australian appears not to receive the major part of his total mercury intake through the consumption of fish.

2.6 (v) <u>Australian Fish Consumption Studies</u>

This section briefly describes the results of fish consumption studies which have been conducted in Australia. It is not possible to compare them directly with one another or with the survey conducted on behalf of the Working Group because of differences in coverage, statistical methodology, interview techniques, etc.

## TABLE 11

## AVERAGE WEEKLY INTAKE OF MERCURY BY AUSTRALIANS

Comparison with the FAO/WHO Standard

| Person | Body Mass (kg) | Weekly intake (mg/person) | |
|---|---|---|---|
| | | FAO/WHO | Survey |
| Infant (male) 9 mths | 9.50 | 0.048 | 0.014 |
| Child (female) 2 yrs | 12.25 | 0.061 | 0.028 |
| Boy 12.5 yrs | 40.50 | 0.203 | 0.070 |
| Girl 12.5 yrs | 43.50 | 0.218 | 0.056 |
| Man 20 - 34 yrs | 70.00 | 0.350 | 0.056 |
| man 20 - 34 yrs | 58.00 | 0.290 | 0.056 |

Source: NH & MRC 1978

which is a lethal human blood level, there was a decrease in mitosis rate. Examination of blood samples from 33 persons showed no increase in chromosomal aberrations with increasing blood mercury concentration compared with controls or with a normal aberration range established in their laboratory.

An interesting experiment was carried out by a doctor ırne University during the above dietary study. On 'asions one or more meals of shark were eaten and blood evel studied over a period afterwards. In the first meal containing 385 mcg mercury in shark was eaten. llowing day whole blood mercury had risen from kg to 0.036 mg/kg, that is, in excess of the "safety" lood mercury fell rapidly thereafter to 0.011 mg/kg in while after 220 days it was still slightly elevated at kg. The other trials gave similar results (McCloskey, communication).

(b) Victorian Department of Health Study

In 1973 the Victorian Department of Health conducted a mercury levels in hair (unpublished) in which mercury :ions were determined for hair samples from ıly selected persons.

ılmost 75% of the samples gave readings below with the concentration range of 0.51 to 1.0 mg/kg with the greatest frequency (38%)(Table 12).

f the 800 persons, 19 (2.4%) were found to have hair vels in excess of 6 mg/kg, ranging up to 360 mg/kg.

lood samples were taken from 13 of the 19 persons and se contained less than 0.02 mg/kg of mercury, the vel being 0.011 mg/kg.

n view of the absence of any correlation between hair nercury concentrations, the analysts concluded that ases external contamination of hair made hair mercury ınreliable measure of exposure to methylmercury.

:) Shark consumption experiment, Tasmania

ı 1975, the wives of two Tasmanian fishermen and a ertook to eat about 900 g per week of shark larger .04 cm), the then maximum legal size of capture in Their purpose was to protest at the size ı. They ate shark for three months during which time blood mercury levels rose progressively from 6 mg/kg, from .01 to .030 mg/kg, and from .019 to respectively. Three months after the end of the the levels dropped to .002, .003 and .005 mg/kg y (Parsons, personal communication). Since the was not continued long enough for the blood of these achieve steady state concentration, no conclusions tionship between shark intake and blood mercury d be drawn.

2.6(vi) Existing data on mercury in tissues of Australian persons

Apart from the investigations by the Working Group, seven studies on mercury levels in Australians have been undertaken. Most studies attempted to relate dietary habits to blood and/or hair mercury levels. Results were treated in terms of the WHO conclusion that first symptoms of mercury poisoning occur when mercury concentration reached 0.2 mg/kg in whole blood, and 60 mg/kg in hair (NH & MRC 1972). Investigators have sought out for clinical investigation persons having levels exceeding 0.02 mg/kg for blood and 6 mg/kg for hair, i.e. the "safety" level obtained by application of a factor of 10.

(a) Melbourne University Studies

The first such study was by the Department of Medicine, Melbourne University in 1972 (Blackstock and Garson 1973, Penington 1973, Wood 1973), following the discovery of igh mercury content in Australian shark. It was a purposive study of groups in Victoria likely to include heavy shark eaters or be "at risk" - school children, pregnant women and fishermen's families - and "control" groups of hospital patients, etc. Three hundred and fifty hair analyses, 100 blood analyses and experimental cytogenetic studies were carried out. Fish consumption was rated as low at less than 100 g/week, moderate 100-500 g/week, and high at greater than 500 g/week.

The results were:

(1) 30 of 310 (9.7%) persons with usable diet histories ate in excess of 500 g of fish per week. Of these 15 were school children. Flake was the most popular fish eaten.

(2) Three persons had blood mercury in excess of 0.02 mg/kg and sixteen had hair mercury levels in excess of 6 mg/kg. Highest hair level was 37 mg/kg, and highest blood was 0.032 mg/kg.

(3) Subjects with high fish consumption had a low proportion of inorganic mercury in their hair, whereas workers in a thermometer factory working with elemental mercury had a high percentage of inorganic mercury;

(4) No symptoms were found in a complete neurological examination of the person with highest hair mercury level, nor were symptoms observed in any subject which could be attributed to mercury poisoning.

(5) Experimental cytogenetic studies showed no increase in *in vitro* aberrations in human tissues with addition of methyl mercuric iodide. However, above 1.0 mg/kg,

which is a lethal human blood level, there was a decrease in mitosis rate. Examination of blood samples from 33 persons showed no increase in chromosomal aberrations with increasing blood mercury concentration compared with controls or with a normal aberration range established in their laboratory.

An interesting experiment was carried out by a doctor at Melbourne University during the above dietary study. On three occasions one or more meals of shark were eaten and blood mercury level studied over a period afterwards. In the first trial, a meal containing 385 mcg mercury in shark was eaten. By the following day whole blood mercury had risen from 0.001 mg/kg to 0.036 mg/kg, that is, in excess of the "safety" level. Blood mercury fell rapidly thereafter to 0.011 mg/kg in 20 days, while after 220 days it was still slightly elevated at 0.003 mg/kg. The other trials gave similar results (McCloskey, personal communication).

(b) Victorian Department of Health Study

In 1973 the Victorian Department of Health conducted a survey of mercury levels in hair (unpublished) in which mercury concentrations were determined for hair samples from 800 randomly selected persons.

Almost 75% of the samples gave readings below 1.6 mg/kg, with the concentration range of 0.51 to 1.0 mg/kg occurring with the greatest frequency (38%)(Table 12).

Of the 800 persons, 19 (2.4%) were found to have hair mercury levels in excess of 6 mg/kg, ranging up to 360 mg/kg.

Blood samples were taken from 13 of the 19 persons and all of these contained less than 0.02 mg/kg of mercury, the highest level being 0.011 mg/kg.

In view of the absence of any correlation between hair and blood mercury concentrations, the analysts concluded that in these cases external contamination of hair made hair mercury levels an unreliable measure of exposure to methylmercury.

(c) Shark consumption experiment, Tasmania

In 1975, the wives of two Tasmanian fishermen and a doctor undertook to eat about 900 g per week of shark larger than 41" (104 cm), the then maximum legal size of capture in Victoria. Their purpose was to protest at the size restriction. They ate shark for three months during which time their whole blood mercury levels rose progressively from .005 to .036 mg/kg, from .01 to .030 mg/kg, and from .019 to .065 mg/kg respectively. Three months after the end of the experiment the levels dropped to .002, .003 and .005 mg/kg respectively (Parsons, personal communication). Since the experiment was not continued long enough for the blood of these persons to achieve steady state concentration, no conclusions on the relationship between shark intake and blood mercury levels could be drawn.

TABLE 12

MERCURY IN HAIR

Number and Percentage Distribution of Randomly Selected Individuals by Mercury in Hair : Melbourne 1973

| Mercury Concentration (mg/kg) | Number | Percentage |
|---|---|---|
| 0 - 0.5 | 140 | 17.5 |
| 0.51 - 1.0 | 302 | 37.8 |
| 1.1 - 1.5 | 156 | 19.5 |
| 1.6 - 2.0 | 76 | 9.5 |
| 2.1 - 3.0 | 67 | 8.4 |
| 3.1 - 6.0 | 40 | 5.0 |
| 6.1 - 9.0 | 5 | 0.6 |
| G.T. 9.0 | 14 | 1.8 |
| Total | 800 | 100 |

(d) Western Australian Government Chemical Laboratories Study

An investigation of mercury in the hair of 42 persons, including 36 staff of a chemical laboratory in Western Australia was carried out in 1976 (Wilson et al 1976). Hair mercury levels were found to bear no relationship to age, sex or fish consumption. Two persons had levels in excess of 6 mg/kg (9.4, 7.0). Re-analysis of the highest sample after washing the hair gave a figure of 5.9 mg/kg. It was concluded that the hair mercury levels were well within the range of normal values published in other countries for persons having no reported occupational exposure to mercury.

(e) Department of Health Study

The Commonwealth Department of Health in 1976/77 carried out a dietary study on behalf of the Working Group (English 1978; see also Section 3.2.(iii), where the study design is discussed in detail). Some 5,000 persons in suspected at risk groups were screened. From this screening a total of 161 persons participated in a detailed survey into low, moderate and high levels of fish consumption in the same manner as the Penington study outlined above. A total of 161 hair and 43 blood samples were analysed. The results were:

(1) Differences in hair mercury levels were found to be highly significant between the three groups.

(2) The average mercury content in hair and blood of the heavy fish eating group was 2.0 mg/kg and .006 mg/kg respectively.

(3) Two persons had blood levels in excess of 0.02 mg/kg, the highest being 0.038 mg/kg, and three (different) persons had hair levels in excess of 6.0 mg/kg, the highest being 7.0 mg/kg. These five people were re-interviewed and further hair samples were taken. In all cases but one the mercury level had fallen and two respondents said they were eating less fish than at the time of the first interview.

(4) There was no significant difference in blood mercury or selenium between the three groups.

(5) The difference between Caucasian and Aboriginal blood selenium levels of heavy fish eaters was highly significant.

The data from this survey were collected in a compatible manner to those of the Working Group's fish consumption survey. Hence it was possible to pool the data from the two surveys for further analysis. The results of these analyses are detailed in Section 3.4 of this report.

(f) University of Sydney study

Hair mercury levels in 220 visitors to the University of Sydney's Open Day 1973 and eleven laboratory staff exposed to elemental mercury were compared in another study (Thomson and Caldwell 1977).

The results differed from the Commonwealth Department of Health study:

(1) Hair mercury showed no significant correlation with fish consumption by either group;

(2) The mean hair level of 5.7 mg/kg in laboratory workers was higher than that of the two groups combined (3.35 mg/kg). However, since the authors showed that mercury was absorbed from the atmosphere onto the hair and could be reduced by washing with thioglycollate, the route of uptake remains unknown;

(3) Blood tests showed two laboratory workers had levels in excess of 0.2 mg/kg (0.5 and 0.8) but no signs or symptoms of poisoning were found in clinical examinations.

(g) Victorian Health Department mercury testing

Media publicity by the Victorian Health Department led to 10 persons coming forward for mercury testing. Most considered themselves to be heavy fish eaters but only one had hair mercury in excess of 6 mg/kg. The latter was a person with a hair mercury concentration of 22 mg/kg and blood mercury of 0.09 mg/kg. No signs or symptoms of mercury poisoning were found. This adult male claimed to have consumed about 700 g of flake per week for the previous 18 months.

The Victorian Health Department also became involved in a suspected case of mercury poisoning in July 1977. The person was a heavy drinker and periodically consumed large quantities of fish with a high mercury level. Symptoms included dizziness and ataxia. The person's blood mercury level was recorded as 0.028 mg/litre while his hair was measured at 6.6 mg/kg for the first 3cm from the scalp and 2.4 mg/kg for the rest. The Department reported that these results were consistent with a high fish diet but were well below the levels at which symptoms would be expected. It was concluded that his symptoms were due to his alcohol intake and not mercury poisoning.

2.6(vii) Current Australian regulations and controls.

(a) Controls on Ingestion of Mercury

All States have a statutory limit for mercury in fish of 0.5 mg/kg except for South Australia which has a limit of 1.0 mg/kg. Imports of fish into Australia are not permitted when levels of mercury exceed 0.5 mg/kg.

In certain instances, additional State regulations have been devised to take care of specific situations. These actions are listed by State in Table 13.

(b) Controls on Emission of Mercury

The following is the text of the National Policy with respect to Mercury Emissions to the Environment, as adopted by the Australian Environment Council:

Draft No. 3

"

NATIONAL POLICY WITH RESPECT TO
MERCURY EMISSIONS TO THE ENVIRONMENT

In recent times, the Australian public is increasingly aware of the problems of mercury contamination of the environment. At the same time, the Commonwealth, States and Territories, recognising the potential hazards of uncontrolled emissions of mercury to the environment, have introduced various measures to control and manage such emissions. However, from an effectiveness point of view, a concerted effort in the fight against mercury pollution on a national scale is obviously desirable. It is in recognition of this fact that the Australian Environment Council has adopted the national policy with respect of mercury emissions to the environment. This policy provides both long term and short term objectives, the achievements of which are vital to the protection of the environment from mercury pollution.

The Council also recognises the economic implications of this policy and is therefore prepared to allow for transition periods during which the attainment of the objectives and targets outlined in the policy may be achieved progressively without exerting unduly harsh pressures on the parties involved. The Council seeks the maximum co-operation from all parties in attaining the Policy objectives and targets as soon as practicable.

For the purpose of managing the mercury pollution of the environment, measures should be adopted:

1.1 to reduce all man-made emissions of mercury to the environment to the lowest possible levels, with particular attention to:

TABLE 13

ADDITIONAL CONTROLS BY STATES ON MERCURY IN FISH

| State | Species | Control |
|---|---|---|
| Victoria | Shark | Prohibition on interstate shark fillets.<br><br>Prohibition on landing and sale of school shark over 63 cm partial length (112 cm total length). |
| New South Wales | Marlin<br>Shark | Prohibited for sale.<br>Restrictions to be placed. |
| Western Australia | Shark | Individuals over 18 kg. tested for mercury content. Confiscated if over 0.5 mg/kg. |

1.1.1 the elimination of alkyl-mercury compounds from all uses that allow this material to reach the environment in any way;

1.1.2 the maximum possible reduction, by best practicable means, of mercury in atmospheric emissions and effluent discharges from all industrial plants using or manufacturing products containing mercury and mercury compounds;

1.1.3 the maximum possible reduction, by best practicable means, in the release of mercury and mercury compounds to the environment from areas which have been affected by man's past and present activities in the mining industry;

1.1.4 the active encouragement of the establishment of any research into suitable methods for the recycling and/or the ultimate disposal of mercury and mercury compounds in liquid and solid wastes;

1.1.5 the active encouragement of the use of substitutes for mercury and mercury compounds that present a significantly reduced environmental hazard.

1.2 for which the targets should be:

1.2.1 the elimination of alkyl-mercury compounds and the phasing out of other organo-mercury compounds from use in agriculture;

1.2.2 the elimination of all mercury compounds from use as slimicide in the pulp and paper industry;

1.2.3 the maximum possible reductions, by best practicable means, in the atmospheric emissions and effluent discharges of mercury and mercury compounds from mercury cell chloralkali plants;

1.2.4 the active discouragement of the installation of new mercury cell chloralkali plants and the imposition of stringent effluent standards on mercury discharges or if necessary, the prohibition of the installation of new mercury cell chloralkali plants;

1.2.5 the active encouragement and where necessary insistence on the conversion of mercury cell to diaphragm cell chloralkali plants;

1.2.6 the maximum possible reduction, by best practicable means, in the release of mercury and mercury compounds from the mining and processing of ores;

1.2.7 the establishment of measures to minimise the emission of mercury and mercury compounds from the burning of fossil fuels, particularly from large coal burning installations;

1.2.8 the establishment of research into substitute products to replace products containing mercury or mercury compounds used for any purposes.

2.1 to establish the extent of mercury pollution in the Australian environment by means of:

2.1.1 chemical and biological monitoring of the ambient levels of mercury and mercury compounds in the environment;

2.1.2 the active co-ordination and exchange of information on monitoring of mercury in the environment on a national scale.

2.2 for which the targets should be:

2.2.1 the establishment of base line mercury levels to determine the proportion of total mercury load from controllable sources with the view of estimating the degree of improvement to be expected from actions taken in controlling mercury emissions from these controllable sources;

2.2.2 the establishment of the interchange of mercury between biota, soil, water and air. "

The Standing Committee on Fisheries noted the document at its 12th Meeting in 1976.

Although the States and Territories are in accord with the establishment of the national policy, the practical implication of implementing the policy will require a slow transition from existing conditions to be recommended conditions of the policy. In the majority of cases, baseline data are limited and the initial stage in the States and Territories requires an assessment of individual situations. However, it is not anticipated that any difficulties will be encountered in implementing the concept of the national programme since all of the States and Territories have provided power in one form or another to require monitoring of waste discharges.

## 2.6 (viii) Monitoring Programs

Essential to any regulatory action to control mercury emissions is the establishment of monitoring systems to ensure routine examinations of the potentially polluted areas. Programs have been or are being implemented throughout Australia.

### (a) The States

#### (1) Victoria

The Victorian Ministry for Conservation receives information from a number of government departments monitoring mercury levels in streams, sewage farms, power stations and certain industrial sites. There is also a sampling program for Port Phillip Bay and Westernport Bay.

#### (2) New South Wales

The New South Wales State Pollution Control Commission does not consider mercury emissions to be a problem and consequently does not, at present, conduct any formal mercury monitoring.

#### (3) Queensland

The Queensland Water Quality Council is currently monitoring mercury in 21 water bodies throughout the State (mostly estuarine) at quarterly intervals. It also collects sediment samples from 33 water bodies. Industries which might have mercury in their effluent are required to carry out their own tests and confirmatory monitoring is carried out by the Council.

There has been some monitoring of underground water in sugar growing areas (mercury compounds are used as a fungicide) but the results have proved negative.

The Brisbane City Council has been monitoring the city water supply for a number of years and mercury levels in some seafoods have also been measured over the past few years.

#### (4) Tasmania

Industries situated in Tasmania which use mercury and mercury compounds are regulated by limits set out in their operator's licence. Monitoring is carried out by both the Department of Environment and by the industries themselves. The Department may specify action to be taken to reduce emissions. Regular surveys of streams and the ocean are also carried out by the Department and these usually include assay of the mercury level in a representative fish (flathead).

(5) South Australia

The Department of Environment is not currently undertaking any monitoring for mercury but, in the past, has monitored Spencer Gulf.

(6) Western Australia

The Department of Conservation and Environment monitors industrial effluents in Cockburn Sound including analyses of surface sediments and marine organisms. There is also a program to analyse the emissions from power stations; this is based on the mercury content of coal.

(7) Northern Territory

There is no monitoring for mercury specifically but the Water Resources Board routinely samples water as part of its investigations connected with uranium mining. The analyses are carried out by AMDEL (consultant analysts).

(8) Australian Capital Territory

In the Australian Capital Territory there is no regular monitoring for mercury although spot sampling may be undertaken in the future. Industries which may pollute with mercury or other materials are carefully scrutinized before being allowed to operate.

(b) The Commonwealth

At a Commonwealth level there are several ongoing programs for monitoring mercury.

The Department of Primary Industry maintains surveillance over pesticide residues in export primary produce as part of the Export Inspection Service. The analyses are done by the Australian Government Analytical Laboratories (AGAL) and mercury levels are monitored in meat and dairy products. There are also additional irregular surveys of contaminants in other products.

The Commonwealth and State Departments of Health have conducted, since 1973, market basket surveys to determine contaminant levels in food characteristics of the Australian diet. (See also Section 2.6(iii)). AGAL undertakes the analyses.

In October 1974 Fisheries Pollution Committee submitted for the consideration of Standing Committee a statement of principles to be met in the establishment of an Australian-wide network of marine environmental observation in conjunction with State environmental agencies. This resulted in (i) a request to CSIRO Division of Fisheries and Oceanography to expand its network of oceanographic observation, (ii) a submission to the Australian Environment Council for its support in implementing a suggested pollution monitoring network.

A system for open sea monitoring has been devised between the Australian Fisheries Council and the Australian Environmental Council. (This system will include analysis for trace metals including mercury in an attempt to determine baseline levels of such trace metals as mercury in the open sea.) The stations will consist of a series of submerged buoy monitoring stations, set at the edge of the continental shelf, ultimately all the way around the Australian coast. Measurements of trace elements including mercury will be made from sediment samples and from organisms contained within cages attached to the buoys. The program is presently in the first stage of a three stage plan which has been in operation for several months.

The CSIRO Division of Fisheries and Oceanography is developing equipment and methods for routine sampling and analysis of heavy metals in sea water. CSIRO Division of Food Research has already carried out other mercury studies including the measurement of mercury levels in fish and shellfish from the Derwent Estuary.

The Commonwealth provides funds for, in part, the Water Quality Assessment Program to monitor baselines of heavy metals in inland waterways and estuaries. Administration is by the Department of National Development.

The Department of Science and Environment is responsible for collecting information on aspects of mercury use in Australia to fulfil an obligation to the Organisation for Economic Co-operation and Development (OECD) Environmental Committee.

### 2.6(ix) Associated substances*

Few studies have been published on selenium and arsenic in Australian species of fish. In a survey of metals in nine species of fish (Bebbington et al 1977) selenium concentrations were found to be in the range 0.1 - 0.8 mg/kg and of arsenic 0.1 - 4.4 mg/kg. Glover (in press) found selenium concentrations of 0.2 - 0.8 mg/kg in school shark and 0.2 - 0.5 mg/kg in gummy shark. Arsenic concentrations ranged from 5 - 15 mg/kg on school shark and 7-30 mg/kg in gummy shark. Average selenium concentrations in black marlin caught off the Australian east coast were 2.2 mg/kg in muscle and 5.4 mg/kg in the liver (Mackay et al 1975a). Selenium levels were significantly correlated with both mercury level and fish size. It will be recalled from Section 2.6 (ii) that the same authors recorded unusually high (averaging 7.3 mg/kg in muscle) but variable concentrations of mercury in black marlin.

In a survey of Sydney rock oysters from nineteen production areas on the New South Wales coast (Mackay et al 1975b) selenium and arsenic concentrations were found to decrease with increasing age, and in one river, the Georges, metal levels increased upstream.

* (Refer also to Sections 2.4(viii) and 2.7)

The NH & MRC standard for selenium is 2.0 mg/kg, and for arsenic 1.14 mg/kg as the metal or 1.5 mg/kg as the trioxide. These standards are currently under review.

A current research programme in Australia (Thrower and Olley, in press) has been aimed at preparing standard fish flours with known mercury and selenium concentrations. These will be used in feeding trials using quail, in Melbourne, Adelaide and the United Kingdom, in order to investigate whether selenium has a protective effect against mercury occurring in Australian fish species. Research in Western Australia has identified the chemical form of arsenic in fish and shellfish (Edmonds et al 1977) and is currently being focussed on the form of selenium.

## 2.7 Background to Health Aspects of Mercury in Fish

### 2.7(i) Introduction

This part of the Report of the Working Group on Mercury on Fish is intended to provide a brief summary of the health aspects of mercury in fish.

The Working Group has recognised that in Australia the assessment of the toxicology of mercury in fish is the responsibility of the National Health and Medical Research Council and its Committees, particularly the Food Science and Technology Sub-committee (FST).

A more complete document on this subject has been prepared by an officer of the Commonwealth Department of Health in conjunction with the FST, and should be referred to if more detailed information is sought. In addition an extensive bibliography has been prepared which cites literature available to February 1979. These documents, because of their size, have not been included as part of the Working Group's report but they are both available from the Commonwealth Department of Health.

The following summary sections were provided by the Commonwealth Department of Health for the guidance of the Working Group and should be considered against the background of the fuller documents cited above:

(1) basic criteria for toxicological assessment of substances

(2) approach to the problem of setting maximum permitted levels of various substances in food
  (a) international approach
  (b) Australian approach

(3) summary of procedures for evaluating the safety of additives and substances in food

(4) nomenclature of mercurial substances

(5) background to mercury poisoning

(6) clinical aspects of mercury poisoning

(7) vulnerable population groups

(8) the toxicity of methylmercury

(9) indices for determination of mercury in the body

(10) calculations based on the Japanese incidents

(11) further considerations

(12) requirements for further research.

## 2.7(ii) Basic criteria for toxicological assessment of substances

### (a) The "no effect level"

When applied to data from animal experiments, the term 'no-effect level' refers to the highest concentration of substance that can be included in the diet of a group of animals without toxic effects.

The determination requires to be made in the most sensitive animal species and be in relation to the most sensitive organ.

When applied to data derived from cases of poisoning in humans, the same considerations apply. That is, the determination of the level of that substance in the most sensitive individual of the most sensitive group and in relation to the most sensitive organ.

### (b) The Acceptable Daily Intake (ADI)

The acceptable daily intake of a chemical is the daily intake which during an entire lifetime, appears to be without appreciable risk on the basis of all known facts at that time. It is expressed as milligrams of the chemical per kilogram of body weight.

### (c) The "Safety Factor"

In the extrapolation of animal and human data, the application of a safety factor is required in order:

(1) to allow for species differences between the animal species and humans.

(2) to allow for wide variations in sensitivity and susceptibility among the human population.

(3) to allow for the fact that the number of animals tested is small compared with the size of the human population exposed to the hazard.

(4) to allow for the greater variety of complicating disease processes in the human population.

(5) to allow for the difficulty in estimating the highly variable human intake and environmental contact.

(6) to allow for the possibility of synergistic action (FAO/WHO 1958, FAO/WHO 1972, FAO/WHO 1973).

Where the substance under examination is relatively innocuous and the effect level can be calculated in the g/kg body weight range, a margin of safety of 100 has been widely used and found to be acceptable in practice over a number of years (FAO/WHO 1958, FAO/WHO 1972, FAO/WHO 1973).

2.7(iii) Approach to the problem of setting maximum permitted levels of various substances in food

(a) International approach

The governing body of the World Health Organisation, the World Health Assembly, in 1953 recognised the growing need to investigate the increasing use of various chemical substances in the food industry.

From this beginning a Joint FAO/WHO Expert Committee on Food Additives was formed and has met annually since 1956 to consider substances both intentionally and unintentionally introduced into human food.

The Expert Committee is composed of a number of internationally recognised experts invited on an ad hoc basis. Those invited by WHO are mainly responsible for the toxicological evaluation and those invited by FAO for the preparation of specifications and for the review of technological efficacy.

The function of the Committee is to provide advice to the two sponsoring organisations, WHO and FAO, the Joint FAO/WHO Codex Alimentarius Commission which is developing international food standards and codes of hygienic practice for foods, and their member States of which Australia is one.

The Expert Committee has laid down the procedures for testing intentional and unintentional food additives to establish their safety for use and to establish provisional tolerable weekly intakes for heavy metals such as mercury, lead and cadmium.

This activity has been further supported by WHO as set out in the report of the WHO Scientific Group on Procedures for Investigating Intentional and Unintentional Food Additives (FAO/WHO 1958).

(b) Australian approach

The examination of substances introduced to food is a part of the responsibilities of the Food Science and Technology Sub-committee of the National Health and Medical Research Council (NH & MRC). Recommendations of this Sub-committee are in the first instance made to the Food Standards Committee among whose responsibilities are the examination of these recommendations, the incorporation of them into appropriate food standards and their recommendation to the NH & MRC.

The Standards, after approval and adoption by the Council are recommended to States and Territories for adoption into their food legislation. In the majority of cases such recommendations are adopted and incorporated into legislation having been developed by consensus, and thus become regulations in the States and Territories, which have the requisite powers in the area of food legislation. This system of co-operation between the States, the Territories and the Commonwealth has been operating since 1952.

The procedures laid down for the consideration of food additives and contaminants are set out in the NH & MRC Format for the Application of a Food Additive (NH & MRC 1975). Details of pharmacological and toxicological considerations are required in accordance with World Health Organisation Procedures.

2..7(iv) <u>Summary of procedures for evaluating the safety of additives and substances in food</u>

The procedures for evaluating the effects of additives and substances in food can be summarized as follows:

(1) Acceptance of a <u>no-effect</u> level established in the course of some appropriately conducted long-term test or tests on laboratory animals.

(2) Application of an arbitrary <u>safety factor</u> which is in keeping with the nature of the compound being evaluated, with the circumstances of its intended use, and with the quality of the experimental studies available. A safety factor of 100 is widely accepted. However, when toxicological data derived from observations in man are available, they may be used to provide a lower safety factor since they obviate the need for inter species extrapolation. A safety factor of 10 was used by the Swedish Commission on Evaluating the Toxicity of Fish.

(3) Allocation of an acceptable daily intake (ADI). The concept of an ADI for any substance is based on the assumption that:

a. each day's intake is ultimately cleared from the body and

b. for the most part: such clearance is rapid and complete.

It is inappropriate to attempt to set ADIs for heavy metals such as mercury, lead and cadmium, for the following reasons:

(1) The metals and some of their organic derivatives are cumulative and may attain equilibrium within the body only after prolonged exposure; selective localisation

of such materials in susceptible organs and tissues of the body may cause injury when high levels are attained. There is also the need to distinguish accurately the relative proportions of different forms of the contaminant, such as inorganic mercury and methylmercury compounds, in view of their distinctive toxicological implications.

(2) A narrow margin exists between the exposure of "normal" populations in many countries and the exposure known to cause overt symptoms and signs of intoxication. The allocation of an ADI on the basis of animal experiments, using a reasonable safety factor, might result in figures that would not permit a normal intake of food.

(3) There is uncertainty concerning many of the essential facts about the response to current levels of population exposure:

a. the degree to which individual adults vary in their susceptibility, and the influence of the usual variables within and between populations, are still unknown;

b. the special susceptibility of the foetus, neonate, and child cannot at present be accurately expressed;

c. subclinical indices of effect, as distinct from measurements indicating exposure, have not been adequately delineated;

d. the possibility of genetic effects exists, but the levels of exposure needed to bring them about (if, in fact, genetic damage is elicited in man) are unknown;

e. the potential biological interactions of heavy metals with each other and with neurotoxic, nephrotoxic, and lipophilic chemicals present in food or derived from the environment have not been evaluated.

(4) ADIs are intended to be used in allocating the acceptable amounts of an additive to specific intended uses where it will serve necessary technological purposes and will be employed in accordance with good manufacturing practice. Such concepts are inapplicable to trace contaminants (FAO/WHO 1972, FAO/WHO 1973).

The Joint FAO/WHO Expert Committee has therefore allocated a provisional tolerable weekly intake for mercury, lead and cadmium (FAO/WHO 1972, FAO/WHO 1973).

The basis for this approach may be summarised as follows:

(1) The contaminants are able to accumulate within the body and at a rate determined by:

a. the levels of intake, and

b. the chemical form of the heavy metal present in the food.

Consequently, the basis on which intake is expressed would be more than the amount corresponding to a single day.

Moreover, individual foods may contain above average levels of a heavy metal contaminant, so that consumption of such foods on any particular day greatly enhances that day's intake. Accordingly the provisional tolerable intake is expressed on a weekly basis.

(2) The term 'tolerable', signifying permissibility rather than acceptability, is used in those cases where intake of a contaminant is unavoidably associated with the consumption of otherwise wholesome and nutritious foods, or with inhalation in air.

2.7(v) Nomenclature of mercurial substances

Inorganic mercury refers to the liquid element and its vapour, to mercurious and mercuric salts, and to complexes in which mercuric ions form reversible bonds, for example to such tissue ligands as thiol groups on proteins.

Examples include mercuric nitrate used in the felt-hat industry, and mercuric sulphide used in vermilion and anti-fouling paints.

Organic mercury refers to mercury in compounds where the mercury is bound to an organic group, and includes alkyl- (e.g. ethyl-, methyl-, methoxyethyl-) and aryl- (e.g. phenyl- and tolyl-) mercury compounds. These may be used for example to control seed-borne diseases of cereals and in the manufacture of fulminate in explosives.

2.7(vi) Background to mercury poisoning

Mercury and many of its compounds have long been known to be toxic substances even at low concentrations (Taylor 1976). Poisoning by metallic mercury has a long history, and mercury mining has proved to be an occupational hazard. Inorganic salts of mercury have been responsible for occupational poisoning, for example intoxication by mercuric nitrate in the felt-hat industry, known as "hatter's shakes", pink disease (acrodynia) of children dosed with calomel (mercuric chloride) for teething, Lancashire policemen affected by mercury in fingerprinting powder (Hartung and Dinman 1972), and so on.

Metallic mercury produces different toxic effects to methylmercury. In addition the route of entry into the body affects the toxicity. The toxicity of inhaled mercury is different from that of mercury ingested as an inorganic salt. The fact that methylmercury has a prolonged half-life in the body compared with metallic mercury means that a different set of kinetics applies.

The mechanisms of toxicity may be related to the target organ in the body. Inorganic mercury is concentrated in the kidney so it exerts major effects there, while methylmercury, because it is lipid soluble, is concentrated in the brain and kidney.

Alkylmercury compounds have presented the greatest toxicological danger to man, particularly with reference to residue levels in food. In Iraq and Pakistan, hundreds of people became ill and many died when grain treated with methyl- and ethylmercury compound was consumed rather than being used for seed as was intended. In New Mexico, a family of seven consumed pork from pigs fed methylmercury dicyandiamide-treated seed grain, and three children in the family evidenced severe brain damage.

There have been two properly documented situations in which humans have suffered illness or death as a result of consuming fish. Both occurred in the Japanese villages of Minamata Bay in 1953, and Niigata in 1960, where contaminated fish were caught and eaten by local villagers. The sources of mercury contamination, believed to be in the form of methylmercury, were from large chemical plants using mercury catalysts in the manufacture of vinyl chloride and acetaldehyde. The fish and shellfish contained up to 100 mg/kg of mercury (Margolin 1978).

Studies in Sweden (Larsson 1970) showed that some rivers and lakes were seriously contaminated with mercury, apparently from the effluents of chlor-alkali and paper industries, and in the affected areas fish and shellfish contained very high levels of mercury. Westoo (1966) found that the mercury in the fish was predominantly a methylmercury compound of unspecified structure, even though the predominant forms in which mercury had been released into the Swedish aquatic environment were inorganic or phenyl salts (Taylor 1976). Comprehensive epidemiological studies, which included heavy fish eaters, however failed to identify symptoms of mercury poisoning:

> "No case of poisoning in Sweden which was due to the consumption of MeHg contaminated fish has been described, but the Hg levels in the blood of extreme fish consumers have approached the lowest Japanese levels in cases of poisoning and, in a few individuals, have even exceeded those values". (Swedish Expert Group, 1971)

More recently, following the discovery that mercury discharged from a chlor-alkali plant had contaminated freshwater fish used as food by North American Indians in reservations on the Wabigoon-English Rivers system in Ontario, the Canadian Government banned the consumption of fish from the area. However, despite the fact that fish were contaminated to levels in excess of 20 mg/kg, and that mercury blood levels in some humans eating the fish had become elevated to nearly double the level shown to cause clinical symptoms of mercury poisoning in the Niigata incidents (Taylor 1976), there were still opposing views (Barbeau et al 1976, Shephard 1974) on the evidence for mercury poisoning.

## 2.7(vii) Clinical Aspects of Mercurial Poisoning

### (a) Minamata Disease

Since the time of the Japanese epidemics, methylmercury in fish has been shown, because of its long retention in the body, its propensity for the nervous system, and its effects on developing tissues, to pose a serious public health problem.

The classic Hunter-Russell syndrome of Minamata disease is characterised by parasthesia, progressive incoordination (dysarthria and ataxia), loss of vision and hearing and intellectual deterioration.

It has since been recognised that there are a number of symptoms attributed to the enlarged concept of Minamata disease. These include various combinations of neuropsychiatric symptoms such as a type of polyneuritis and mental deterioration.

These symptoms have been found in patients in Japan years after the period of most acute exposure. It has been concluded that some patients only showed symptoms of illness after a lapse of many years. In addition there are cases of chronic intoxication in patients due to the ingestion over periods of 10 years or more of fish having low levels of mercury.

### (b) Congenital Minamata Disease

Cerebral palsy-like symptoms (Congenital Minamata Disease) have been reported in children who had not eaten contaminated fish and whose mothers had apparently not been affected. The disease varied in severity; some children having mild to moderate spasticity and ataxia, and others having severe intellectual retardation, seizures and evidence of more generalised brain damage. Clinical symptoms were more difficult to elicit and more varied than in the case of Minanata Disease in adults.

The aetiology of the congenital disease has been attributed to the passage of methylmercury both transplacentally to the foetus and through mother's milk to the infant. Research has also shown that methylmercury in red blood cells of pregnant women, is concentrated by a factor of 1.3 in the foetal red blood cells. Bearing in mind the small body weight of the foetus, this observation is considered to have serious implications for the possibilities of congenital disorders arising from quite low levels of exposure of the parent. The Japanese experience appears to confirm this.

(c) Subclinical poisoning

Symptoms attributed to subclinical poisoning include loss of appetite, loss of weight, objective tremor, insomnia, erethism, shyness, nervousness, dizziness, frequent colds, diarrhoea, sore gums, fatigue, headache, impaired power of concentration, impaired memory, tingling and numbness of fingers or mouth, irritability.

(d) Micromercurialism

The effect of exposure to small concentrations of mercury has been called micromercurialism in the USSR where the syndrome has been extensively studied and reported on in great detail (Trakhtenberg 1974).

Typical symptomatology consists of complaints of one or more of the following:

> Headaches, dizziness, increased irritability, emotional instability, personality change, weakness, nausea, loss of appetite, insomnia, daytime drowsiness, alterations of bowel habit, depression, apathy and an overall increase in number of the frequency of various complaints.

The onset of symptoms was related to the length of time of exposure of minute amounts of mercury. Therefore neurological symptoms were more often noticed among older people.

In the older group a variety of pathological problems were noted more frequently such as hypotension (31-33%) and hypertension (7-12%) particularly in those with a long history of contact.

Most of the subjects were apparently healthy, although many of them complained of feelings of weakness and some of emotional disturbance and often a progressive decline in work capacity.

The difficulty of diagnosing micromercurialism was acknowledged in that there had been cases misdiagnosed as neurasthenia, hysteria or neuroses.

A correct medical diagnosis of this condition can only be determined after a detailed investigation of the effects on a wide variety of organs such as the thyroid and liver, and the cardiovascular, olfactory and central nervous systems and the motor functions.

2.7(viii) Vulnerable Population Groups

On the basis of available evidence the most vulnerable population groups are:

Foetus
Neonates
Infants 0-12 months
Breastfed infants
Children
9-16 year age group
Pregnant women
Enthnic groups and
Occupationally exposed groups:

- those persons associated with the fishing industry and private fishermen
- snack food consumers
- dentists
- thermometer makers
- chlor-alkali plant and paper workers.

(a) The foetus, newborn, infant and young child

(1) Methylmercury crosses the placental barrier and achieves a higher concentration in the foetal red blood cells than in maternal red blood cells.

(2) The foetus can exhibit signs of methylmercury poisoning when there are no maternal signs of toxicity.

(3) Exposure of the newborn through milk from the mother will constitute a hazard, especially in cases in which the initial body burden is already raised due to transplacental transfer. Investigations reveal that total mercury concentrations in milk average about 5% of the total mercury concentrations in blood and the organic mercury concentrations in milk average about 3% of the mean organic mercury in blood. This is particularly relevant when considered in the light of data which show that absorption of methylmercury from the gastrointestinal tract is about 95% of the administered dose.

Scientific evidence, much of it derived from animal experiments and supported by clinical observation indicates that newborn and very young children are particularly sensitive to the harmful effects of foreign chemicals. Among the reasons for this are the immaturity of enzymatic detoxifying mechanisms, incomplete function of excretory organs, low levels of plasma proteins capable of binding toxic chemicals, and incomplete development of physiological barriers such as the blood-brain barrier. Moreover, there appears to be a general vulnerability of rapidly growing tissues, which is particularly important with regard to the developing central nervous system.

(b) Children

It has been demonstrated in Japan, where Minamata disease was widespread, that there were many children with apparent mental disorders.

A higher frequency of severe symptoms and damage is seen among persons younger than 5 years old, and persons older than 40 years especially those over 60 years.

2.7(ix) Toxicity of methylmercury

Methylmercury (MeHg) compounds are much more toxic to man than other forms of mercury.

When ingested MeHg being lipid soluble is almost completely absorbed from the gastro-intestinal tract. In other words, approximately 100% of MeHg ingested from any source will pass into the blood stream, where some 90% of the ingested dose enters the erythrocytes and is concentrated in the acute phase in the liver and kidney, which account for some 50% of the total body burden (Aberg et al 1969). In the liver MeHg is contained in the lysosomes (Cairncross 1978 unpublished).

The entry of MeHg into the brain is slower than concentration into the liver and kidney, but the concentration in the brain will reach a value of one fourth to one half of that found in the kidney. In man, the amount in the brain is some 10-15% of the total body burden. MeHg is concentrated mainly in the cell bodies of sensory neurones, where it produces distinct physiological effects (Somjen et al 1973 (a) and (b)).

It is of significance that animal studies (rat) show that about 40% of ingested MeHg is converted to inorganic mercury and excreted as such, however the brain content of inorganic mercury does not exceed 3%. (Cairncross 1978 unpublished).

The action of MeHg at a cellular level is not fully understood. Mercury readily forms covalent bonds with sulphur. When exposed to sulphydryl groups, the divalent mercury replaces the hydrogen atom to form mercaptides. Organic mercurials form mercaptides of the form RMe-Hg-SR where R is protein. Thus, MeHg will interfere with those enzymatic and biochemical processes in which sulphydryl groups are incorporated into amino-acids, e.g. glutathione and cystathione (Cairncross 1978 unpublished).

2.7(x) The antagonistic and synergistic effects of other substances on methylmercury

It has been suggested that MeHg accumulation in tuna fish, marlin, swordfish and shark is correlated with a concomitant rise in selenium (Se) content in fish muscular tissue, and that the MeHg:Se ratio offers a degree of protection against the toxicological actions of MeHg in man (Ganther et al 1972, Ganther 1975 unpublished). The aim of this section of the report is to discuss that hypothesis.

Feeding experiments in quail and rats indicate that the toxicity of methylmercury is reduced when selenium is present in the diet. It should be noted that in these studies the toxicity of methylmercury was reduced not eliminated (Cairncross 1978 unpublished).

Results of further studies indicate that selenium administered as selenite is more effective in preventing neurological damage in rats than is selenium administered as tuna flesh (Ohi et al 1976).

It has been reported (Steinwall and Olsson 1969) that the blood-brain barrier is impaired following methylmercury poisoning, and that in such circumstances available selenium accumulates within the central nervous system. It is important therefore to consider the toxicology of selenium in such circumstances. The acceptable daily intake for selenium has been reported as 70 micrograms per kg body weight per day (Sakurai et al 1975, Haar and Muth 1972).

Selenium is an essential component of the diet, it functions in oxidative phosphorylation reactions as selenopersulphide which facilitates the transfer of electrons from sulphydryl containing compounds to cytochrome C (Sakurai et al 1975). A deficiency of selenium results in a decrease in the availability of sulphydryl groups in sulphur containing amino acids. The presence of non-reduced sulphydryl groups in biochemical function relates to transmembrane transport of macromolecules and the problem of reduced antibody formation. Vitamins C and E are intricately involved in these physiological mechanisms.

With respect to the toxicity of selenium, this element has been implicated in man with the syndrome of amyotrophic lateral sclerosis (Kilness and Hochberg 1977) which is referred to as 'blind staggers' when occurring in domestic animals.

Therefore, impairment of the efficiency of the blood-brain barrier, as occurs in the presence of methylmercury poisoning (Steinwall and Olsson 1969), can induce a situation in which excess selenium can enter the central nervous system. It is further established that an excess of selenium in the central nervous system can produce severe toxic effects, particularly in sensory and motor neurones. One of the effects of methylmercury poisoning is peripheral parasthesia caused by damage to sensory cell bodies. Therefore in certain circumstances the interaction between selenium and methylmercury could be toxicologically synergistic rather than antagonistic. This supposition is supported by the finding that administration of dimethyl selenide to experimental animals prior to feeding methylmercury enhances the toxicity of methylmercury (Parizek et al 1971, Frost and Lish 1975).

The hypothesis is complicated further by the observation that the syndrome described as amytrophic lateral sclerosis can be induced separately by chronic lead and methylmercury poisoning as well as selenium (Felmus et al 1976, Kilness and Hochberg 1977, British Medical Journal 1978, Conradi et al 1976 and 1978, Brown 1961). Therefore it is obvious that the whole question of methylmercury and selenium interactions is more complex than the literature would suggest. Thus, as early as 1939 it was reported that rats fed selenium in their diet at a level of 10 micrograms/ml in water, were protected from toxic manifestation by the concurrent feeding of either arsenic or tungsten (Moxom and Dubois 1939). More recent observations show that selenium protects experimental animals against cadmium induced testicular necrosis (Parizek et al 1974). Thus a superficial examination of the literature unfolds a toxicological problem involving interaction between selenium and mercury, lead, cadmium, tungsten, arsenic, silver and zinc (Cairncross 1978 unpublished).

Experimental evidence would suggest therefore that superficial examination of the supposed antagonism and hence alleged protective action of selenium against the toxic action of methylmercury is an integral part of a far more complicated problem, which might reasonably be considered, toxicologically, as the "heavy metal syndrome". A problem which broadly speaking relates to the interaction of selenium complexing with a variety of heavy metals (Cairncross 1978 unpublished).

In conclusion, the hypothesis that selenium exerts a protective action against the inherent toxicity of methylmercury is not a matter that can be superficially discussed. The metal tissue relationship between selenium and methylmercury is a complex one, which is complicated by the additive affect of methylmercury with other heavy metals in a total heavy metal-selenium physiological interaction (Cairncross 1978 unpublished).

2.7(xi) Indices for Determination of Mercury in the Body

Indices are needed for two purposes:

(1) to establish a general relationship between mercury intake/body burden and symptoms of mercury poisoning, and

(2) to help diagnose mercury poisoning in individuals.

Both blood and hair can be useful indicators of methylmercury exposure in man. Total mercury consumption from contaminated fish has been shown to correlate with total blood mercury and also with the mercury content of erythrocytes. Similar relationships have been found between mercury intake and the total mercury concentration detectable in hair. A correlation has also been demonstrated between levels of mercury present in whole blood or erythrocytes and the levels present in hair, the hair levels being about 300 times higher than the whole blood levels for methylmercury (FAO/WHO 1972, FAO/WHO 1973).

Methylmercury concentrates mainly in the erythrocytes whereas other forms of mercury are more evenly distributed throughout the blood.

It should be noted that there are problems associated with using blood levels as an indication of poisoning. With a nstant intake of methylmercury it could be 1-2 years before a steady state is reached in the body. In addition there appears to be a latent period before the symptoms become obvious.

Because of ease of collection, hair samples are the most frequently used method in determining exposure to methylmercury through diet. Mercury determinations in hair provide a retrospective index to mercury levels in the body. Variations in mercury concentration exist between the roots and tips of the hair and care must be taken to ensure that mercury is not washed out in the analytical process.

While hair may reflect the ingestion of levels of mercury above that occurring in uncontaminated environments, its value is overshadowed by the fact that it is readily subject to external contamination. Variable results obtained in different studies between those who have ingested relatively higher levels of mercury in their diet and those who have not, negate its value as a diagnostic aid for individuals.

Studies have shown a considerable individual variation in response to methylmercury (Iknan 1963, Bakir et al 1973, Matsumoto et al 1965, Kurland et al 1960, Skerfving 1974, Swedish Expert Group 1971, Sumari et al 1972, Penington et al - unpublished, Birke et al 1972). For example many persons whose hair contained less than 20 or 10 mg/kg mercury in 1960 were diagnosed as Minamata disease patients. On the other hand a female whose hair contained 630 mg/kg mercury in 1961, did not currently (1977) show any symptoms or signs (Tsubaki, T. and Irukayama, K. 1977).

There are also large individual differences in the metabolism of mercury, which is evidenced by its clearance half-time from blood and hair. In the outbreak of methylmercury toxicity in Iraq, the half-time of clearance from blood ranged from 45 to 105 days in sixteen subjects and from the hair - 35 to 189 days (Bakir et al 1973). In Sweden, Skerfving reported a half life from blood of 58-164 days for four subjects (Skerfving 1974). It has been noted that particularly at low levels of exposure, a large individual variation in tissue concentrations may occur (WHO 1976).

On a group basis however, it is accepted that mercury levels in hair and blood can be used to classify the exposure of people in some circumstances.

2.7(xii) Calculations Based on Japanese Incidents

The Swedish Commission on Evaluating the Toxicity of Fish recommended the use of an acceptable daily intake (ADI) concept to evaluate the toxicological risk of fish contaminated in Swedish inland waters.

The basis for the Swedish ADI for methylmercury is as follows:

(1) From Japanese studies the lowest demonstrated whole blood concentration for the appearance of clinical symptoms of toxicity is 0.2 mg/kg blood (approximately), which is equivalent to about 60 mg/kg of hair. This would imply a daily intake of 0.3 milligrams of mercury as methylmercury per day for 70 kg men.

(2) Allowing a safety factor of 10, this would give the following "safe" levels:

| | |
|---|---|
| Whole blood | 0.02 mg/kg |
| Hair | 6.0 mg/kg |
| ADI | 0.03 mg/70kg or |
| | 0.4 mcg/kg |

(3) If the fish were contaminated to 0.5 mg/kg the average man's diet should not exceed 410 grams of such fish per week, according to the Swedish calculation.

The following limitations to this approach were recognised:

(1) it was not known to what extent particular individuals are more or less sensitive to mercury than others;

(2) the estimates were based on the "lowest level that caused an effect" rather than the normal procedure of using a "no effect dose level";

(3) questions about dose/response relationships in human foetuses and newborn infants were unanswered; and

(4) there is a possibility of subclinical effects arising from exposure to very low levels of methylmercury.

In addition these calculations were based on a safety factor of 10, whereas food additives are normally evaluated on a safety factor of 100.

Sometime after the Swedish studies the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1972 (FAO/WHO 1972) established a provisional tolerable weekly intake of 0.3 mg of total mercury per person, of which no more than 0.2 mg should be present as methylmercury. These amounts are equivalent to 0.005 mg and 0.0033 mg respectively per kg body weight. JECFA maintained that where the total mercury intake in the diet is found to exceed 0.3 mg per week, the level of methylmercury compounds should also be investigated. If the excessive intake is attributable entirely to inorganic mercury, the above provisional limit for total mercury no longer applies and will need to be reassessed in the light of all prevailing circumstances.

Subsequent to these investigations and calculations many nations including the United States, Canada and in Australia, the NH & MRC in 1971 established a maximum permitted level of 0.5 mg/kg of mercury in fish, crustaceans, molluscs, the fish content of fish products and the fish content of canned fish.

JECFA in 1972 noted that "the available information shows that some 99% of the world's commercial catch has a total mercury content not exceeding 0.5 mg/kg, and 95% probably contains less than 0.3 mg/kg".

In 1979 the US/FDA raised the maximum permitted level of mercury in fish to 1.0 mg/kg. This followed consideration of extensive comment particularly from the National Marine Fisheries Service.

2.7(xiii) Further Considerations

Since the 0.5 mg/kg action level was proposed, there have been further studies of individuals exposed to methylmercury as a result of the poisoning episode in Iraq in 1972, in which homemade bread prepared from seed wheat treated with a methylmercurial fungicide was consumed. There are also reports on populations ingesting large amounts of fish that show that many individuals have blood mercury levels that clearly exceed the allowable limit and appear to be asymptomatic. The Iraqi studies contained indications that toxic effects were associated with a total intake of methylmercury in the range of 40 to 60 milligrams for a 70 kilogram man or with blood levels of 400 to 600 parts per billion.

Additional data developed on the biological half-life of methylmercury in humans, however, indicate a need to take into account the problem of variations among individuals. In the Iraqi episode, 90 per cent of the individuals studied had a bilogical half-life of methylmercury of 35 to 100 days and 10 per cent showed values of 110 to 120 days. Individuals having a long biological half-life would accumulate much higher steady state levels than those having short biological half-lives and would thus be at greater risk from the same level of methylmercury intake.

In addition, information has been developed on the so-called "late onset of symptoms" associated with methylmercury poisoning. Specifically, by 1973, in the Agano area of Niigata, Japan, new cases of methylmercury poisoning were detected years after the consumption of contaminated fish had ceased. This finding indicates that there may be some damage which is not diagnosed under current procedures, and it introduces further uncertainty into the determination of the "lowest effect level" used to estimate tolerable intakes.

2.7(xiv) Requirements for Further Research

The mechanisms of methylmercury toxicology have not been fully elucidated. A scientific assessment of a safe or even an acceptable level of intake of methylmercury cannot be accurately determined until answers to the following areas of uncertainty have been found:

(1) The degree to which individual adults vary in their susceptibility and the influence of the usual variables within and between populations, including consideration of cases of high exposure resulting from unusual diets or high atmospheric levels, or in medical disorders that may produce a low tolerance to mercury.

(2) The special susceptibility of the foetus, neonate, and child which cannot at present be accurately expressed.

(3) Subclinical indices of effect, as distinct from measurements indicating exposure, which have not been adequately delineated.

(4) The mechanisms of toxic action of mercury, particularly.

(5) The effects of low level exposure (particularly to organic compounds) over long periods of time.

(6) The possibility of genetic effects and the levels of exposure needed to bring them about.

(7) The potential biological interactions of heavy metals with each other and with neurotoxic, nephrotoxic and lipophilic chemicals present in food or derived from the environment.

# 3. INVESTIGATIONS BY THE WORKING GROUP

## 3.1 Mercury in Australian fish

### 3.1(i) Effects of processing

Mercury analyses may be undertaken on fish tissues which are fresh, or which have been frozen, cooked or dried. It is therefore important when comparing or pooling results from different sources to be aware of the condition of the material analysed and the likely effects of processing on mercury concentrations.

Some results are expressed as mg/kg dry weight and these clearly must be adjusted for water loss. Frozen fish is usually considered to give similar results to fresh fish. However, the information available about the effects of cooking on the concentration of mercury in fish is limited and often conflicting. Some workers (Noren and Westoo 1967) report an increase in mercury levels in pike while others (Jegrelius 1971, Schelenz and Diehl 1975) report a decrease in mercury levels in pike and roach respectively after frying and boiling.

No change was reported in either organic or inorganic mercury in fish after baking for one hour in a vacuum oven (Shultz and Crear 1976), which is in agreement with other results (Westoo 1966) for methylmercury in boiled fish tissue and for inorganic mercury in baked, spiked, calf liver (Rohala et al 1973).

Analogies to fish can be drawn from cooking tests on duck breast muscle (Hough and Zabik 1973). In general mercury levels decreased and this effect appeared to be influenced by the cooking method. Moist heat cooking raises the internal temperature faster and maintains it longer than roasting, and thus appears to contribute to greater mercury losses. It was also postulated that the increased mercury levels encountered after roasting by earlier studies (Noren and Westoo 1967) may be due to structural changes in mercury binding proteins, (e.g. Hamm and Hofman 1965) thus releasing more mercury for analysis. The amount of mercury lost was relatively independent of the level found in the tissue.

A comparison of trace metal levels in the common mussel Mytilus edulis when raw or steamed (fresh, frozen and canned) found that for mercury there was no difference between raw and frozen-steamed (.012 mg/kg) but slight increases when steamed fresh (.014 mg/kg) and steamed canned (.017 mg/kg) (Slabyj and Carpenter 1977). These results are averages of six readings.

An examination of the effects on mercury content in Atlantic hake and a dogfish of (i) boiling for 5-10 mins (ii) frying at 170°C for 1-2 min (iii) drying at 50-60°C for 24 hours, found in the case of boiling that all fish had slightly lowered levels of mercury (about 5%) (Legrand and Le Moan 1977). In terms of total mercury in the sample however, there were losses of 10-25%. Frying increased mercury levels by an average 74.4%, but in terms of total mercury in the samples, there were losses of 14-38%. Drying increased mercury concentration almost 300% but 19-21% of the mercury was lost in terms of the total samples.

The amount of research on this problem undertaken in Australia is limited. Comparisons of raw and cooked fish from Australian metropolitan fish shops by the Australian Government Analytical Laboratory (Hansard Report, Australian House of Representatives 1975) indicated higher average levels of mercury in cooked than raw flake (shark) samples. The average level of mercury in raw flake was 0.71 mg/kg, and in cooked flake 0.91 mg/kg. However, the raw and cooked samples were taken from different individual fish and are therefore not strictly comparable. There was no apparent difference in mercury levels between cooked and raw snapper or butterfish.

Some tests have also been undertaken in Victoria on the effect of duration of cooking on mercury levels in fish fillets (snapper, gummy shark and school shark) (Bacher unpublished manuscript). Thick (2 cm) and thin (1 cm) fish fillets were deep fried in oil for three, six and nine minutes and the water loss and mercury levels relative to the cooked weight at those times determined. There was a progressive water loss from cooked tissue which resulted in a 60-70% increase in both organic and inorganic mercury levels relative to the cooked weight after nine minutes cooking. However, there was no significant change in mercury concentration relative to the original fresh weight for both organic and inorganic mercury. The results broadly support those noted above (Legrand and Le Moan 1977), although the latter study did not measure moisture content.

The Victorian research results led to a re-appraisal of data collected in the past and a re-examination of future data collection methods, especially for enforcement purposes. Mercury analyses by Victorian Health Department officials of both cooked and uncooked flake are now accompanied by results of moisture content analyses. A separate figure is provided for "standard" raw flesh mercury levels after conversion to 80% moisture content, the latter figure representing normal moisture content of fresh raw fish.

3.1(ii) Accuracy of measurement - analytical workshops

(a) Overseas studies

The validity of results of mercury analyses has obvious consequences in assessment of the overall mercury issue. Concentrations of mercury in fish and human tissues approach the detection limits of instrumentation. Error due to operator, equipment and methodology can therefore make substantial differences to results.

This problem was raised by the Swedish Expert Group (1971), who cited early Japanese studies in which differences of 100% and more were found between the results of different laboratories. An inter-laboratory calibration exercise in Sweden in 1968 (ibid.) using fish flesh showed a 20% scatter in MeHg and 40% scatter in total Hg concentrations respectively. A further joint exercise between Swedish and Japanese laboratories indicated that mercury concentrations of a Japanese sample were reported as 64-82% lower in Japanese than Swedish laboratories. For a Swedish pike sample the difference was 109-123%.

In Europe between 1971 and 1976, 21 laboratories participated in intercalibration exercises under the auspices of ICES (International Council for the Exploration of the Sea) using a fish flour sample. The first exercise gave mean readings from 0.09 to 0.23 mg/kg. In the second, the scatter was 0.60-0.83 mg/kg, but when all operators used the same technique the scatter was 0.47-0.83 mg/kg. The third exercise yielded means of 0.74-1.26 mg/kg. Only six laboratories participated in all three exercises, but overall improvement was noted in the performance of laboratories which participated in more than one exercise (Topping and Holden 1978).

A worldwide intercalibration exercise involving 87 laboratories was carried out on a variety of elements using dried oyster homogenate (Fukai et al 1978). For the 44 laboratories which tested for mercury, the average value was 0.27 mg/kg while the range was 0.059-1.6 mg/kg. The authors remarked "Maintenance of good 'housekeeping' in laboratories to avoid contamination, to adopt proper calibration etc. seems to be more important than the choice of analytical techniques although there exists some systematic tendencies inherent in analytical techniques which produce erroneous results".

In another international calibration study of environmental materials (Heinonen and Suschy 1974) in the concentration range 5-100 parts per billion (ppb), concern at the wide scatter of results was again recorded. For a fish solubles assay, 14 laboratories recorded mean results ranging from 32.8 to 300 ppb.

(b) Australian studies

In Australia, some inter-laboratory tests have been carried out on an unofficial basis, usually involving two laboratories. The only published instance was a six laboratory exercise in Victoria which compared analyses of shark flesh (Walker 1977a). The scatter of results was such that given a sample of 0.5 mg/kg mercury, 95% confidence limits were 0.30-0.66 mg/kg respectively.

In 1975 the Joint Technical Working Group on Marine Pollution (a joint Australian Fisheries Council/Australian Environment Council Sub-Committee) undertook a review of current metal methodology in Australia which concluded:

> "It is recommended that an attempt should be made to achieve agreement on standard (or at least reference) methods and that the fullest co-operation with the Australian Standards Association be maintained. A series of workshops, one for each class of pollutant, should be organized in appropriate laboratories".

During 1977/78, a series of workshops* organized by the Joint Technical Working Group on Marine Pollution and sponsored by the Working Group on Mercury in Fish using funds from the Fishing Industry Research Trust Account was held to investigate the comparability of mercury in fish data from as many laboratories as possible. Dried shark homogenate was distributed to laboratories and was analysed (i) by their own routine method, i.e., an inter-laboratory exercise, (ii) by a common "reference" method, that of the Australian Government Analytical Laboratories (AGAL), and (iii) in a follow-up exercise using 3 samples, containing different concentrations of mercury, both by routine and the AGAL method if applicable. The routine methods used a variety of digestion processes and all employed cold vapour atomic absorption measurement techniques. Further information was sought on the methods of analysis of methylmercury in fish with a view to preparing a draft reference method.

The inter-laboratory project (i) in which 20 laboratories participated, showed that a significantly better analytical result could be expected from experienced laboratories carrying out routine determinations, compared with those which only occasionally analysed for mercury in fish. The sample used gave a range of 0.39-1.00 mg/kg over all laboratories.

The inter-operator experiment (ii), carried out by 12 analysts, showed that the AGAL reference method under the ideal test conditions would have given results between 0.487 and 0.513 mg/kg (i.e. standard deviation of 0.013).

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* Further details may be obtained from Mr T. McKay, Department of Science and Environment, Canberra.

The third survey showed an overall improvement in all laboratory results using both their own and the draft reference method for total mercury. For three shark samples the combined results were:

| Sample | Total Mercury mg/kg | No. in sample | Standard Deviation |
|---|---|---|---|
| 1 | 0.25 | 92 | 0.045 |
| 2 | 0.38 | 113 | 0.051 |
| 3 | 0.69 | 120 | 0.108 |

As part of the third survey, participating laboratories were also asked to report methylmercury concentrations in these school shark samples. Only four laboratories regularly undertake these measurements, two using selective reduction and two using gas chromatography. The scatter of results, summarized below, was quite small. However, at a subsequent workshop it appeared that some analysts had difficulties with the selective reduction method (Kacprzak and Chvojka 1976)*, which suggests that earlier methylmercury results from some laboratories, included elsewhere in this report, may be inaccurate.

Reference methods using both analytical procedures are being prepared so future data is expected to be more reliable.

Meanwhile. the results from this methylmercury exercise indicate general agreement with the Working Groups use of a 90% methylmercury value for the purpose of ingestion calculations:

| Sample | Methylmercury mg/kg | No. in Sample | Standard Deviation | % Methyl-mercury of Total |
|---|---|---|---|---|
| 1 | 0.23 | 19 | 0.024 | 92 |
| 2 | 0.33 | 24 | 0.024 | 87 |
| 3 | 0.64 | 23 | 0.073 | 93 |

Whereas the worldwide study reported negligible change in trace element content of their freeze dried samples during more than 2 years storage, the Australian exercise noted that similar material increased in weight by 10% in the first 2½ hours exposure at average ambient humidity. Even in desiccation, the sample "increased" in mercury concentration from 0.6 to 0.7 mg/kg after six months storage. However, another study (Gardner and Dal Pont 1979) found no change in mercury content of frozen wet fish samples over more than a year.

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* These authors have subsequently achieved improved results with a modified technique (Chvojka and Kacprzak 1979).

This latter study used a technique similar to the AGAL method, but with an improved digestion procedure, in a class 100 clean room. It analysed the shark samples used in the Australian intercalibration exercise. Precision and accuracy were excellent and the results were closest to overall mean values for mercury concentration and always had the smallest standard deviations in the inter-laboratory exercise.

However the results of this exercise show that two sources of error must be taken into account in assessing analytical results from a single laboratory - bias, which is unaffected by replicate sampling and the likely error of an individual result from that laboratory's true (biased) mean.

Thus, a reading (the $j$th replicate) from the $i$th laboratory can be represented as:

$$\mu + e_i + \alpha_j$$

where $\mu$ is the laboratory (biased) mean, $e_i$ is the bias in that laboratory's work and $\alpha_j$ is the error from its true (biased) mean of the $j$th replicate measurement.

A mean of n replicates from that laboratory has the variance

$$\delta i^2 + \frac{1}{n} \delta \alpha^2$$

where $\delta i$ is the standard deviation of the distribution of random bias (between laboratories).

From the present data the confidence interval for a sample with mercury reading of 0.5 mg/kg is 0.4 - 0.6 mg/kg and for a sample at 1.0 mg/kg, the confidence interval is 0.8 - 1.2 mg/kg, if measurements are carried out at a single laboratory.

Both the Australian and overseas intercalibration studies show improved performances as a result of the exercises. They point to the need for careful preservation, minimisation of contamination and careful calibration. However, there is still room for improvement of methods employed (Gardner and Dal Pont 1979).

A specific inter-laboratory exercise was carried out for the Working Group to investigate consistent differences in the results of hair mercury analyses which were undertaken by two laboratories, from the PA survey and Health survey respectively. Findings are discussed in Section 3.4(ii).

3.1(iii) Data base collections and analyses

The specific objective of the Group's study of mercury in fish was to determine which species, by their high consumption and/or high mercury content, would make a significant contribution to mercury ingestion in relation to existing or proposed health legislation.

Mercury analyses have been carried out on tissues of a wide variety of Australian and imported marine and freshwater organisms. The Working Group agreed that it would not be practicable to attempt to collect the results of analyses for all species. Instead, the selection of species which were significant with regard to mercury was made using several criteria:

(1) species commercially important

(2) species most frequently consumed

(3) species of special significance to heavy fish eaters

From the outset, only fish species were examined. All available data on domestic and imported molluscs and crustaceans showed that these organisms contained very low and rather uniform concentrations of mercury. Further, intra-specific size differences are minimal such that there was no necessity to further analyse the data in a way appropriate to fish, i.e. seeking relationships between mercury and size. However, mollusc and crustacean concentrations have been tabulated where these are relevant to the consumption surveys.

Determination of commercially important species was made with reference to the annual production figures of Australian fish and import statistics, both provided by the Australian Bureau of Statistics (ABS).

Since very little fish (as opposed to mollusc and crustacean produce) is exported, ranking of Australian consumption by weight was made by combining the ABS data with figures for 1974/75 for imported fish obtained from the Bureau of Customs. The twenty most "important" fish types were chosen as significant for the Group's purposes. The word "types" is used here because most common names of fishery products include more than one species. The top twenty types are shown in Table 14. These types accounted for nearly 70% of total available fish products. Remaining types each constituted 1% or less of "apparent consumption". Catches by State were investigated to ensure that important species were all included and that a significant species in one State was not omitted due to low national production.

Determination of species most frequently consumed was a parallel exercise undertaken as a check against the results of Table 35. In this case, data were used from the PA fish

TABLE 14

TOP TWENTY FISH TYPES CONSUMED IN AUSTRALIA 1974/75
(based on ABS figures and other sources)

| Fish Type | Live Weight (Tonnes) | % Australian Fish Consumption | Mean Mercury Level |
|---|---|---|---|
| Japanese Hake | 12,362 | 8.3 | 0.12 |
| Australian Tuna | 11,082 | 7.4 | 0.22 |
| South African Hake | 7,398 | 5.0 | 0.12 |
| Imported Canned Salmon | 7,314 | 4.9 | 0.04 |
| Imported Canned Sardines | 6,350 | 4.3 | 0.05 |
| Imported Smoked Fish | 6.294 | 4.2 | 0.10 |
| Australian Mullet | 5,999 | 4.0 | 0.04 |
| Australian Salmon | 5,178 | 3.5 | 0.19 |
| Japanese Turbot | 5,040 | 3.4 | 0.09 |
| Australian Shark | 4,733 | 3.2 | 0.82 |
| ıported Canned Tuna | 4,710 | 3.2 | 0.21 |
| ᴜK Whiting | 4,100 | 2.8 | 0.08 |
| Imported Fish Fingers | 4,100 | 2.8 | 0.07 |
| Imported Canned Herring | 3,368 | 2.3 | 0.04 |
| New Zealand Snapper | 3,026 | 2.0 | 0.58 |
| Australian Flathead | 2,848 | 1.9 | 0.20 |
| Australian Whiting | 2,268 | 1.5 | 0.17 |
| Australian Snapper | 2,190 | 1.4 | 0.38 |
| Imported Canned Mackerel | 2,028 | 1.4 | 0.07 |
| Australian Snoek | 2,005 | 1.3 | 0.06 |

Mean Mercury Level weighted for consumption = 0.167

consumption survey. That survey investigated fish consumption as fish served at home, bought at take-away establishments, or eaten in restaurants, etc. Most were served in the home and the twenty main fish types in order of their consumption frequency at home are shown in Table 35.

Table 35 is based on only the first quarter or round of the PA "broad brush" fish consumption survey, since it was necessary to decide on significant fish species and begin analytical work before the consultants completed and reported on their survey. However, separate data were available from the survey for each State and these allowed the Group to detect local preferences, which were masked in the overall national figures. The ABS figures provide State production figures, but due to interstate movement of fish produce, they do not necessarily reflect local consumption patterns. Home consumption survey data were of two forms - raw fish cooked and served on each occasion and pre-cooked fish served last occasion. Both were used to determine significant fish types.

It can be seen that Tables 14 and 35 differ in the ranking of "important" fish types. The differences are partly due to nomenclature confusion and partly the fact that PA data related to home consumption only.

In determining fish types of special significance to heavy fish eaters, an arbitrary consumption level of 5 or more fish meals per week was taken as the criterion. The fish types eaten by persons satisfying this criterion were enumerated and a four point scale used to determine relative importance of each type by State.

There have been major new fishery developments in Australian waters during the years since the consultants' fish consumption survey in 1976. The main events are the establishment of a trawl fishery in the western Great Australian Bight and the emergence of a new dominant species - gemfish, in the south-eastern trawl fishery. While the impact of these events had not yet appeared in ABS figures, it was agreed that gemfish and the dominant Bight species should be included in the Working Group's data bank.

The result of the above approaches to selecting significant species with regard to mercury led to 114 local species, 14 imported types of fish and fish product and 11 other local fish for which specific names were not known, being considered by the Working Group. These are listed in Tables 15, 16, 17, and 18.

A special multipage form (Appendix 2) was designed to facilitate collection of data in a uniform manner and to ensure there was no duplication of entries. Allowance was made for the inclusion of all available information associated with the mercury analyses and source including length, weight, environmental parameters and analyses, etc.

TABLE 15

SPECIES OF AUSTRALIAN SALTWATER FISH ANALYSED FOR MERCURY

| Common Name | Generic Name |
|---|---|
| Anchovy | Engraulis australis |
| Australian Herring | Arripis georgianus |
| Australian Salmon | Arripis trutta |
| Australian Tusk | Dannevigia tusca |
| Barramundi | Lates calcarifer |
| Bight Redfish (Red Snapper) | Trachichthodes gerrardi |
| Blue Grenadier | Macruronus novaezelandiae |
| Bream, Black | Acanthopagrus butcheri |
| Bream, Yellowfin (Eastern) | Acanthopagrus australis |
| Boarfish, Black-spot | Zanclistius elevatus |
| Boarfish, Long-snout | Pentaceropsis recurvirostris |
| Boarfish, Yellow-spot | Paristiopteris gallipavo |
| Cobbler (Estuary Catfish) | Cnidoglanis macrocephalus |
| Cod, Southern Rock | Physiculus barbatus |
| Cucumber Fish | Chlorophthalmus nigripinnus |
| Dory, John | Zeus faber |
| Dory, Mirror | Zenopsis nebulosus |
| Dory, Silver | Cyttus australis |
| Flathead, Deepwater | Neoplatycephalus speculator |
| Flathead, Dusky | Platycephalus fuscus |
| Flathead, Sand | Platycephalus bassensis |
| Flathead, Tiger | Neoplatycephalus richardsoni |
| Flounder, Greenback | Rhombosolea taparini |
| Gemfish | Rexea solandri |
| Hapuku | Polyprion oxygeneios |
| Kingfish, Yellowtail | Seriola grandis |
| Knifejaw | Oplegnathus woodwardi |
| Latchet | Pterygotrigla polyommata |
| Leatherjacket (Tasmanian) | Family Aluteridae |
| Leatherjacket (West Australian) | Nelusetta ayraud |
| Ling | Genypterus blacodes |
| Luderick | Girella tricuspidata |
| Mackerel, Blue | Scomber australasicis |
| Mackerel, Jack | Trachurus declivis |
| Mackerel, Trevalla | Seriolella maculata |
| Marlin, Black | Makaira indica |
| Morwong, Blue | Sciaenoides valenciennesi |
| Morwong, Brown banded | Cheilodactylis spectabilis |
| Morwong, Jackass | Nemadactylus macropterus |
| Morwong, Rubberlip | Plectorhyncus schotaf |
| Mullet, Sea | Mugil cephalus |
| Mullet, Yellow-eye | Aldrichetta forsteri |
| Mulloway | Sciaena antarctica |
| Nannygai | Centroberyx affinis |
| Oilfish | Ruvettus tydemani |
| Parrot Fish | Pseudolabrus sp. |
| Perch, Butterfly | Caesioperca lepidoptera |
| Perch, Gulf | Neosebastes panticus |
| Perth, Ocean | Helicolensus papillosus |

| | |
|---|---|
| Ray, Fiddler | Trygonorhina fasciata |
| Ruby Fish | Plagiogeneion macrolepis |
| Sandpaper Fish | Paratrachichthys trailli |
| Sea Carp | Dactylosargus arctidens |
| Sharks:- | |
| Angel | Squatina australis |
| Blacktip Whaler | Carcharhinus sp. |
| Blue Pointer (= Mako) | Isurus glaucus |
| Blue Whaler | Prionace glauca |
| Bronze Whaler | Carcharhinus greyi and Carcharhinus obscurus |
| Carpet Shark | Orectolobus spp. and Sutorectus tentaculatus |
| Common Saw Shark | Pristiophorus cirratus |
| Draughtboard Shark | Cephaloscyllium isabella laticeps |
| Elephant Shark | Callorhynchus milii |
| Graceful Shark | Carcharhinus amblyrhynchos |
| Grey Nurse | Odontaspis taurus |
| Gulf Catshark | Halaelurus vincenti |
| Gummy Shark | Mustelus antarcticus (= Emmissola antarctica) |
| Hammerhead Shark | Sphyrna lewini |
| One finned Shark | Heptranchias dakini |
| Ornate Angel Shark | Squatina tergocellata |
| Pencil Shark | Notogaleus rhinophanes |
| Piked Spurdog | Squalus megalops |
| Port Jackson Shark | Heterodontus portusjacksoni |
| Rusty Catshark | Parascyllium ferrugineum |
| School Shark | Galeorhinus australis |
| Seven gilled Shark | Notorhynchus cepedianus |
| Southern Saw Shark | Pristiophorus nudipinnus |
| Thickskin Shark | Carcharhinus plumbeus |
| Thresher Shark | Alopias caudatus |
| Varied Catshark | Parascyllium variolatum |
| Whiskery Shark | Furgaleus ventralis |
| White Pointer | Carcharodon carcharias |
| White Spotted Spurdog | Squalus kirki |
| Skate, White-spotted | Raja cerva |
| Skippy | Caranx georgianus |
| Snapper (Eastern States) | Chrysophrys auratus |
| Snapper (West Australia) | Chrysophrys unicolor |
| Snapper, Queen | Nemadactylus valenciennesi |
| Snoek | Leionura atun |
| Snook | Australuzza novaehollandiae |
| Southern Frost Fish | Lepidopus lex |
| Stargazer | Kathetostoma spp. |
| Stingaree, Common | Urolophus testaceus |
| Stingaree, White Spotted | Urolophus paucimaculatus |
| Tailor | Pomatomus saltator |
| Trevally | Caranx nobilis |
| Trevalla, Deep Sea | Hyperoglyphe porosa |
| Trumpeter, Bastard | Latridopsis forsteri |
| Tuna, Skipjack | Katsuwonus pelamis |
| Tuna, Southern Bluefin | Thunnus maccoyii |
| Tuna, Yellowfin | Thunnus albacares |

| | |
|---|---|
| Warehou | *Seriolella brama* |
| Whiptail | *Coelorhynchus* spp. |
| Whiting, King George | *Sillaginodes punctatus* |
| Whiting, Sand | *Sillago ciliata* |
| <u>Other seafoods analysed</u> | |
| Cuttlefish | *Sepia* sp. |
| Oysters | *Crassostrea commercialis* |
| Squid | *Nototodares gouldi* |

TABLE 16

SPECIES OF AUSTRALIAN FRESHWATER FISH ANALYSED FOR MERCURY

- and used by the Working Group

| Common Name | Generic Name |
| --- | --- |
| Catfish | Tandanus tandanus |
| European Carp | Cyprinus carpio |
| Golden Perch | Plectroplites ambiguus |
| Murray Cod | Maccullochella peeli |
| Redfin | Perca fluviatilis |
| Silver Perch | Bidyanus bidyanus |
| Tench | Tinca tinca |

## TABLE 17

## NON SPECIFIC FISH AND SEAFOOD ANALYSED FOR MERCURY

- and used by the Working Group

Abalone
Coral Cod
Coral Trout
Crab
Crabmeat
Crayfish, Freshwater
Crayfish, Saltwater
Garfish
Scallops
Sweetlip
Trout

## TABLE 18

## IMPORTED FISH AND FISH PRODUCTS ANALYSED FOR MERCYRY

- and used by the Working Group

Barramundi
Fish fingers
Hake, Japanese
Hake, South African
Hake, South African (smoked)
Herring, (canned)
Herring, United Kingdom (smoked)
Mackerel (canned)
Salmon (canned)
Sardines (canned)
Snapper, New Zealand
Tuna (canned)
Turbot, Japanese
Whiting, United Kingdom

However, in addition to sample characteristics, the Group needed information on the size composition of the appropriate commercial fisheries in order to relate mathematically the sample to the fishery. Accordingly, information on length-frequency and length-weight relationships of the selected species was required.

On that basis, appropriate State and Commonwealth organizations were asked to provide data where gaps occurred in existing information.

Sources of mercury data were widespread and included both published and unpublished information. Most were provided by State Fisheries organizations and those organizations were requested to undertake additional analyses to provide the Group with sufficient results for mathematical analysis. Imported fish mercury analyses are carried out by the Department of Science on behalf of Customs. Gaps in knowledge of mercury content of imported fish could not be filled.

The Group requested at least 30 analyses of each species over the size range of the fish available to capture by conventional fishing gear. Where differences in mercury content of a species in different areas were suspected, a minimum of 10 samples per site was requested. Any available data on other trace elements, particularly selenium were also requested.

The majority of the data was coded onto the Cyber 76 computer used by the Department of Primary Industry and this was converted to a form compatible with an existing package - A Statistical Package for the Social Sciences (SPSS). This is a multifacet program designed to statistically analyse most data sets.

The data which was not entered onto the Cyber 76 was either already analysed, in the case of some published information, or was in small enough sets to be handled manually.

The data base allowed for all of the following parameters to be recorded for each sample:-

- Analysing organization
- Date of Capture
- Date of analysis
- Submitting organization
- Collecting organization
- Species
- The portion from which the species was identified
- If there was any doubt in identification of the species
- Length
- The method of length measurement
- Weight

The method of weight measurement
Sex
Age
The method of age measurement
Development stage
State of landing
Port of landing
Latitude and longitude of capture site
Country of origin (if imported)
The number in the sample
The type of water body from which the sample was captured
The origin of the sample (e.g. commercial, research, etc.)
The condition of the sample (e.g. raw, frozen, canned, etc.)
Digestion method
Analysis method
The estimated accuracy of measurement
Whether the sample was wet or dry when analysed
Total mercury in muscle
Organic mercury in muscle
Selenium levels in muscle
Arsenic levels in muscle
Copper levels in muscle
Zinc levels in muscle

For various reasons, principally because the data came from so many different sources, not all of the parameters were recorded for all cases. This was not considered to be detrimental since not all parameters were essential to the analysis of the data for the Working Group's purposes.

In total, the data base consisted of 6678 samples, of which 551 were imported.

The data was used for the following:

(1) to find basic statistical information (e.g. mean, range, etc.) for each species and thereby to get an overview of the levels of mercury likely to be found in the fish available to the Australian consumer (see Tables 19, 20 and 21)

(2) to extrapolate from the levels found a method of predicting the mercury level of fish likely to be on the market (see Section 4.2)

(3) to estimate the ingestion of mercury by Australian consumers (see Section 3.3)

(4) to determine the proportion of total mercury which was in an organic form (see Section 3.1(iv))

(5) to determine the relative concentrations of mercury and other heavy metals in fish muscle (see Section 3.1(v))

(6) to try to determine the effects of given mercury levels, if enforced, on the consumers' probable mercury ingestion and on the economics of the fishing industry (see Section 4).

It has been pointed out (Section 3.1(ii)) that total mercury and organic mercury analyses are subject to error. However, while recognising the problem and keeping it in mind when interpreting anomalous results, it was not thought practicable to attempt to standardise the data provided by so many analytical organizations.

3.1(iv) Organic mercury content

The selective reduction method where used in these analyses is not specific for methylmercury but measures "inorganic" and "organic" mercury. It is likely however that the organic portion revealed by this method is, in the case of fish, methylmercury and this will be assumed in this report.

Organic mercury levels, have been measured in a number of Australian fish species. Results are expressed as mean percentage of total mercury in Table 22 below. Data were extracted from the Group's data base.

All species sampled contained, on average, more than 75% organic mercury; most exceeded 90% organic mercury.

The Working Group has used 90% to estimate methylmercury ingestion in consumption calculations, the figure also used as a rule-of-thumb value by United States authorities. Limitations on the accuracy of the results are discussed in Section 3.1(ii).

As noted in Section 2.6(ii) marlin appear to be unusual in that the proportion of organic to total mercury is low - around 10% (J.S. Edmonds, pers. comm.)

TABLE 19

UNWEIGHTED MEAN MERCURY LEVELS AND RANGES AND MEAN LENGTHS OF AUSTRALIAN FISH SAMPLES

| Common Name | State | Mean Mercury (mg/kg) | Range | No. in Sample | Mean Length (mm) | No. in Sample |
|---|---|---|---|---|---|---|
| Anchovy | Tas | 0.25 | 0.22-0.30 | 3 | | - |
| Australian Herring | Vic | 0.27 | 0.14-0.66 | 15 | 224 | 15 |
| | SA | 0.11 | 0.05-0.14 | 3 | 180 | 3 |
| | WA | 0.12 | 0.05-0.74 | 103 | 211 | 103 |
| | Combined | 0.14 | 0.05-0.74 | 121 | 212 | 121 |
| Australian Salmon | NSW | 0.23 | 0.01-0.62 | 22 | - | - |
| | Vic | 0.11 | 0.02-0.33 | 30 | 408 | 30 |
| | SA | 0.19 | - | 1 | 720 | 1 |
| | Tas | 0.17 | 0.09-0.37 | 20 | - | - |
| | WA | 0.21 | 0.15-0.30 | 9 | - | - |
| | Combined | 0.17 | 0.01-0.62 | 82 | 418 | 31 |
| Australian Tusk | WA | 0.22 | 0.07-0.42 | 50 | | |
| Barramundi | Qld | 0.11 | - | 1 | - | - |
| | NT | 0.21 | 0.10-0.60 | 33 | 432 | 1 |
| | Combined | 0.21 | 0.10-0.60 | 34 | 432 | - |
| Bight Redfish | WA | 0.52 | 0.20-1.32 | 50 | - | - |
| Blue Grenadier | NSW | 0.31 | 0.08-1.55 | 44 | 579 | 44 |
| Bream, Black | NSW | 0.22 | 0.03-0.81 | 31 | 270 | 30 |
| | Vic | 0.25 | 0.03-1.17 | 35 | 290 | 35 |
| | SA | 0.15 | 0.07-0.27 | 3 | 375 | 1 |
| | Combined | 0.23 | 0.03-1.17 | 69 | 282 | 66 |
| Bream, Yellowfin | NSW | 0.23 | 0.03-0.81 | 30 | - | - |
| | Qld | 0.11 | 0.04-0.16 | 4 | - | - |
| | Combined | 0.22 | 0.03-0.81 | 34 | - | - |
| Boarfish, Black Spot | WA | 0.21 | 0.05-0.39 | 24 | - | - |
| Boarfish, Long Snout | Tas | 0.34 | - | 1 | - | - |
| Boarfish, Yellow Spot | WA | 0.34 | 0.02-0.87 | 50 | - | - |
| Cobbler | WA | 0.03 | 0.01-0.07 | 27 | - | - |
| Cod, Southern Rock | Tas | 0.13 | 0.04-0.45 | 9 | - | - |
| Cucumber Fish | Tas | 0.12 | 0.02-0.36 | 17 | - | - |
| Dory, John | Tas | 0.19 | 0.13-0.29 | 4 | - | - |
| | WA | 0.32 | 0.06-0.84 | 50 | - | - |
| | Combined | 0.31 | 0.06-0.84 | 54 | - | - |
| Dory, Mirror | NSW | 0.16 | 0.05-0.36 | 30 | 416 | 30 |
| Dory, Silver | Tas | 0.05 | 0.01-0.10 | 30 | - | - |
| | WA | 0.17 | 0.06-0.50 | 47 | - | - |
| | Combined | 0.12 | 0.01-0.50 | 77 | - | - |
| Flathead, Deepwater | Vic | 0.31 | 0.18-0.87 | 37 | - | - |
| | Tas | 0.33 | 0.12-0.62 | 29 | - | - |
| | WA | 0.43 | 0.12-0.77 | 50 | - | - |
| | Combined | 0.37 | 0.12-0.87 | 116 | - | - |
| Flathead, Dusky | NSW | 0.13 | 0.05-0.22 | 30 | 436 | 30 |
| | SA | 0.19 | 0.09-0.35 | 14 | 441 | 14 |
| | Combined | 0.15 | 0.05-0.35 | 44 | 438 | 44 |
| Flathead, Sand | Vic | 0.47 | 0.06-1.12 | 203 | 304 | 193 |
| | SA | 0.17 | 0.03-0.32 | 16 | 357 | 14 |
| | Tas | 0.23 | 0.01-0.68 | 94 | 400 | 92 |
| | Combined | 0.38 | 0.01-1.12 | 313 | 336 | 299 |

| Common Name | State | Mean Mercury (mg/kg) | Range | No. in Sample | Mean Length (mm) | No. in Sample |
|---|---|---|---|---|---|---|
| Flathead, Tiger | NSW | 0.24 | 0.08-0.75 | 29 | 432 | 29 |
| | Vic | 0.15 | 0.04-0.74 | 10 | 379 | 10 |
| | Tas | 0.52 | 0.10-1.81 | 12 | 435 | 12 |
| | Combined | 0.29 | 0.04-1.81 | 51 | 422 | 51 |
| Flounder, Greenback | Vic | 0.04 | 0.03-0.14 | 44 | 279 | 44 |
| | SA | 0.08 | - | 1 | 200 | 1 |
| | Tas | 0.03 | 0.02-0.05 | 9 | 246 | 9 |
| | Combined | 0.04 | 0.2-0.05 | 54 | 272 | 54 |
| Gemfish | NSW | 0.68 | 0.10-3.07 | 148 | 783 | 104 |
| | SA | 0.29 | 0.12-0.62 | 3 | 740 | 3 |
| | Tas | 0.39 | 0.07-1.40 | 37 | - | - |
| | WA | 0.83 | 0.14-1.67 | 49 | - | - |
| | Combined | 0.66 | 0.07-3.07 | 237 | 782 | 107 |
| Hapuku | WA | 0.48 | 0.01-0.95 | 54 | - | - |
| Kingfish, Yellowtail | NSW | 0.18 | 0.06-0.70 | 20 | - | - |
| Knifejaw | WA | 0.11 | 0.04-0.24 | 50 | - | - |
| Latchet | Tas | 0.58 | 0.06-5.71 | 122 | - | - |
| | WA | 0.55 | 0.01-1.39 | 58 | - | - |
| | Combined | 0.57 | 0.01-5.71 | 180 | - | - |
| Leatherjacket | Tas | 0.08 | 0.02-0.40 | 30 | - | - |
| | WA | 0.25 | 0.09-0.64 | 50 | - | - |
| | Combined | 0.19 | 0.02-0.64 | 80 | - | - |
| Ling | Vic | 0.52 | 0.20-1.10 | 10 | 641 | 10 |
| Luderick | NSW | 0.05 | 0.02-0.12 | 88 | - | - |
| Mackerel, Blue | WA | 0.15 | 0.05-0.37 | 50 | - | - |
| Mackerel, Jack | Tas | 0.10 | 0.04-0.25 | 27 | 382 | 10 |
| | WA | 0.11 | 0.04-0.18 | 50 | - | - |
| | Combined | 0.11 | 0.04-0.25 | 77 | 382 | 10 |
| Mackerel Trevalla | Tas | 0.03 | 0.01-0.05 | 28 | - | - |
| Marlin, Black | Qld | 7.27 | 0.50-16.50 | 42 | 3060 | 42 |
| Morwong, Blue | Tas | 0.10 | 0.05-0.16 | 15 | 597 | 15 |
| Morwong, Brown-banded | Tas | 0.18 | 0.02-0.59 | 10 | - | - |
| Morwong, Jackass | NSW | 0.27 | 0.12-0.49 | 26 | 390 | 26 |
| | Vic | 0.21 | 0.11-0.37 | 6 | 432 | 6 |
| | SA | 0.23 | 0.21-0.24 | 2 | 435 | 2 |
| | Tas | 0.24 | 0.05-0.74 | 110 | - | - |
| | WA | 0.12 | 0.05-0.22 | 50 | - | - |
| | Combined | 0.21 | 0.05-0.74 | 194 | 400 | 34 |
| Morwong, Rubberlip | NSW | 0.22 | 0.03-0.49 | 30 | 376 | 30 |
| Mullet, Sea | NSW | 0.03 | 0.01-0.20 | 31 | 342 | 30 |
| | Vic | 0.04 | 0.04-0.04 | 2 | 444 | 2 |
| | Qld | 0.02 | 0.01-0.08 | 25 | - | - |
| | WA | 0.01 | 0.01-0.03 | 26 | 363 | 26 |
| | Combined | 0.02 | 0.01-0.20 | 84 | 355 | 58 |
| Mullet, Yellow-eye | Vic | 0.07 | 0.01-0.45 | 50 | 267 | 50 |
| Mulloway | NSW | 0.22 | 0.06-0.82 | 31 | - | - |
| | SA | 0.61 | 0.48-0.75 | 3 | 1141 | 3 |
| | WA | 0.13 | 0.04-0.40 | 13 | - | - |
| | NT | 0.20 | 0.20-0.20 | 2 | 711 | 1 |
| | Combined | 0.22 | 0.04-0.82 | 49 | 1033 | 4 |

| Common Name | State | Mean Mercury (mg/kg) | Range | No. in Sample | Mean Length (mm) | No. in Sample |
|---|---|---|---|---|---|---|
| Nannygai | WA | 0.38 | 0.20-0.56 | 20 | - | - |
| Oilfish | WA | 0.09 | - | 1 | - | - |
| Parrot fish | Tas | 0.21 | 0.15-0.31 | 4 | - | - |
| Perch, Butterfly | Tas | 0.75 | - | 1 | - | - |
| Perch, Gulf | Tas | 0.27 | 0.11-0.61 | 9 | - | - |
| Perch, Ocean | Tas | 0.27 | 0.19-0.36 | 2 | - | - |
| Ray, Fiddler | NSW | 0.20 | 0.06-0.52 | 30 | 452 | 30 |
| | SA | 0.21 | 0.01-0.41 | 2 | 260 | 1 |
| | Combined | 0.21 | 0.01-0.52 | 32 | 446 | 31 |
| Ruby Fish | WA | 0.11 | 0.03-0.22 | 50 | - | - |
| Sandpaper Fish | Tas | 0.12 | 0.03-0.50 | 20 | - | - |
| Sea Carp | Tas | 0.01 | 0.01-0.02 | 8 | - | - |
| Sharks:- | | | | | | |
| Angel | NSW | 0.40 | 0.06-1.60 | 29 | 692 | 29 |
| | SA | 0.28 | 0.15-0.40 | 2 | 743 | 2 |
| | Tas | 0.13 | 0.07-0.29 | 5 | 677 | 5 |
| | Combined | 0.36 | 0.06-1.60 | 36 | 693 | 36 |
| Blacktip Whaler | Vic | 1.48 | 0.61-2.10 | 8 | 2397 | 8 |
| Blue Pointer | SA | 0.71 | - | 1 | 1465 | 1 |
| | Tas | 3.15 | - | 1 | 1980 | 1 |
| | Combined | 1.93 | 0.71-3.15 | 2 | 1722 | 2 |
| Blue Whaler | Tas | 0.41 | 0.25-0.57 | 2 | 1104 | 2 |
| Bronze Whaler | Vic | 0.84 | 0.47-1.22 | 3 | 2176 | 2 |
| | SA | 0.43 | 0.23-0.80 | 4 | 1652 | 4 |
| | WA | 0.73 | 0.10-2.60 | 152 | 1240 | 63 |
| | Combined | 0.72 | 0.10-2.60 | 159 | 1291 | 69 |
| Carpet Shark | WA | 1.02 | 0.10-3.40 | 76 | - | - |
| Common Saw Shark | Vic | 0.38 | 0.10-1.16 | 21 | 969 | 21 |
| | Tas | 0.56 | 0.07-1.32 | 49 | 1082 | 44 |
| | WA | 0.34 | 0.20-0.60 | 23 | - | - |
| | Combined | 0.47 | 0.07-1.32 | 93 | 1045 | 65 |
| Draughtboard Shark | Vic | 1.39 | 0.70-2.30 | 6 | 885 | 6 |
| | Tas | 2.29 | 0.34-10.50 | 9 | 747 | 4 |
| | Combined | 1.93 | 0.34-10.50 | 15 | 830 | 10 |
| Elephant Shark | Vic | 0.43 | 0.09-0.91 | 14 | 639 | 14 |
| | Tas | 0.24 | 0.02-0.97 | 125 | 783 | 125 |
| | Combined | 0.26 | 0.02-0.97 | 139 | 769 | 139 |
| Grey Nurse | WA | 1.69 | 0.07-6.73 | 18 | - | - |
| Graceful Shark | Qld | 0.43 | 0.34-0.56 | 5 | 641 | 5 |
| Gulf Cat Shark | Tas | 0.64 | 0.55-0.73 | 2 | 520 | 2 |
| Gummy Shark | NSW | 0.66 | 0.10-1.81 | 36 | 782 | 36 |
| | Vic | 0.42 | 0.08-2.40 | 218 | 1057 | 7 |
| | SA | 0.45 | 0.16-1.39 | 17 | - | - |
| | Tas | 0.42 | 0.03-3.04 | 126 | 577 | 45 |
| | WA | 0.44 | 0.10-2.10 | 110 | 1230 | 95 |
| | Combined | 0.44 | 0.03-3.04 | 507 | 975 | 183 |
| Hammerhead Shark | Vic | 0.89 | - | 1 | 689 | 1 |
| | WA | 0.92 | 0.42-1.72 | 14 | - | - |
| | Combined | 0.92 | 0.42-1.72 | 15 | 689 | 1 |
| One finned Shark | WA | 1.48 | - | 1 | - | - |
| Ornate Angel Shark | WA | 0.35 | 0.15-0.84 | 50 | - | - |
| Pencil Shark | WA | 2.44 | 0.40-9.65 | 5 | - | - |

| Common Name | State | Mean Mercury (mg/kg) | Range | No. in Sample | Mean Length (mm) | No. in Sample |
|---|---|---|---|---|---|---|
| Piked Spurdog | Tas | 1.68 | 0.01-4.20 | 71 | 471 | 71 |
| | WA | 2.63 | 0.95-4.15 | 23 | - | - |
| | Combined | 1.91 | 0.01-4.20 | 94 | 471 | 71 |
| Port Jackson Shark | Vic | 0.50 | 0.43-0.59 | 5 | 744 | 5 |
| | SA | 0.35 | 0.16-0.69 | 13 | 693 | 13 |
| | Tas | 0.49 | 0.12-3.07 | 53 | 758 | 51 |
| | Combined | 0.46 | 0.12-3.07 | 71 | 745 | 69 |
| Rusty Catshark | Vic | 0.45 | 0.36-0.57 | 6 | 660 | 6 |
| | Tas | 0.60 | 0.26-1.26 | 10 | 741 | 10 |
| | Combined | 0.54 | 0.26-1.26 | 16 | 711 | 16 |
| School Shark | NSW | 0.55 | 0.21-1.39 | 21 | 806 | 21 |
| | Vic | 0.89 | 0.01-3.30 | 185 | 1263 | 91 |
| | SA | 1.17 | 0.31-2.74 | 20 | - | - |
| | Tas | 0.53 | 0.02-2.13 | 135 | 529 | 65 |
| | Combined | 0.75 | 0.01-3.30 | 361 | 940 | 177 |
| Seven-gilled Shark | Vic | 1.19 | 0.70-1.77 | 3 | 793 | 3 |
| | SA | 1.23 | 0.39-1.98 | 4 | 1157 | 4 |
| | Tas | 1.48 | 0.96-2.06 | 15 | 1351 | 15 |
| | Combined | 1.39 | 0.39-2.06 | 22 | 1240 | 22 |
| Southern Saw Shark | Tas | 0.49 | 0.01-2.92 | 62 | 922 | 51 |
| Thickskin Shark | WA | 0.73 | 0.30-1.60 | 84 | - | - |
| Thresher Shark | SA | 0.14 | - | 1 | 3180 | 1 |
| Varied Catshark | Tas | 0.25 | 0.11-0.38 | 4 | 692 | 4 |
| Whiskery Shark | SA | 0.59 | 0.34-0.84 | 2 | 1385 | 2 |
| | Tas | 0.75 | 0.43-1.35 | 4 | 991 | 4 |
| | WA | 0.59 | 0.10-1.70 | 165 | 1240 | 138 |
| | Combined | 0.59 | 0.10-1.70 | 171 | 1235 | 144 |
| White Pointer | SA | 1.29 | - | 1 | 3150 | 1 |
| White Spotted Spurdog | SA | 0.50 | 0.44-0.52 | 4 | 709 | 4 |
| | Tas | 0.88 | 0.28-2.28 | 73 | 774 | 73 |
| | Combined | 0.86 | 0.28-2.28 | 77 | 770 | 77 |
| Skate, White Spotted | Tas | 0.26 | 0.03-0.82 | 32 | - | - |
| Skippy | WA | 0.19 | 0.01-0.57 | 45 | 285 | 32 |
| | NT | 0.20 | - | 1 | - | - |
| | Combined | 0.19 | 0.01-0.57 | 46 | 285 | 32 |
| Snapper (Eastern) | NSW | 0.34 | 0.05-1.94 | 30 | 378 | 30 |
| | Vic | 0.44 | 0.07-1.50 | 57 | 560 | 57 |
| | Qld | 0.20 | - | 1 | - | - |
| | SA | 0.58 | 0.04-1.30 | 16 | 775 | 14 |
| | Combined | 0.43 | 0.04-1.94 | 104 | 536 | 101 |
| Snapper (Western) | WA | 0.20 | 0.02-1.25 | 72 | 491 | 72 |
| Snapper, Queen | WA | 0.20 | 0.05-0.61 | 51 | - | - |
| Snoek | Vic | 0.07 | 0.01-0.22 | 31 | 728 | 11 |
| | SA | 0.09 | 0.01-0.31 | 20 | 833 | 20 |
| | Tas | 0.11 | 0.01-0.54 | 82 | 783 | 50 |
| | WA | 0.15 | 0.01-0.31 | 50 | - | - |
| | Combined | 0.11 | 0.01-0.54 | 183 | 788 | 81 |

| Common Name | State | Mean Mercury (mg/kg) | Range | No. in Sample | Mean Length (mm) | No. in Sample |
|---|---|---|---|---|---|---|
| Snook | SA | 0.32 | 0.06-0.63 | 33 | - | - |
| Southern Frost Fish | WA | 0.38 | 0.25-0.58 | 5 | - | - |
| Stargazer | Tas | 0.22 | 0.09-0.55 | 11 | - | - |
| Stingaree, Common | Vic | 0.48 | 0.39-0.58 | 3 | 554 | 3 |
| Stingaree, White Spot | Vic | 0.20 | 0.11-0.35 | 9 | - | - |
| Tailor | NSW | 0.22 | 0.14-0.41 | 16 | - | - |
| | Qld | 0.23 | 0.04-0.55 | 16 | - | - |
| | Combined | 0.22 | 0.04-0.55 | 32 | - | - |
| Trevally | WA | 0.16 | 0.09-0.39 | 50 | - | - |
| Trevalla, Deep Sea | NSW | 0.47 | 0.11-1.23 | 50 | 729 | 50 |
| | Vic | 0.06 | 0.04-0.07 | 3 | - | - |
| | Combined | 0.45 | 0.04-1.23 | 53 | 729 | 50 |
| Trumpeter, Bastard | Tas | 0.05 | 0.01-0.28 | 28 | - | - |
| Tuna, Skipjack | Tas | 0.15 | 0.11-0.17 | 20 | - | - |
| Tuna, Southern Bluefin | NSW | 0.10 | - | 1 | - | - |
| | SA | 0.22 | 0.06-0.63 | 218 | 833 | 7 |
| | Combined | 0.22 | 0.06-0.63 | 219 | 833 | 7 |
| Tuna, Yellowfin | NSW | 0.38 | 0.11-0.66 | 20 | - | - |
| Warehou | Tas | 0.04 | 0.01-0.06 | 2 | - | - |
| | WA | 0.05 | 0.02-0.08 | 13 | - | - |
| | Combined | 0.05 | 0.01-0.08 | 15 | - | - |
| Whiptail | Tas | 0.24 | 0.05-0.43 | 9 | - | - |
| Whiting, King George | Vic | 0.07 | 0.02-0.34 | 60 | 347 | 60 |
| | SA | 0.05 | 0.01-0.13 | 36 | 287 | 27 |
| | Combined | 0.06 | 0.01-0.34 | 96 | 329 | 87 |
| Whiting, Sand | NSW | 0.30 | 0.09-0.66 | 24 | 351 | 24 |
| Other Seafoods | | | | | | |
| Cuttlefish | Tas | 0.03 | 0.02-0.04 | 2 | - | - |
| Oysters | NSW | 0.03 | 0.01-0.10 | 149 | - | - |
| Squid | Tas | 0.05 | 0.02-0.27 | 13 | - | - |
| Freshwater Species | | | | | | |
| Catfish | SA | 0.34 | 0.31-0.37 | 2 | - | - |
| European Carp | SA | 0.17 | 0.08-0.28 | 4 | - | - |
| Golden Perch | SA | 0.38 | 0.28-0.49 | 7 | - | - |
| Murray Cod | SA | 1.20 | 1.10-1.30 | 3 | - | - |
| Redfin | SA | 0.47 | 0.15-0.92 | 31 | - | - |
| Silver Perch | SA | 0.51 | 0.38-0.61 | 3 | - | - |
| Tench | SA | 0.40 | 0.27-0.53 | 2 | - | - |

TABLE 20

MEAN MERCURY LEVELS AND RANGES OF AUSTRALIAN FISH AND SEAFOOD (GROUPED BY LEVEL)

| Common Name | Mean Mercury Level (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|
| Species with a mean mercury level between 0.01 and 0.10 mg/kg | | | |
| Cobbler | 0.03 | 0.01-0.07 | 27 |
| Cuttlefish | 0.03 | 0.02-0.04 | 2 |
| Flounder, Greenback | 0.04 | 0.02-0.05 | 54 |
| Luderick | 0.05 | 0.02-0.12 | 88 |
| Mackerel Trevalla | 0.03 | 0.01-0.05 | 28 |
| Morwong, Blue | 0.10 | 0.05-0.16 | 15 |
| Mullet, Sea | 0.02 | 0.01-0.20 | 84 |
| Mullet, Yellow-eye | 0.07 | 0.01-0.45 | 50 |
| Oilfish | 0.09 | - | 1 |
| Oysters | 0.03 | 0.01-0.10 | 149 |
| Sea Carp | 0.01 | 0.01-0.02 | 8 |
| Squid | 0.05 | 0.02-0.27 | 13 |
| Trumpeter, Bastard | 0.05 | 0.01-0.28 | 28 |
| Warehou | 0.05 | 0.01-0.08 | 15 |
| Whiting, King George | 0.06 | 0.01-0.34 | 96 |
| Species with a mean mercury level between 0.11 and 0.20 mg/kg | | | |
| Australian Herring | 0.14 | 0.05-0.74 | 121 |
| Australian Salmon | 0.17 | 0.01-0.62 | 82 |
| Cod, Southern Rock | 0.13 | 0.04-0.45 | 9 |
| Cucumber Fish | 0.12 | 0.02-0.36 | 17 |
| Dory, Mirror | 0.16 | 0.05-0.36 | 30 |
| Dory, Silver | 0.12 | 0.01-0.50 | 77 |
| Flathead, Dusky | 0.15 | 0.05-0.35 | 44 |
| Kingfish, Yellowtail | 0.18 | 0.06-0.70 | 20 |
| Knifejaw | 0.11 | 0.04-0.24 | 50 |
| Leatherjacket | 0.19 | 0.02-0.64 | 80 |
| Mackerel, Blue | 0.15 | 0.05-0.37 | 50 |
| Mackerel, Jack | 0.11 | 0.04-0.25 | 77 |
| Morwong, Brown Banded | 0.18 | 0.02-0.59 | 10 |
| Ruby Fish | 0.11 | 0.03-0.22 | 50 |
| Sandpaper Fish | 0.12 | 0.03-0.50 | 20 |
| Shark, Thresher | 0.14 | - | 1 |
| Skippy | 0.19 | 0.01-0.57 | 46 |
| Snapper (Western) | 0.20 | 0.02-1.25 | 72 |
| Snapper, Queen | 0.20 | 0.05-0.61 | 51 |
| Snoek | 0.11 | 0.01-0.54 | 183 |
| Stingaree, White Spot | 0.20 | 0.11-0.35 | 9 |
| Trevally | 0.16 | 0.09-0.39 | 50 |
| Tuna, Skipjack | 0.15 | 0.11-0.17 | 20 |

Species with a mean mercury level between 0.21 and 0.30 mg/kg

| | | | |
|---|---|---|---|
| Anchovy | 0.25 | 0.22-0.30 | 3 |
| Australian Tusk | 0.22 | 0.07-0.42 | 50 |
| Barramundi | 0.21 | 0.10-0.60 | 34 |
| Bream, Black | 0.23 | 0.03-1.17 | 69 |
| Bream, Yellowfin | 0.22 | 0.03-0.81 | 34 |
| Boarfish, Black Spot | 0.21 | 0.05-0.39 | 24 |
| Flathead, Tiger | 0.29 | 0.04-1.81 | 51 |
| Morwong, Jackass | 0.21 | 0.05-0.74 | 194 |
| Morwong, Rubberlip | 0.22 | 0.03-0.49 | 30 |
| Mulloway | 0.22 | 0.04-0.82 | 49 |
| Parrot Fish | 0.21 | 0.15-0.31 | 4 |
| Perch, Gulf | 0.27 | 0.11-0.61 | 9 |
| Perch, Ocean | 0.27 | 0.19-0.36 | 2 |
| Ray, Fiddler | 0.21 | 0.01-0.52 | 32 |
| Shark, Elephant | 0.26 | 0.02-0.97 | 139 |
| Shark, Varied Cat- | 0.25 | 0.11-0.38 | 4 |
| Skate, White Spotted | 0.26 | 0.03-0.82 | 32 |
| Stargazer | 0.22 | 0.09-0.55 | 11 |
| Tailor | 0.22 | 0.04-0.55 | 32 |
| Tuna, Southern Bluefin | 0.22 | 0.06-0.63 | 219 |
| Whiptail | 0.24 | 0.05-0.43 | 9 |
| Whiting, Sand | 0.30 | 0.09-0.66 | 24 |

Species with a mean mercury level between 0.31 and 0.40 mg/kg

| | | | |
|---|---|---|---|
| Blue Grenadier | 0.31 | 0.08-1.55 | 44 |
| Boarfish, Long Snout | 0.34 | - | 1 |
| Boarfish, Yellow Spot | 0.34 | 0.02-0.87 | 50 |
| Dory, John | 0.31 | 0.06-0.84 | 54 |
| Flathead, Deepwater | 0.37 | 0.12-0.87 | 116 |
| Flathead, Sand | 0.38 | 0.01-1.12 | 313 |
| Nannygai | 0.38 | 0.20-0.56 | 20 |
| Shark, Angel | 0.36 | 0.06-1.60 | 36 |
| Shark, Ornate Angel | 0.35 | 0.15-0.84 | 50 |
| Snook | 0.32 | 0.06-0.63 | 33 |
| Southern Frost Fish | 0.38 | 0.25-0.58 | 5 |
| Tuna, Yellowfin | 0.38 | 0.11-0.66 | 20 |

Species with a mean mercury level between 0.41 and 0.50 mg/kg

| | | | |
|---|---|---|---|
| Hapuku | 0.48 | 0.01-0.95 | 54 |
| Shark, Blue Whaler | 0.41 | 0.25-0.57 | 2 |
| Shark, Common Saw | 0.47 | 0.07-1.32 | 93 |
| Shark, Graceful | 0.43 | 0.34-0.56 | 5 |
| Shark, Gummy | 0.44 | 0.03-3.04 | 507 |
| Shark, Port Jackson | 0.46 | 0.12-3.07 | 71 |
| Shark, Southern Saw | 0.49 | 0.01-2.92 | 62 |
| Snapper (Eastern) | 0.43 | 0.04-1.94 | 104 |
| Stingaree, Common | 0.48 | 0.39-0.58 | 3 |
| Trevalla, Deep Sea | 0.45 | 0.04-1.23 | 53 |

Species with a mean mercury level between 0.51 and 0.60 mg/kg

| | | | |
|---|---|---|---|
| Bight Redfish | 0.52 | 0.20-1.32 | 50 |
| Latchet | 0.57 | 0.01-5.71 | 180 |
| Ling | 0.52 | 0.20-1.10 | 10 |
| Shark, Rusty Cat- | 0.54 | 0.26-1.26 | 16 |
| Shark, Whiskery | 0.59 | 0.10-1.70 | 171 |

Species with a mean mercury level between 0.61 and 0.70 mg/kg

| | | | |
|---|---|---|---|
| Gemfish | 0.66 | 0.07-3.07 | 237 |
| Shark, Gulf Cat- | 0.64 | 0.55-0.73 | 2 |

Species with a mean mercury level between 0.71 and 0.80 mg/kg

| | | | |
|---|---|---|---|
| Perch, Butterfly | 0.75 | - | 1 |
| Shark, Bronze Whaler | 0.72 | 0.10-2.60 | 159 |
| Shark, School | 0.75 | 0.01-3.30 | 361 |
| Shark, Thickskin | 0.73 | 0.30-1.60 | 84 |

Species with a mean mercury level between 0.81 and 0.90 mg/kg

| | | | |
|---|---|---|---|
| Shark, White Spotted Spurdog | 0.86 | 0.28-2.28 | 77 |

Species with a mean mercury level between 0.91 and 1.00 mg/kg

| | | | |
|---|---|---|---|
| Shark, Hammerhead | 0.92 | 0.42-1.72 | 15 |

Species with a mean mercury level greater than 1.00 mg/kg

| | | | |
|---|---|---|---|
| Marlin Black | 7.27 | 0.50-16.50 | 42 |
| Shark, Blacktip Whaler | 1.48 | 0.61- 2.10 | 8 |
| Shark, Blue Pointer | 1.93 | 0.71- 3.15 | 2 |
| Shark, Carpet | 1.02 | 0.10- 3.40 | 76 |
| Shark, Draughtboard | 1.93 | 0.34-10.50 | 15 |
| Shark, Grey Nurse | 1.69 | 0.07- 6.73 | 18 |
| Shark, One finned | 1.48 | - | 1 |
| Shark, Pencil | 2.44 | 0.40- 9.65 | 5 |
| Shark, Piked Spurdog | 1.91 | 0.01- 4.20 | 94 |
| Shark, Seven Gilled | 1.39 | 0.39- 2.06 | 22 |
| Shark, White Pointer | 1.29 | - | 1 |

TABLE 21

MEAN MERCURY LEVELS AND RANGES OF IMPORTED FISH AND FISH PRODUCTS

| Import | Mean Mercury Level (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|
| Barramundi | 0.47 | 0.12-0.60 | 17 |
| Fish fingers | 0.07 | 0.01-0.20 | 42 |
| Hake, Japanese | 0.12 | 0.01-0.33 | 26 |
| Hake, South Africa | 0.12 | 0.01-0.90 | 34 |
| Hake, South African (smoked) | 0.10 | 0.01-0.28 | 12 |
| Herring (canned) | 0.04 | 0.01-0.16 | 21 |
| Herring, UK (smoked) | 0.10 | 0.02-0.38 | 17 |
| Mackerel (canned) | 0.07 | 0.01-0.22 | 52 |
| Salmon (canned) | 0.04 | 0.01-0.27 | 30 |
| Sardines (canned) | 0.05 | 0.01-0.15 | 15 |
| Snapper, New Zealand | 0.58 | 0.10-1.80 | 46 |
| Tuna (canned) | 0.21 | 0.01-2.60 | 170 |
| Turbot, Japanese | 0.09 | 0.01-0.50 | 55 |
| Whiting, UK | 0.08 | 0.01-0.21 | 54 |

## TABLE 22

## ORGANIC MERCURY CONTENT OF AUSTRALIAN FISH

| Common Name | State | Percentage organic Mercury | Standard Deviation | Number in Sample |
|---|---|---|---|---|
| Sea Mullet | NSW | 87.0 | 17.1 | 20 |
| Dusky Flathead | NSW | 94.8 | 4.3 | 30 |
| Mirror Dory | NSW | 79.2 | 10.0 | 30 |
| Aust. Salmon | NSW | 96.6 | 3.8 | 20 |
| Fiddler Ray | NSW | 95.8 | 5.4 | 30 |
| Black Bream | NSW | 93.0 | 6.6 | 30 |
| Mulloway | NSW | 94.9 | 4.7 | 31 |
| Rubberlip Morwong | NSW | 95.6 | 3.8 | 30 |
| Tailor | NSW | 94.6 | 4.7 | 16 |
| Jackass Morwong | NSW | 95.2 | 4.2 | 26 |
| Tiger Flathead | NSW | 94.6 | 5.8 | 29 |
| Sand Whiting | NSW | 95.4 | 5.9 | 24 |
| Snapper | NSW | 96.1 | 4.1 | 30 |
| Angel Shark | NSW | 94.0 | 4.6 | 14 |
| Gummy Shark | NSW | 95.4 | 2.9 | 31 |
| | VIC | 77.3 | 16.1 | 6 |
| | Combined | 92.5 | 9.4 | 37 |
| Gemfish | NSW | 94.1 | 4.8 | 125 |
| School Shark | NSW | 96.9 | 2.6 | 21 |
| | VIC | 89.2 | 8.5 | 6 |
| | Combined | 95.2 | 5.4 | 27 |

### 3.1(v) Relative Concentrations of Selenium and Other Trace Elements

Information gathered for the data base included heavy metal concentrations of selenium, arsenic, copper and zinc as well as mercury (see Table 23).

Selenium was considered to be of importance because of the discovery in recent years of its detoxifying or ameliorating effect with respect to the toxicity of mercury (see Sections 2.4(viii), 2.6(ix) and 2.7 and Table 24). Information on selenium levels in muscle tissue was available for 20 Australian teleosts (bony fishes) and 21 elasmobranchs (sharks and rays).

The mean absolute levels of selenium for teleosts range in general from 0.19 mg/kg for dusky flathead to 0.94 mg/kg for West Australian snapper. The only exception is for black marlin which has a mean level of 2.17 mg/kg. The range of mean levels in elasmobranchs is similar, being from 0.10 mg/kg for a single white pointer sample to 1.03 mg/kg for piked spurdog.

If the precise 1:1 molar ratio of mercury to selenium found in the livers of marine mammals (Koeman et al 1973) is the result of a detoxification process it may be reassuring to know that all the fish analysed and reported have had an excess of selenium over mercury (on a molar basis) and thus the raw materials for such a process would be available to the consumer from the fish eaten.

The molar ratio can be calculated by multiplying the weight ratio by 2.54 and, in the teleost samples, this ratio exceeded unity in every species except for black marlin which had a ratio of 0.99. This is similar to the ratio found for this species by other workers. The molar proportions of the elements would suggest the relative metabolism of these substances by each species.

The teleost species were found to have much higher average ratios of selenium to mercury (range = 3.58 for deepwater flathead to 50.67 for greenback flounder) than the elasmobranchs (range = 0.20 for a single white pointer sample to 5.69 for blue whaler shark) (Table 25). The effects of the source of the sample are still unclear and it would require a more detailed series of analyses to resolve the questions of mercury and selenium ratios with respect to this parameter.

The levels of other heavy metals (arsenic, zinc and copper) have been included, where available, not because they appear to have any specific relationship with mercury levels in the same way as selenium, but to give some indication of a species' proclivity to concentrate these elements as well as mercury and selenium.

It can be seen from Table 23 that there is no apparent pattern of heavy metal concentration with regard to each species and that it is possible that the source of the sample is a more critical factor when considering these results. However, the figures certainly suggest that arsenic and zinc are evident in greater concentrations than is copper.

TABLE 23

MEAN LEVELS (MG/KG) OF HEAVY METALS (OTHER THAN MERCURY) IN FISH MUSCLE
(number of analyses in brackets)

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| Australian Herring | Vic | 0.27 (15) | - | - | - | - |
| | SA | 0.11 (3) | - | - | 1.11 (3) | - |
| | WA | 0.12(103) | 0.36 (1) | - | - | - |
| | Combined | 0.14(121) | 0.36 (1) | - | 1.11 (3) | - |
| Australian Salmon | NSW | 0.23 (22) | 0.36 (12) | 0.34 (12) | 0.78 (22) | 4.88 (22) |
| | Vic | 0.11 (30) | 0.41 (30) | 0.60 (30) | 1.46 (30) | 6.20 (30) |
| | SA | 0.19 (1) | - | 1.00 (1) | 1.45 (1) | 10.20 (1) |
| | Tas | 0.17 (20) | - | - | - | - |
| | WA | 0.21 (9) | - | 1.60 (1) | - | 7.00 (1) |
| | Combined | 0.17 (82) | 0.39 (42) | 0.56 (44) | 1.18 (53) | 5.75 (54) |
| Bream, Black | NSW | 0.22 (31) | 0.36 (12) | - | - | - |
| | Vic | 0.25 (35) | 0.47 (30) | 1.70 (30) | 1.04 (30) | 3.96 (30) |
| | SA | 0.15 (3) | - | 13.50 (2) | 0.93 (3) | 8.03 (3) |
| | Combined | 0.23 (69) | 0.44 (42) | 2.44 (32) | 1.03 (33) | 4.33 (33) |
| Bream, Yellowfin | NSW | 0.23 (30) | - | - | 0.50 (30) | 4.85 (30) |
| | Qld | 0.11 (4) | - | - | - | - |
| | Combined | 0.22 (34) | - | - | 0.50 (30) | 4.85 (30) |
| Dory, Mirror | NSW | 0.16 (30) | 0.43 (30) | - | - | - |
| Flathead, Deepwater | Vic | 0.31 (37) | 0.52 (15) | 0.40 (15) | 0.20 (15) | 3.82 (15) |
| | Tas | 0.33 (29) | 0.39 (10) | 0.54 (10) | 0.25 (10) | 3.64 (10) |
| | WA | 0.43 (50) | - | - | - | - |
| | Combined | 0.37(116) | 0.47 (25) | 0.45 (25) | 0.22 (25) | 3.75 (25) |
| Flathead, Dusky | NSW | 0.13 (30) | 0.19 (12) | - | 0.47 (30) | 6.79 (30) |
| | SA | 0.19 (14) | - | 2.44 (14) | 0.21 (14) | 6.56 (14) |
| | Combined | 0.15 (44) | 0.19 (12) | 2.44 (14) | 0.39 (44) | 6.72 (44) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| Flathead, Sand | Vic | 0.47(203) | 0.33 (30) | 3.76 (30) | 0.64 (30) | 3.50 (30) |
| | SA | 0.17 (16) | - | 5.18 (15) | 0.25 (16) | 7.10 (16) |
| | Tas | 0.23 (94) | 0.34 (10) | 3.93 (10) | 0.17 (10) | 3.44 (10) |
| | Combined | 0.38(313) | 0.33 (40) | 4.13 (55) | 0.44 (56) | 4.52 (56) |
| Flathead, Tiger | NSW | 0.24 (29) | 0.47 (29) | - | - | - |
| | Vic | 0.15 (10) | 0.28 (10) | 1.42 (10) | 0.61 (10) | 3.48 (10) |
| | Tas | 0.52 (12) | 0.40 (12) | 1.14 (12) | 0.21 (12) | 4.00 (12) |
| | Combined | 0.29 (51) | 0.42 (51) | 1.27 (22) | 0.39 (22) | 3.77 (22) |
| Flounder, Greenback | Vic | 0.04 (44) | 0.50 (29) | 1.65 (29) | 0.62 (29) | 9.73 (29) |
| | SA | 0.08 (1) | - | - | 0.74 (1) | 1.90 (1) |
| | Tas | 0.03 (9) | - | - | - | - |
| | Combined | 0.04 (54) | 0.50 (29) | 1.65 (29) | 0.63 (30) | 4.85 (30) |
| Gemfish | NSW | 0.68(148) | - | - | - | - |
| | SA | 0.29 (3) | - | 1.03 (3) | 1.27 (3) | 3.60 (3) |
| | Tas | 0.39 (37) | - | - | - | - |
| | WA | 0.83 (49) | - | - | - | - |
| | Combined | 0.66(237) | - | 1.03 (3) | 1.27 (3) | 3.60 (3) |
| Kingfish, Yellowtail | NSW | 0.18 (20) | - | - | 0.59 (20) | 5.15 (20) |
| Marlin, Black | Qld | 7.27 (42) | 2.17 (42) | 0.61 (42) | 0.42 (42) | 8.54 (42) |
| Morwong, Jackass | NSW | 0.27 (26) | 0.66 (26) | - | - | - |
| | Vic | 0.21 (6) | - | - | - | - |
| | SA | 0.21 (2) | - | 40.00 (2) | 0.45 (2) | 3.95 (2) |
| | Tas | 0.24(110) | - | - | - | - |
| | WA | 0.12 (50) | - | - | - | - |
| | Combined | 0.21(194) | 0.66 (26) | 40.00 (2) | 0.45 (2) | 3.95 (2) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
| --- | --- | --- | --- | --- | --- | --- |
| Morwong, Rubberlip | NSW | 0.22 (30) | 0.51 (30) | - | - | - |
| Mullet, Sea | NSW | 0.03 (31) | - | - | 0.86 (30) | 4.24 (30) |
| | Vic | 0.04 (2) | - | - | - | - |
| | Qld | 0.02 (25) | - | - | - | - |
| | WA | 0.01 (26) | - | - | - | - |
| | Combined | 0.02 (84) | - | - | 0.86 (30) | 4.24 (30) |
| Mullet, Yellow-eye | Vic | 0.07 (50) | 0.40 (50) | 1.08 (50) | 0.94 (50) | 4.41 (50) |
| Mulloway | NSW | 0.22 (31) | 0.32 (13) | 0.64 (13) | 0.57 (31) | 5.85 (30) |
| | SA | 0.61 (3) | - | 0.85 (3) | 0.37 (3) | 6.07 (3) |
| | WA | 0.13 (13) | - | - | - | - |
| | NT | 0.20 (2) | - | - | - | - |
| | Combined | 0.22 (49) | 0.32 (13) | 0.68 (16) | 0.55 (34) | 5.87 (33) |
| Ray, Fiddler | NSW | 0.20 (30) | 0.28 (30) | - | - | - |
| | SA | 0.21 (2) | - | 8.00 (2) | 0.70 (2) | 5.80 (2) |
| | Combined | 0.21 (32) | 0.28 (30) | 8.00 (2) | 0.70 (2) | 5.80 (2) |
| Sharks:- | | | | | | |
| Angel Shark | NSW | 0.40 (29) | 0.37 (14) | - | - | - |
| | SA | 0.28 (2) | 0.85 (1) | 17.50 (2) | 2.43 (2) | 4.19 (2) |
| | Tas | 0.13 (5) | 0.53 (4) | 5.53 (4) | 0.52 (4) | 5.32 (4) |
| | Combined | 0.36 (36) | 0.43 (19) | 9.52 (6) | 1.16 (6) | 4.94 (6) |
| Blacktip Whaler | Vic | 1.48 (8) | 0.34 (8) | 6.00 (8) | 0.69 (8) | 3.01 (8) |
| Blue Pointer | SA | 0.71 (1) | 0.55 (1) | 0.71 (1) | 0.40 (1) | 3.70 (1) |
| | Tas | 3.15 (1) | 0.27 (1) | 1.30 (1) | 0.47 (1) | 2.91 (1) |
| | Combined | 1.93 (2) | 0.41 (2) | 1.01 (2) | 0.44 (2) | 3.31 (2) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| Blue Whaler | Tas | 0.41 (2) | 0.69 (2) | 4.05 (2) | 0.58 (2) | 3.48 (2) |
| Bronze Whaler | Vic | 0.84 (3) | 0.64 (3) | 12.17 (3) | 0.40 (3) | 3.26 (3) |
| | SA | 0.43 (4) | 0.61 (4) | 31.53 (4) | 0.32 (4) | 4.16 (4) |
| | WA | 0.73(152) | - | - | - | - |
| | Combined | 0.72(159) | 0.62 (7) | 23.23 (7) | 0.35 (7) | 3.78 (7) |
| Common Saw Shark | Vic | 0.38 (21) | 0.31 (4) | 13.39 (4) | 0.19 (4) | 3.05 (4) |
| | Tas | 0.56 (49) | 0.30 (5) | 13.21 (5) | 0.16 (5) | 3.03 (5) |
| | WA | 0.34 (23) | - | - | - | - |
| | Combined | 0.47 (93) | 0.30 (9) | 13.29 (9) | 0.17 (9) | 3.04 (9) |
| Draughtboard Shark | Vic | 1.39 (6) | 0.18 (6) | 47.56 (6) | 0.31 (6) | 8.96 (6) |
| | Tas | 2.29 (9) | 0.21 (4) | 45.85 (4) | 0.47 (4) | 9.53 (4) |
| | Combined | 1.93 (15) | 0.19 (10) | 46.88 (10) | 0.37 (10) | 9.19 (10) |
| Elephant Shark | Vic | 0.43 (14) | 0.55 (11) | 5.16 (11) | 0.65 (11) | 4.35 (11) |
| | Tas | 0.24(125) | - | - | - | - |
| | Combined | 0.26(139) | 0.55 (11) | 5.16 (11) | 0.65 (11) | 4.35 (11) |
| Gummy Shark | NSW | 0.66 (36) | 0.29 (31) | - | - | - |
| | Vic | 0.42(218) | - | - | - | - |
| | SA | 0.45 (17) | - | - | - | - |
| | Tas | 0.42(126) | - | - | - | - |
| | WA | 0.44(110) | - | - | - | - |
| | Combined | 0.44(507) | 0.29 (31) | - | - | - |
| Hammerhead Shark | Vic | 0.89 (1) | 0.55 (1) | 17.00 (1) | 0.48 (1) | 4.42 (1) |
| | WA | 0.92 (14) | - | - | - | - |
| | Combined | 0.92 (15) | 0.55 (1) | 17.00 (1) | 0.48 (1) | 4.42 (1) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| Piked Spurdog | Tas | 1.68 (71) | 1.03 (10) | 26.88 (10) | 0.57 (10) | 2.78 (10) |
| | WA | 2.63 (23) | - | - | - | - |
| | Combined | 1.91 (94) | 1.03 (10) | 26.88 (10) | 0.57 (10) | 2.78 (10) |
| Port Jackson Shark | Vic | 0.50 (5) | - | - | - | - |
| | SA | 0.35 (13) | - | - | - | - |
| | Tas | 0.49 (53) | 0.66 (10) | 5.92 (10) | 0.56 (10) | 4.78 (10) |
| | Combined | 0.46 (71) | 0.66 (10) | 5.92 (10) | 0.56 (10) | 4.78 (10) |
| Rusty Catshark | Vic | 0.45 (6) | 0.85 (2) | 16.55 (2) | 0.39 (2) | 10.85 (2) |
| | Tas | 0.60 (10) | 0.82 (8) | 27.26 (8) | 0.46 (8) | 11.24 (8) |
| | Combined | 0.54 (16) | 0.82 (10) | 25.12 (10) | 0.45 (10) | 11.16 (10) |
| School Shark | NSW | 0.55 (21) | 0.34 (21) | - | - | - |
| | Vic | 0.89(185) | - | - | - | - |
| | SA | 1.17 (2) | - | - | - | - |
| | Tas | 0.53(135) | - | - | - | - |
| | Combined | 0.175(361) | 0.34 (21) | - | - | - |
| Seven Gilled Shark | Vic | 1.19 (3) | 0.20 (3) | 12.47 (3) | 0.51 (3) | 4.70 (3) |
| | SA | 1.23 (4) | 0.30 (4) | 18.98 (4) | 0.27 (4) | 3.55 (4) |
| | Tas | 1.48 (15) | 0.36 (8) | 15.74 (9) | 0.41 (9) | 3.56 (9) |
| | Combined | 1.39 (22) | 0.31 (15) | 15.94 (16) | 0.40 (16) | 3.77 (16) |
| Southern Saw Shark | Tas | 0.49 (62) | 0.49 (10) | 6.93 (10) | 0.29 (10) | 3.70 (10) |
| Thresher Shark | SA | 0.14 (1) | 0.41 (1) | 10.60 (1) | 1.28 (1) | 4.10 (1) |
| Whiskery Shark | SA | 0.59 (2) | 0.40 (1) | 36.10 (1) | 0.24 (1) | 3.92 (1) |
| | Tas | 0.75 (4) | 0.38 (4) | 5.98 (4) | 1.18 (4) | 5.79 (3) |
| | WA | 0.59(165) | - | - | - | - |
| | Combined | 0.59(171) | 0.38 (5) | 12.00 (5) | 0.99 (5) | 5.33 (4) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| White Pointer | SA | 1.29 (1) | 0.10 (1) | 10.10 (1) | 0.30 (1) | 3.38 (1) |
| White Spotted Spurdog | SA | 0.50 (4) | - | - | - | - |
| | Tas | 0.88 (73) | 0.42 (10) | 7.06 (10) | 1.80 (10) | 4.24 (10) |
| | Combined | 0.86 (77) | 0.42 (10) | 7.06 (10) | 1.80 (10) | 4.24 (10) |
| Snapper (Eastern) | NSW | 0.34 (30) | 0.31 (12) | - | - | - |
| | Vic | 0.44 (57) | 0.53 (28) | 1.38 (28) | 0.35 (28) | 4.47 (28) |
| | Qld | 0.20 (1) | - | - | - | - |
| | SA | 0.58 (16) | - | - | 0.38 (16) | 7.19 (16) |
| | Combined | 0.43(104) | 0.46 (40) | 1.38 (28) | 0.36 (44) | 5.45 (44) |
| Snapper (Western) | WA | 0.20 (72) | 0.94 (29) | - | - | - |
| Snoek | Vic | 0.07 (31) | 0.52 (30) | 0.49 (30) | 0.78 (30) | 4.85 (30) |
| | SA | 0.09 (20) | - | - | - | |
| | Tas | 0.11 (82) | - | - | - | - |
| | WA | 0.15 (50) | - | - | - | - |
| | Combined | 0.11(183) | 0.52 (30) | 0.49 (30) | 0.78 (30) | 4.85 (30) |
| Tailor | NSW | 0.22 (16) | - | 0.27 (3) | 0.78 (16) | 7.72 (16) |
| | Qld | 0.23 (16) | - | - | - | - |
| | Combined | 0.22 (32) | - | 0.27 (3) | 0.78 (16) | 7.72 (16) |
| Trevalla, Deep Sea | NSW | 0.47 (50) | 0.75 (10) | 0.70 (10) | 0.42 (10) | 4.38 (10) |
| | Vic | 0.06 (3) | 0.77 (3) | 1.40 (3) | 0.47 (3) | 3.20 (3) |
| | Combined | 0.45 (53) | 0.75 (13) | 0.86 (13) | 0.43 (13) | 4.11 (13) |
| Tuna, Yellowfin | NSW | 0.38 (20) | - | - | 0.40 (20) | 4.82 (20) |

| Common Name | State | Mercury | Selenium | Arsenic | Copper | Zinc |
|---|---|---|---|---|---|---|
| Whiting, King George | Vic | 0.07 (60) | 0.48 (40) | 10.45 (40) | 0.35 (40) | 4.96 (40) |
| | SA | 0.05 (36) | - | 20.89 (35) | 0.70 (36) | 8.18 (36) |
| | Combined | 0.06 (96) | 0.48 (40) | 15.32 (75) | 0.51 (76) | 6.48 (76) |
| Whiting, Sand | NSW | 0.30 (24) | 0.37 (24) | - | - | - |

## TABLE 24

## MEAN SELENIUM LEVELS AND RANGES IN AUSTRALIAN FISH SAMPLES

| Common Name | State | Mean Selenium (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|---|
| Australian Herring | WA | 0.36 | 0.36 | 1 |
| Australian Salmon | NSW | 0.36 | 0.20-0.50 | 12 |
| | Vic | 0.41 | 0.05-1.00 | 30 |
| | Combined | 0.39 | 0.05-1.00 | 42 |
| Bream, Black | NSW | 0.36 | 0.10-0.80 | 12 |
| | Vic | 0.47 | 0.10-1.10 | 30 |
| | Combined | 0.44 | 0.10-1.10 | 42 |
| Dory, Mirror | NSW | 0.43 | 0.24-0.73 | 30 |
| Flathead, Deepwater | Vic | 0.52 | 0.13-0.67 | 15 |
| | Tas | 0.39 | 0.28-0.47 | 10 |
| | Combined | 0.47 | 0.13-0.67 | 25 |
| Flathead, Dusky | NSW | 0.19 | 0.05-0.30 | 12 |
| Flathead, Sand | Vic | 0.33 | 0.05-0.69 | 30 |
| | Tas | 0.34 | 0.25-0.44 | 10 |
| | Combined | 0.33 | 0.05-0.69 | 40 |
| Flathead, Tiger | NSW | 0.47 | 0.30-0.63 | 29 |
| | Vic | 0.28 | 0.05-0.50 | 10 |
| | Tas | 0.40 | 0.29-0.54 | 12 |
| | Combined | 0.42 | 0.05-0.63 | 51 |
| Flounder, Greenback | Vic | 0.50 | 0.23-0.82 | 29 |
| Marlin, Black | Qld | 2.17 | 0.40-4.30 | 44 |
| Morwong, Jackass | NSW | 0.66 | 0.43-1.00 | 26 |

| Common Name | State | Mean Selemium (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|---|
| Morwong, Rubberlip | NSW | 0.51 | 0.26-0.78 | 30 |
| Mullet, Yellow-eye | Vic | 0.40 | 0.11-0.90 | 50 |
| Mulloway | NSW | 0.32 | 0.10-0.50 | 13 |
| Ray, Fiddler | NSW | 0.28 | 0.15-0.46 | 30 |
| Sharks:- | | | | |
| Angel | NSW | 0.37 | 0.13-0.67 | 14 |
| | SA | 0.85 | 0.85 | 1 |
| | Tas | 0.53 | 0.31-0.68 | 4 |
| | Combined | 0.43 | 0.13-0.85 | 19 |
| Blacktip Whaler | Vic | 0.34 | 0.22-0.43 | 8 |
| Blue Pointer | SA | 0.55 | 0.55 | 1 |
| | Tas | 0.27 | 0.27 | 1 |
| | Combined | 0.41 | 0.27-0.55 | 2 |
| Blue Whaler | Tas | 0.69 | 0.46-0.92 | 2 |
| Bronze Whaler | Vic | 0.64 | 0.50-0.82 | 3 |
| | SA | 0.61 | 0.30-1.10 | 4 |
| | Combined | 0.62 | 0.30-1.10 | 7 |
| Common Saw Shark | Vic | 0.31 | 0.26-0.39 | 4 |
| | Tas | 0.30 | 0.27-0.31 | 5 |
| | Combined | 0.30 | 0.26-0.39 | 9 |
| Draughtboard Shark | Vic | 0.18 | 0.15-0.21 | 6 |
| | Tas | 0.21 | 0.18-0.23 | 4 |
| | Combined | 0.19 | 0.15-0.23 | 10 |

| Common Name | State | Mean Selemium (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|---|
| Elephant Shark | Vic | 0.55 | 0.49-0.63 | 11 |
| Gummy Shark | NSW | 0.29 | 0.23-0.39 | 31 |
| Hammerhead Shark | Vic | 0.55 | 0.55 | 1 |
| Piked Spurdog | Tas | 1.03 | 0.72-1.52 | 10 |
| Port Jackson Shark | Tas | 0.66 | 0.37-1.24 | 10 |
| Rusty Catshark | Vic | 0.85 | 0.74-0.96 | 2 |
| | Tas | 0.82 | 0.30-1.64 | 8 |
| | Combined | 0.82 | 0.30-1.64 | 10 |
| School Shark | NSW | 0.34 | 0.22-0.97 | 21 |
| Seven-gilled Shark | Vic | 0.20 | 0.05-0.51 | 3 |
| | SA | 0.30 | 0.26-0.36 | 4 |
| | Tas | 0.36 | 0.28-0.51 | 8 |
| | Combined | 0.31 | 0.05-0.51 | 15 |
| Southern Saw Shark | Tas | 0.49 | 0.31-1.12 | 10 |
| T. esher Shark | SA | 0.41 | 0.41 | 1 |
| Whiskery Shark | SA | 0.40 | 0.40 | 1 |
| | Tas | 0.38 | 0.30-0.50 | 4 |
| | Combined | 0.38 | 0.30-0.50 | 5 |
| White Pointer | SA | 0.10 | 0.10 | 1 |
| White Spotted Spurdog | Tas | 0.42 | 0.29-0.53 | 10 |

| Common Name | State | Mean Selemium (mg/kg) | Range (mg/kg) | No. in Sample |
|---|---|---|---|---|
| Snapper (Eastern) | NSW | 0.31 | 0.10-0.60 | 12 |
| | Vic | 0.53 | 0.20-1.00 | 28 |
| | Combined | 0.46 | 0.10-1.00 | 40 |
| Snapper (Western) | WA | 0.94 | 0.11-1.90 | 29 |
| Snoek | Vic | 0.52 | 0.30-0.80 | 30 |
| Trevalla, Deep Sea | NSW | 0.75 | 0.30-1.80 | 10 |
| | Vic | 0.77 | 0.40-1.00 | 3 |
| | Combined | 0.75 | 0.30-1.80 | 13 |
| Whiting, King George | Vic | 0.48 | 0.26-1.34 | 40 |
| Whiting, Sand | NSW | 0.37 | 0.26-0.51 | 24 |

TABLE 25

RATIOS OF SELENIUM TO MERCURY IN FISH MUSCLE
(ie Total Selenium in Muscle Divided by Total Mercury in Muscle)

| Common Name | State | Selenium/Mercury Ratio (by weight) | Molar Selenium/ Mercury Ratio | No. in Sample |
|---|---|---|---|---|
| Australian Herring | WA | 2.57 | 6.53 | 1 |
| Australian Salmon | NSW | 7.64 | 19.41 | 12 |
| | Vic | 4.30 | 10.92 | 30 |
| | Combined | 5.25 | 13.34 | 42 |
| Bream, Black | NSW | 1.90 | 4.83 | 12 |
| | Vic | 4.73 | 12.01 | 30 |
| | Combined | 3.92 | 9.96 | 42 |
| [illegible]y, Mirror | NSW | 3.01 | 7.65 | 30 |
| Flathead, Deepwater | Vic | 1.60 | 4.06 | 30 |
| | Tas | 0.86 | 2.18 | 10 |
| | Combined | 1.41 | 3.58 | 40 |
| Flathead, Dusky | NSW | 1.52 | 3.86 | 40 |
| Flathead, Sand | Vic | 1.60 | 4.06 | 30 |
| | Tas | 0.86 | 2.18 | 10 |
| | Combined | 1.4 | 3.58 | 40 |
| Flathead, Tiger | NSW | 2.54 | 6.45 | 29 |
| | Vic | 3.81 | 9.68 | 10 |
| | Tas | 1.60 | 4.06 | 12 |
| | Combined | 2.57 | 6.53 | 51 |
| Flounder, Greenback | Vic | 19.95 | 50.67 | 29 |
| M[illegible]in, Black | Qld | 0.39 | 0.99 | 42 |
| Morwong, Jackass | NSW | 2.65 | 6.73 | 26 |
| Morwong, Rubberlip | NSW | 2.94 | 7.47 | 30 |
| Mullet, Yellow-eye | Vic | 11.38 | 28.91 | 50 |
| Mulloway | NSW | 2.26 | 5.74 | 13 |
| Ray, Fiddler | NSW | 1.89 | 4.80 | 30 |
| Sharks:- | | | | |
| Angel | NSW | 1.09 | 2.77 | 14 |
| | SA | 5.67 | 14.40 | 1 |
| | Tas | 5.41 | 13.74 | 4 |
| | Combined | 2.24 | 5.69 | 19 |

| Common Name | State | Selenium/Mercury Ratio (by weight) | Molar Selenium/ Mercury Ratio | No. in Sample |
|---|---|---|---|---|
| Blacktip Whaler | Vic | 0.24 | 0.61 | 8 |
| Blue Pointer | SA | 0.78 | 1.98 | 1 |
| | Tas | 0.09 | 0.23 | 1 |
| | Combined | 0.43 | 1.09 | 2 |
| Blue Whaler | Tas | 2.24 | 5.69 | 2 |
| Bronze Whaler | Vic | 0.90 | 2.29 | 3 |
| | SA | 1.89 | 4.80 | 4 |
| | Combined | 1.47 | 3.73 | 7 |
| Common Saw Shark | Vic | 0.93 | 2.36 | 4 |
| | Tas | 0.72 | 1.83 | 5 |
| | Combined | 0.81 | 2.06 | 9 |
| Draughtboard Shark | Vic | 0.16 | 0.41 | 6 |
| | Tas | 0.43 | 1.09 | 4 |
| | Combined | 0.27 | 0.69 | 10 |
| Elephant Shark | Vic | 1.47 | 3.73 | 11 |
| Gummy Shark | NSW | 0.82 | 2.08 | 31 |
| Hammerhead | Vic | 0.62 | 1.57 | 1 |
| Piked Spurdog | Tas | 0.47 | 1.19 | 10 |
| Port Jackson Shark | Tas | 1.60 | 4.06 | 10 |
| Rusty Catshark | Vic | 1.95 | 4.95 | 2 |
| | Tas | 1.50 | 3.81 | 8 |
| | Combined | 1.59 | 4.04 | 10 |
| School Shark | NSW | 0.77 | 1.96 | 21 |
| Seven Gilled Shark | Vic | 0.14 | 0.36 | 3 |
| | SA | 0.37 | 0.94 | 4 |
| | Tas | 0.24 | 0.61 | 8 |
| | Combined | 0.25 | 0.64 | 15 |
| Southern Saw Shark | Tas | 0.78 | 1.98 | 10 |
| Thresher Shark | SA | 2.93 | 7.44 | 1 |
| Whiskery Shark | SA | 1.18 | 3.00 | 1 |
| | Tas | 0.63 | 1.60 | 4 |
| | Combined | 0.74 | 1.88 | 5 |
| White Pointer | SA | 0.08 | 0.20 | 1 |

| Common Name | State | Selenium/Mercury Ratio (by weight) | Molar Selenium/ Mercury Ratio | No. in Sample |
|---|---|---|---|---|
| White Spotted Spurdog | Tas | 0.55 | 1.40 | 10 |
| Snapper (Eastern) | NSW | 1.01 | 2.57 | 12 |
| | Vic | 2.12 | 5.38 | 28 |
| | Combined | 1.79 | 4.55 | 40 |
| Snapper (Western) | WA | 3.44 | 8.74 | 29 |
| Snoek | Vic | 15.41 | 39.14 | 30 |
| Trevalla, Deep Sea | NSW | 1.61 | 4.09 | 10 |
| | Vic | 13.18 | 33.48 | 3 |
| | Combined | 4.28 | 10.87 | 13 |
| ,hiting, King George | Vic | 8.08 | 20.52 | 40 |
| Whiting, Sand | NSW | 1.73 | 4.39 | 24 |

## 3.2 Quantities of Fish Consumed in Australia

### 3.2(i) Introduction

Official statistics show that average fish consumption in Australia is relatively low, at 6 to 7 kg per person annually. In 1976 Australia was ranked 61st out of 132 countries in per capita fish consumption*.

Nevertheless it had been suggested to the Working Group that this average was likely to conceal individuals or groups consuming fairly large quantities of fish, including fish with high mercury content.

The Working Group hypothesised that some individuals from groups within the community were more likely to be at risk from the ingestion of mercury through eating fish either because they consumed large quantities of fish or because they were especially susceptible to mercury ingestion. The groups selected were based on earlier consumer surveys concerned with mercury intake in Australia and overseas+ and on the advice of medical and nutrition experts.

The groups considered more likely to eat large quantities of fish were:

(1) ethnic groups

(2) low income groups

(3) persons who fished for recreation

(4) persons connected with the fishing industry, for example fishermen and fish retailers

(5) those aborigines and others in isolated areas where the traditional diet includes large quantities of fish and,

(6) persons on a diet

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* Calculated from information collected by the Food and Agriculture Organisation of the United Nations (FAO).

\+ These studies are discussed in Sections 2.5 and 2.6(v) of this report. None of the previous Australian studies have been made available to the general public.

Groups likely to be more susceptible to the effects of mercury ingestion were considered to be:

(1) pregnant women, because of the effects of mercury on the foetus and,

(2) young persons especially in the 14-18 age group who have a high food consumption.

Studies of fish consumption were undertaken at two levels. The first, referred to as the 'broad brush' survey was aimed to quantify the level, distribution, frequency and species of fish consumed by randomly selected individuals. The second phase of the consumer study, referred to as the 'purposive' or screening surveys, sampled 6,500 individuals from all the groups listed above, excepting pregnant women. Two purposive surveys were undertaken, one by PA Consulting Services and the other under the general supervision of the Commonwealth Department of Health.

A weekly diet record was administered to the 299 highest fish eaters drawn from the broad brush and both purposive surveys and a sample of hair was obtained from each subject. Of these, 151 were interviewed by PA Consulting Services personnel and 148 by community health nurses and students at Dietitians' and Teachers Training Institutes for the Department of Health. Hair samples and some information on eating habits were also collected from a control group of 12 persons who rarely or never ate fish. The hair samples were later analysed for mercury content and the individuals showing the highest mercury levels were re-interviewed. The two surveys used a common questionnaire but their hair samples were analysed in different laboratories. The Health survey also took samples of blood from 43 subjects and these were analysed for mercury and selenum content. Selenium levels in hair and the blood were also measured for 135 individuals in the Health survey.

The purpose of this section is to report on both the broad brush and purposive studies with a view to establishing the distribution of heavy fish eaters throughout the community, and in Section 3.4, the extent to which fish consumption is related to mercury levels in the hair and blood.

The section is in two parts. In the first the results of the broad brush survey are presented with a view to setting out the distribution of fish consumption among the capital city populations and to test the hypotheses formulated by the Working Group that individuals from certain groups in the community were more likely to be consuming large quantities of fish. The second part examines fish consumption from the purposive surveys, while the associated mercury analyses are examined in section 3.4.

## 3.2(ii) Fish Consumption in Australia(*)

### (a) Level of Consumption

Persons living in Australian capital cities were estimated to have eaten an average of 10 kg of fish and seafood per person in 1976/77 (Tables 26 and 27). Because of lower consumption in rural areas and other factors it was estimated that the per capita consumption for the population as a whole was about 8 to 9 kg annually.

There was considerable variation in consumption between capital cities, ranging from 11.7 kg per capita annually in Sydney to 7.2 kg in Hobart.

A distribution of the percentage of individuals falling between selected consumption levels in the week before interview is shown in Table 28. Some 38% of individuals had not eaten fish or seafood in that week and an additional one third ate less than 200 grams. However, 6% of the capital city population ate more than 500 grams per week. The figure of 500 grams weekly has been used as an arbitrary level to define heavy fish eaters in some Australian dietary studies undertaken to examine mercury intake (Penington 1972/73, English 1978). About 2% of the survey population ate more than 750 grams in the survey week and 0.9% ate more than 1000 grams.

These percentages need to be interpreted with caution as they do not purport to represent the consumption levels of individuals over a period of time. For example it is extremely unlikely that all the 2% eating more than 750 grams during the survey week would consume at this level every week. Information on consumption at two periods of time was collected in the course of the purposive surveys for some 150 respondents and the results are analysed in Appendix 3. The analysis suggests that the greater the weekly consumption of fish at one point in time the lower the likelihood that consumers will be at this level in subsequent periods. It would seem that the great majority of Australians are relatively low consumers of fish but some may eat large quantities over a short period of time owing to changes in diet associated with leisure fishing, dieting, social occasions and so on.

### (b) Frequency of Consumption

During the week preceding the interview, some form of fish was served in the home by 60% of households, cooked fish from take-away outlets was eaten by 15% of households and 11% of respondents ate fish while dining out (Table 29). Tinned fish was eaten more frequently than any other form of fish and seafood.

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(*) The information in this section will be found in greater detail in Department of Primary Industry (1978).

## TABLE 26

## ANNUAL PER CAPITA CONSUMPTION OF FISH AND SEAFOOD IN CAPITAL CITIES

| | Fish kg | Seafood kg | Total kg |
|---|---|---|---|
| Sydney | 8.35 | 3.34 | 11.69 |
| Melbourne | 7.66 | 1.28 | 8.94 |
| Brisbane | 8.02 | 2.34 | 10.36 |
| Adelaide | 6.36 | 1.33 | 7.69 |
| Perth | 7.30 | 2.24 | 9.54 |
| Canberra | 5.88 | 2.14 | 8.02 |
| All Cities | 7.80 | 2.27 | 10.07 |

## TABLE 27

## ANNUAL PER CAPITA CONSUMPTION OF FISH BY CITY AND ITS FORM

PA Broad Brush Survey

| | Total kg | Sydney kg | Melbourne kg | Perth kg | Brisbane kg | Adelaide kg | Canberra kg | Hobart kg |
|---|---|---|---|---|---|---|---|---|
| FISH: (At Home) | | | | | | | | |
| Fresh | 2.90 | 3.16 | 2.71 | 2.70 | 3.49 | 2.49 | 1.80 | 2.50 |
| Fish Fingers | 0.66 | 0.75 | 0.66 | 0.52 | 0.50 | 0.63 | 0.65 | 0.47 |
| Frozen Fish | 0.30 | 0.28 | 0.35 | 0.38 | 0.21 | 0.27 | 0.26 | 0.20 |
| Tinned Fish | 1.82 | 1.99 | 1.68 | 1.64 | 1.53 | 0.27 | 1.83 | 0.73 |
| Smoked Fish | 0.24 | 0.29 | 0.21 | 0.27 | 0.26 | 2.26 | 0.25 | 0.21 |
| Other Fish | 0.04 | 0.03 | 0.02 | 0.08 | - | 0.21 | - | 0.07 |
| = Sub-Total | 5.96 | 6.50 | 5.63 | 5.59 | 5.99 | 5.96 | 4.79 | 4.18 |
| Cooked from Take Away Outlets: | 1.10 | 1.06 | 1.26 | 1.04 | 1.10 | 0.96 | 0.59 | 0.92 |
| Eaten Outside the Home: | 0.74 | 0.79 | 0.77 | 0.67 | 0.93 | 0.44 | 0.50 | 0.45 |
| Total Fish | 7.80 | 8.35 | 7.66 | 7.30 | 8.02 | 6.36 | 5.88 | 5.55 |
| Total Seafood | 2.27 | 3.34 | 1.28 | 2.24 | 2.34 | 1.33 | 2.14 | 1.60 |
| Total Fish and Seafood | 10.07 | 11.69 | 8.94 | 9.54 | 10.36 | 7.69 | 8.02 | 7.15 |

TABLE 28

PERCENTAGE DISTRIBUTION OF FISH AND SEAFOOD CONSUMED

PA Broad Brush Survey

Grams per person weekly

| Grams per Week | Total % | Sydney % | Melbourne % | Brisbane % | Adelaide % | Perth % | Hobart % | Canberra % |
|---|---|---|---|---|---|---|---|---|
| None consumed in past week | 37.8 | 37.6 | 37.6 | 40.7 | 36.6 | 34.1 | 49.5 | 43.0 |
| 1 to 100 grams | 17.9 | 16.4 | 19.4 | 16.0 | 17.2 | 21.9 | 17.9 | 19.0 |
| 101 to 200 grams | 17.5 | 16.6 | 17.8 | 17.1 | 19.6 | 18.6 | 15.1 | 16.8 |
| 201 to 300 grams | 10.9 | 11.6 | 10.7 | 9.9 | 11.3 | 11.0 | 6.3 | 8.8 |
| 301 to 400 grams | 6.1 | 6.2 | 6.2 | 5.8 | 6.2 | 5.4 | 4.8 | 4.9 |
| 401 to 500 grams | 3.4 | 3.7 | 2.9 | 3.3 | 3.1 | 3.7 | 2.1 | 3.6 |
| 501 to 750 grams | 4.2 | 4.9 | 3.7 | 4.4 | 4.2 | 3.5 | 2.9 | 2.9 |
| 751 to 1000 grams | 1.3 | 1.7 | 0.9 | 1.7 | 1.2 | 1.5 | 0.5 | 0.8 |
| Over 1000 grams | 0.9 | 1.3 | 0.6 | 0.9 | 0.7 | 0.5 | 1.1 | 0.4 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

## TABLE 29

## FREQUENCY OF SERVING ALL FORMS OF FISH

All Cities

Percentage of Consumers and Average Times Served

PA Broad Brush Survey

| | Cooked Fish | Fresh & Frozen Fish | Fish Fingers | Frozen Packaged Fish | Tinned Fish | Smoked Fish | Other Fish | Total Fish at Home | Fish Eaten Out |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % | % |
| Never Serve | 35.4 | 18.0 | 49.6 | 74.3 | 12.8 | 61.9 | 95.1 | 4.7 | 39.6 |
| None in past week | 50.1 | 56.3 | 38.0 | 22.1 | 50.4 | 34.7 | 4.0 | 35.4 | 49.4 |
| % Serving in past 7 days of which: | 14.6 | 25.7 | 12.4 | 3.6 | 36.8 | 3.4 | 0.9 | 59.9 | 10.9 |
| Once | 13.1 | 19.3 | 10.3 | 3.2 | 26.2 | 3.0 | 0.6 | 30.4 | 9.7 |
| Twice | 1.2 | 4.7 | 1.6 | 0.2 | 6.9 | 0.3 | 0.2 | 17.0 | 1.1 |
| Three | 0.2 | 1.0 | 0.3 | 0.1 | 2.3 | 0.1 | - | 7.1 | 0.1 |
| Four | 0.1 | 0.4 | 0.1 | - | 0.7 | - | - | 2.6 | 0.1 |
| Five or Over | - | 0.3 | - | - | 0.7 | - | - | 2.8 | - |
| Average times per week | 0.16 | 0.35 | 0.15 | 0.04 | 0.54 | 0.04 | 0.01 | 1.15 | 0.13 |
| Average times per annum | 8.3 | 18.2 | 7.8 | 2.1 | 28.1 | 2.1 | 0.5 | 59.8 | 6.8 |

(c) Factors Influencing Consumption

Patterns of household consumption are influenced by a number of factors. Those which change relatively frequently such as price, availability and freshness of fish offered for sale will determine the nature of individual purchases. In the longer term consumption will be influenced by other economic and social factors such as income and country of origin. Data collected in the survey concerning these latter features are discussed below.

In general, persons from households with higher total incomes ate more fish and seafood than those from lower income households, although this trend was not strong (Table 30). This would not appear to support the original supposition that low income groups are more likely to eat larger quantities of fish.

Households comprising only adult males ate considerably more fish and seafood per person than any other group at an average consumption of some 17 kg per year (Table 31). Adult males and females with no children were also relatively high consumers of fish and seafood while couples with children had relatively low average consumption.

The country of origin of the respondent had little discernible effect on the overall amount of fish and seafood consumed (Table 32). However, it had a marked influence on the form of fish consumed; "Mediterranean" households for example ate more fresh fish and seafood while "British" households, i.e. where the respondent was born in Australia, New Zealand or the U.K., ate more packaged and tinned fish.

Persons eating fish and seafood primarily for dietary reasons, who made up some 2.7% of respondents, ate about twice as much of this food as was average for all persons (Tables 33 and 34). The top 25% of dieters all ate over 500 grams fish per week and averaged 29 kg annually.

(d) Species Consumed

The species of fish most frequently served at home was tuna, served on 18% of fish consumption occasions (Table 35). Tinned salmon was also commonly served and of fresh fish, whiting and bream were most frequently eaten. There were considerable differences in the species of fish eaten out and from take-away outlets in the capital cities. Flake (shark) was the most common species of cooked fish purchased, largely because of its predominance in Melbourne and Hobart. When dining-out, whiting was most commonly eaten in Adelaide and Melbourne, barramundi in Brisbane and flounder in Hobart. Canberra and Sydney consumers ate a wider range of species than residents of other cities.

## TABLE 30

### ANNUAL PER CAPITA CONSUMPTION OF FISH AND SEAFOOD BY TOTAL HOUSEHOLD INCOME

All Capital Cities

PA Broad Brush Survey

| | Not known | Under $4000 | $4000-$5999 | $6000-$7999 | $8000-$9999 | $10,000-$11,999 | $12,000-$14,999 | $15,000-$17,999 | $18,000 & over |
|---|---|---|---|---|---|---|---|---|---|
| **Fish** | kg | kg | kg | kg | kg | kg | kg | kg | kg |
| Fresh | 3.04 | 2.84 | 3.16 | 2.89 | 2.47 | 2.65 | 2.88 | 2.74 | 3.31 |
| Fish Fingers | 0.64 | 0.43 | 0.73 | 0.76 | 0.82 | 0.74 | 0.57 | 0.51 | 0.61 |
| Frozen Packaged | 0.36 | 0.34 | 0.15 | 0.16 | 0.29 | 0.37 | 0.31 | 0.29 | 0.36 |
| Tinned | 1.72 | 1.73 | 1.78 | 2.00 | 1.60 | 1.88 | 1.81 | 1.61 | 2.21 |
| Smoked | 0.30 | 0.29 | 0.18 | 0.15 | 0.25 | 0.28 | 0.14 | 0.19 | 0.34 |
| Other | 0.03 | 0.03 | 0.05 | 0.05 | 0.02 | 0.06 | 0.03 | 0.06 | 0.03 |
| Sub Total | 6.09 | 5.66 | 6.05 | 6.01 | 5.45 | 5.98 | 5.74 | 5.40 | 6.86 |
| Cooked from take-away outlets | 0.95 | 0.80 | 0.68 | 1.05 | 1.13 | 1.26 | 1.43 | 1.50 | 1.12 |
| Eaten when dining out | 0.46 | 0.69 | 0.64 | 0.53 | 0.74 | 0.65 | 1.15 | 1.06 | 1.04 |
| Total Fish | 7.50 | 7.15 | 7.37 | 7.59 | 7.32 | 7.89 | 8.32 | 7.96 | 9.02 |
| **Seafood** | | | | | | | | | |
| Fresh | 0.81 | 0.52 | 1.11 | 0.71 | 0.79 | 0.72 | 0.56 | 1.03 | 1.13 |
| Frozen | 0.03 | 0.08 | 0.06 | 0.04 | 0.04 | 0.10 | 0.26 | 0.10 | 0.09 |
| Tinned | 0.08 | 0.04 | 0.16 | 0.08 | 0.15 | 0.12 | 0.12 | 0.13 | 0.23 |
| Other | 0.02 | 0.01 | - | 0.02 | 0.04 | 0.01 | 0.03 | - | 0.04 |
| Sub Total | 0.94 | 0.65 | 1.33 | 0.85 | 1.02 | 0.95 | 0.97 | 1.26 | 1.49 |
| Cooked from take-away outlets | 0.59 | 0.33 | 0.61 | 0.21 | 0.90 | 0.66 | 0.35 | 0.51 | 0.64 |
| Eaten when dining out | 0.33 | 0.26 | 0.50 | 0.62 | 0.81 | 1.15 | 0.87 | 0.26 | 1.36 |
| Total Seafood | 1.86 | 1.24 | 2.44 | 1.68 | 2.73 | 2.76 | 2.19 | 2.03 | 3.49 |
| Total Fish & Seafood | 9.36 | 8.39 | 9.81 | 9.27 | 10.05 | 10.65 | 10.51 | 9.99 | 12.51 |

TABLE 31

ANNUAL PER CAPITA CONSUMPTION OF FISH AND SEAFOOD BY HOUSEHOLD COMPOSITION

All Capital Cities

PA Broad Brush Survey

| | Adult Male Only | Adult Female Only | Adult Male & Female | Families with One Child | Families with Two Children | Families with Three or more Children |
|---|---|---|---|---|---|---|
| **Fish** | kg | kg | kg | kg | kg | kg |
| Fresh | 3.09 | 2.33 | 3.66 | 2.95 | 2.33 | 2.35 |
| Fish fingers | 0.79 | 0.55 | 0.47 | 0.55 | 0.78 | 0.91 |
| Frozen packaged | 0.49 | 0.31 | 0.39 | 0.29 | 0.28 | 0.16 |
| Tinned | 1.59 | 2.21 | 2.05 | 1.88 | 1.64 | 1.53 |
| Smoked | 0.19 | 0.34 | 0.33 | 0.25 | 0.21 | 0.10 |
| Other | 0.12 | - | 0.05 | 0.02 | 0.02 | 0.04 |
| Sub Total | 6.27 | 5.74 | 6.95 | 5.94 | 5.26 | 5.09 |
| Cooked from take-away outlets | 2.84 | 0.99 | 1.06 | 0.96 | 1.13 | 1.12 |
| Eaten outside the home | 2.25 | 1.09 | 1.11 | 0.70 | 0.42 | 0.32 |
| Total Fish | 11.36 | 7.82 | 9.12 | 7.60 | 6.81 | 6.53 |
| **Seafood** | | | | | | |
| Fresh | 0.55 | 0.28 | 0.86 | 1.00 | 0.86 | 0.57 |
| Frozen | 0.04 | 0.04 | 0.10 | 0.06 | 0.02 | 0.02 |
| Tinned | 0.15 | 0.08 | 0.02 | 0.02 | 0.09 | 0.07 |
| Other | 0.01 | 0.01 | 0.03 | 0.01 | 0.03 | - |
| Sub Total | 0.75 | 0.41 | 1.01 | 1.09 | 1.00 | 0.66 |
| Cooked from take-away outlets | 1.00 | 0.26 | 0.53 | 0.73 | 0.66 | 0.23 |
| Eaten outside the home | 3.96 | 0.84 | 1.02 | 0.50 | 0.62 | 0.13 |
| Total Seafood | 5.71 | 1.51 | 2.56 | 2.32 | 2.28 | 1.02 |
| Total Fish and Seafood | 17.07 | 9.33 | 11.68 | 9.92 | 9.09 | 7.55 |

## TABLE 32

## ANNUAL PER CAPITA CONSUMPTION OF FISH AND SEAFOOD BY COUNTRY OF ORIGIN

All Capital Cities

PA Broad Brush Survey

| | Australia kg | Italy kg | Greece kg | U.K./N.Z. kg | Other kg |
|---|---|---|---|---|---|
| **Fish** | | | | | |
| Fresh | 2.67 | 3.90 | 5.02 | 2.87 | 3.38 |
| Fish Fingers | 0.64 | 0.39 | 0.39 | 0.77 | 0.71 |
| Frozen Packaged | 0.25 | 0.03 | - | 0.32 | |
| Tinned | 1.89 | 1.21 | 1.22 | 1.84 | 1.75 |
| Smoked | 0.23 | - | - | 0.49 | 0.16 |
| Other | 0.02 | - | - | 0.01 | 0.10 |
| Sub Total | 5.70 | 5.53 | 6.63 | 6.60 | 6.42 |
| Cooked from take-away outlets | 1.14 | 0.62 | 0.62 | 0.96 | 0.85 |
| Eaten outside the home | 0.80 | 0.11 | 0.15 | 0.92 | 0.52 |
| Total Fish | 7.64 | 2.26 | 7.40 | 8.48 | 7.79 |
| **Seafood** | | | | | |
| Fresh | 0.70 | 1.46 | 1.43 | 0.52 | 1.20 |
| Frozen Packaged | 0.11 | 0.03 | - | 0.05 | 0.08 |
| Tinned | 0.11 | 0.05 | 0.14 | 0.12 | 0.15 |
| Other | 0.02 | - | - | 0.01 | 0.05 |
| Sub Total | 0.94 | 1.54 | 1.57 | 0.70 | 1.48 |
| Cooked from take-away outlets | 0.57 | 0.25 | 0.99 | 0.61 | 0.26 |
| Eaten outside the home | 0.66 | 0.39 | 0.20 | 0.94 | 0.30 |
| Total Seafood | 2.17 | 2.18 | 2.76 | 2.25 | 2.04 |
| Total Fish and Seafood | 9.81 | 8.44 | 10.16 | 10.73 | 9.83 |

## TABLE 33

### ANNUAL FISH AND SEAFOOD CONSUMPTION FOR ALL PERSONS AND THOSE EATING FISH FOR DIETARY REASONS[1]

By City

PA Broad Brush Survey

| | Total kg | Sydney kg | Melbourne kg | Brisbane kg | Adelaide kg | Perth kg | Hobart kg | Canberra kg |
|---|---|---|---|---|---|---|---|---|
| All persons | 7.7 | 8.4 | 7.2 | 7.6 | 7.7 | 7.7 | 5.7 | 6.3 |
| Persons eating fish for dietary reasons | 17.2 | 16.8 | 15.5 | 16.9 | 22.0 | 21.8 | 15.2 | 12.1 |

(1) Does not include consumption outside the home by other family members which are not known to the respondent.

## TABLE 34

## PERCENTAGE DISTRIBUTION OF FISH AND SEAFOOD CONSUMED BY PERSONS EATING FOR DIETARY REASONS

Grams per Person Weekly

PA Broad Brush Survey

| | Total % | Sydney % | Melbourne % | Brisbane % | Adelaide % | Perth % | Hobart % | Canberra % |
|---|---|---|---|---|---|---|---|---|
| None consumed in past week | 15.1 | 17.9 | 10.2 | 10.2 | 8.5 | 31.5 | 29.7 | 25.4 |
| 1 to 100 | 9.4 | 9.5 | 10.1 | 6.1 | 8.2 | 5.7 | 17.5 | 14.9 |
| 101 to 200 | 16.0 | 12.2 | 26.0 | 8.1 | 11.5 | 5.8 | 17.5 | 12.7 |
| 201 to 300 | 13.9 | 16.7 | 12.0 | 12.2 | 11.9 | 11.4 | - | 10.6 |
| 301 to 400 | 12.1 | 10.0 | 15.0 | 16.3 | 10.0 | 11.3 | 5.9 | 12.7 |
| 401 to 500 | 8.2 | 7.8 | 9.5 | 10.2 | 9.8 | - | - | 11.1 |
| 501 to 750 | 16.7 | 16.8 | 11.0 | 20.4 | 30.5 | 22.8 | 17.5 | 10.7 |
| 750 to 1000 | 6.5 | 7.3 | 3.9 | 12.2 | 5.1 | 11.5 | 5.9 | 2.1 |
| Over 1000 | 2.3 | 1.7 | 2.4 | 4.1 | 4.7 | - | 5.9 | - |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

## TABLE 35

## SPECIES OF FISH SERVED AT HOME IN EACH CITY
### Percentage of Consumption Occasions

### PA Broad Brush Survey

| | Total | Sydney | Melbourne | Perth | Brisbane | Adelaide | Canberra | Hobart |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | % | % | % |
| Tuna | 18.4 | 17.8 | 18.8 | 14.1 | 14.2 | 26.8 | 27.2 | 7.8 |
| Salmon | 16.9 | 20.9 | 15.0 | 13.5 | 17.6 | 11.2 | 17.3 | 14.7 |
| Fish Fingers | 9.4 | 7.4 | 9.8 | 11.1 | 9.4 | 12.7 | 14.1 | 13.2 |
| Sardines | 7.9 | 7.2 | 8.3 | 10.9 | 8.2 | 6.3 | 7.8 | 10.6 |
| Cod - Smoked | 1.3 | 0.9 | 2.5 | 0.3 | 1.0 | 0.4 | 1.6 | 2.0 |
| - Other | 5.0 | 6.2 | 5.3 | 3.8 | 4.7 | 1.7 | 2.8 | 5.1 |
| Whiting | 4.6 | 2.1 | 6.2 | 3.5 | 7.0 | 8.0 | 2.4 | 2.4 |
| Snapper | 3.5 | 3.7 | 3.6 | 5.0 | 1.1 | 4.1 | 2.6 | 0.3 |
| Bream | 3.6 | 6.7 | 1.3 | - | 5.6 | 0.3 | 4.6 | 1.3 |
| Flathead | 3.4 | 4.3 | 4.6 | - | 1.9 | 0.1 | 2.2 | 6.5 |
| Flounder | 3.0 | 3.1 | 4.0 | 1.7 | 1.5 | 2.1 | 2.6 | 4.4 |
| Mullet | 2.1 | 1.8 | 0.6 | 1.5 | 7.5 | 3.9 | 0.4 | - |
| Herrings | 2.3 | 1.2 | 2.2 | 7.1 | 3.0 | 2.3 | 2.0 | 2.7 |
| Other (mainly Fresh Fish) | 18.6 | 16.7 | 17.8 | 27.5 | 17.3 | 20.1 | 13.4 | 29.0 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

(e) Source of Supply

The supermarket was the most important source of supply of fish consumed in the home, almost all tinned fish, fish fingers and frozen packaged fish being obtained from this outlet (Table 36). Fresh fish was generally bought from a retail fish shop or fish market although the proportion eaten which respondents claimed to have caught was relatively high (27%).

(f) Cooking Method

On 40% of occasions fish, mainly tinned, was served "straight" i.e. without cooking, most often for sandwiches and salads (Table 37). There was little variety in the methods of cooking fish at home. On a third of occasions, the fish was fried. Fish was infrequently served grilled, baked, boiled, as mornay or other methods.

(g) Conclusions on Heavy Fish Eating Groups

Generally the proportion of heavy fish eaters in each city closely followed the ranking of cities by fish consumption shown in Table 26. Some 8.6% of the Sydney population was estimated to have eaten more than 500 grams weekly compared with less than 5% for Hobart and Canberra.

An examination of the proportion of persons eating more than 500 grams of fish and seafood weekly revealed that only two groups had a significantly high percentage in this category. These were:

1. where individuals were on a diet. As observed earlier about 2.7% of individuals covered by the survey were reported to be on a diet and their average consumption of fish per person was double that for the population as a whole (Table 33). Some 25% of these ate more than 500 grams weekly and 9% ate more than 750 grams (see Table 34).

2. where total household income exceeded $18,000. Some 11% of individuals in this group ate more than 500 grams weekly and 4.6% consumed in excess of 750 grams. Persons in this group ate considerably more seafood and more fresh and frozen and tinned fish than the average (Table 30).

There are a number of general conclusions which may be drawn from the survey of fish consumption in capital cities.

The first is that the great majority of Australians do not eat fish in large quantities although they do eat it regularly.

## TABLE 36

## SOURCE OF SUPPLY OF EACH FORM OF FISH FOR HOME CONSUMPTION

All Cities

Percentage of Occasions each Form Bought

PA Broad Brush Survey

| Source | Fresh Fish | Fish Fingers | Frozen Packaged Fish | Tinned Fish | Smoked Fish | Other Fish | Total |
|---|---|---|---|---|---|---|---|
| '000 of Occasions | 2208 | 1357 | 691 | 2349 | 1025 | 131 | 7761 |
| | % | % | % | % | % | % | % |
| Fish Market | 18.1 | 0.1 | 1.6 | - | 4.4 | 2.3 | 6.0 |
| Retail Fish Shop | 38.6 | 0.7 | 4.6 | 0.2 | 16.1 | 4.6 | 13.8 |
| Supermarket | 7.3 | 92.9 | 78.3 | 95.0 | 37.0 | 41.2 | 59.7 |
| Delicatessen | 1.7 | 1.0 | 2.2 | 1.2 | 19.6 | 29.8 | 4.3 |
| Caught/Gift | 27.1 | 0.1 | 2.6 | 0.2 | 1.4 | 1.5 | 8.2 |
| Other | 7.1 | 5.2 | 10.7 | 3.2 | 21.6 | 20.0 | 8.0 |

The questionnaire was administered to:

a. 393 customers of inner city fish shops;
b. 50 persons buying or selling fish at metropolitan wholesale markets (Melbourne only);
c. 648 teenage students at secondary schools;
d. 57 members of a weight watchers group (Melbourne only);
e. 41 commercial fishermen and
f. 60 leisure fishermen.

Results of this survey (the 'screening' survey) were combined with those of the first and second quarter of the broad brush survey and 187 individuals were selected for further interview. The basis for selection was consumption of five or more meals of fish or seafood in the week preceding the interview and at least four meals a week frequently. In addition, a further 72 individuals with somewhat lower consumption frequency were chosen on the basis of fish species eaten and form of fish. For example persons eating three or four meals of shark weekly were chosen in preference to individuals consuming tinned fish with similar frequency. Of the 259 individuals chosen for further interview 83 were from the first and second quarters of the broad brush survey and 176 from the screening survey.

Attempts were made to contact all 259 individuals in February 1977 and those visited were asked to record their consumption of meat, eggs and fish for a week and provide a sample of hair for analysis. The diary records were collected at a second visit and some further details obtained on typical fish consumption habits.

Completed diary records and a sample of hair was obtained from 156 individuals. The hair samples were analysed for total mercury content by the Industrial Hygiene Laboratory, Victorian Department of Health. Five of the samples sent to the laboratory had insufficient hair, leaving a total of 151 individuals for whom fish consumption and mercury data on mercury concentration in hair were available. Of these, 60 resided in Victoria, 29 in New South Wales, 21 in Queensland, 18 in Western Australia, 14 in South Australia, 7 in the ACT and 2 in Tasmania.

Fifteen individuals with the highest mercury readings in their hair were recontacted and samples of blood as well as hair were taken from twelve subjects and hair only from three. Information on dietary habits at that time was also collected.

(2) Commonwealth Department of Health Survey

The major objective of this study was to provide detailed dietary data on consumption by individuals eating significant quantities of fish and seafood and to relate that consumption to levels of total mercury and selenium, estimated in hair and blood samples of the participants.

The study was carried out in co-operation with Dietitians' Training Institutes at Geelong, Adelaide and Brisbane, Sydney Teacher's College and the Community Health Service in Western Australia. Data were collected between October 1976 and October 1977 by students at the training institutions and by community health nurses in Western Australia.

Initially a screening survey was conducted to identify individuals consuming significant quantities of fish, who were willing to participate in the dietary survey and provide hair, and possibly blood samples. Forms were distributed to about -000 individuals in selected community groups which included:-

a. students in primary and secondary schools;
b. staff and students at tertiary institutes of education;
c. patients attending health centres and hospitals;
d. staff of health centres and hospitals
e. customers of fish retail and wholesale establishments;
f. leisure fishermen
g. aborigines believed to be eating large quantities of fish at One-Arm Point, near Derby, Western Australia.

Following the screening survey in each State, persons were selected for more detailed dietary investigation on the basis of frequency of fish consumption, type of fish consumed and where bought. It was proposed that two-thirds of participants in this investigation be high fish eaters (four or more servings a week) and the balance be eating moderate quantities (two to three servings per week).

The selected participants were asked to fill in a diary record for a week, give details of food consumption and provide personal information such as height, weight, age, etc. The diary record, which was designed by the Department of Health, was the same as that used in the PA Consulting Services survey. In addition to visits at the beginning and end of the recording period efforts were made to visit participants during the diary week.

Completed diaries and hair samples were collected from 148 respondents, 37 of whom also provided blood samples. Of the 148 respondents, 41 came from Western Australia, 33 from Victoria, 31 from New South Wales, 22 from Queensland, 19 from South Australia and 2 from the ACT. In addition, 12 persons from the Australian Capital Territory who rarely eat fish were used as a control group and hair and some blood samples were collected from them.

All the blood samples and most of the hair samples were examined at the CSIRO Division of Human Nutrition, Adelaide. The remainder of the hair samples was analyzed at the Australian Mineral Development Laboratory, Adelaide. The laboratories used similar analytical techniques.

Five individuals were later recontacted and further hair samples were taken and analysed. Information on any changes in dietary habits was also collected.

### (c) Survey Results

#### (1) Introduction

When interpreting the results of both surveys it is important to bear in mind that the data were collected from individuals who varied widely in their dietary pattern and who could be expected to have a heterogeneous metabolic response to elements in their diet. To that extent each individual was a unique case study and it is not possible to draw general conclusions applicable to the population of heavy fish eaters. Any conclusions which are drawn should be regarded as statements of general tendency from which it is not possible to make inferences as to the probability of their occurrence in the population as a whole or in particular groups in the population.

#### (2) Differences Between PA and Health Surveys

In most of the discussion which follows the results of the two surveys have been combined. The basic objectives of the surveys were similar as were the questionnaire used and the relative proportions of heavy to moderate fish eaters for which data were collected.

But there were also some differences which could potentially influence the results of one compared with the other.

First, PA Consulting Services used interviewers trained primarily in the conduct of market research studies. The Health Department study mainly employed dietetic students with little interview experience. The students were in many instances able to devote more time to visiting respondents in order to ensure that diaries were being filled out correctly.

It is not possible to measure whether this biased the results in a systematic manner nor if so, the direction of this bias. If any bias did occur as a result of the different interviewing techniques used in the two surveys it was probably small and less than that which occurs in all such surveys as a result of differences in interpretation and conduct between individual interviewers.

Second, fieldwork for both surveys was undertaken at different times. The PA survey was carried out in February 1977 whereas the Health survey was conducted between October 1976 and October 1977. It is unlikely that this introduced any bias; a comparison of seasonal results in the broad brush survey revealed little variation in fish consumption.

Third, the two surveys selected respondents from different groups in the population. This undoubtedly affected any comparison between average results for both surveys lthough where individuals were drawn from similar groups in the population results were comparable. For example, the average frequency of weekly fish consumption for persons on a diet was 4.8 in both the PA survey and in the Health survey. Results for leisure fishermen and students were also similar.

Despite these differences in selection it was notable that the proportion of male and female respondents was very similar in both surveys at about 38% male (see Table 38). However, the occupational breakdown varied between surveys as a direct result of the selection procedure. The Health survey contained more aborigines and persons in income earning occupations and the PA survey had more individuals connected with the fishing industry and housewives. The differences in occupation were also reflected in the country of origin of respondents. For example, a high proportion of persons connected with the fishing industry in the PA survey were of Mediterranean origin and this accounted for a large proportion the 14% of respondents in that classification.

The PA survey had a higher percentage of persons on a diet - 31% as against 24% in the Health survey. There was a close relationship between sex of respondent and dieting (Table 39). About 38% of women interviewed were on a diet compared with 10% of men.

The fourth area of difference between the two surveys concerned the laboratories used to analyse total mercury in hair. This will be discussed in Section 3.4.

## TABLE 38

### SELECTED CHARACTERISTICS OF PERSONS INTERVIEWED BY P.A. CONSULTING SERVICES AND DEPARTMENT OF HEALTH SURVEYS

| Number of Respondents | P.A. Survey 151 % | Health 160 % | Total 311 % |
|---|---|---|---|
| **Sex** | | | |
| Male | 39.1 | 36.3 | 37.6 |
| Female | 60.9 | 63.8 | 62.4 |
| Total | 100.0 | 100.0 | 100.0 |
| **Occupation** | | | |
| Domestic duties | 21.5 | 19.6 | 23.0 |
| Student | 23.8 | 21.5 | 22.7 |
| Fishing industry | 11.9 | 0.0 | 5.8 |
| Aboriginal reserve | 0.0 | 9.5 | 4.9 |
| Other | 37.7 | 49.4 | 43.7 |
| Total | 100.0 | 100.0 | 100.0 |
| **Country of Origin** | | | |
| Aust./N.Z. | 69.5 | 81.9 | 75.9 |
| Mediterranean | 13.9 | 0.6 | 7.1 |
| Other | 14.6 | 16.9 | 15.8 |
| Not known | 2.0 | 0.6 | 1.3 |
| Total | 100.0 | 100.0 | 100.0 |
| **Dieting** | | | |
| On a diet | 31.1 | 24.3 | 27.8 |
| Not on a diet | 68.9 | 75.7 | 72.2 |
| Total | 100.0 | 100.0 | 100.0 |
| **Leisure Fishing** | | | |
| Leisure fishermen | 11.9 | 11.9 | 11.9 |
| Other respondents | 88.1 | 88.1 | 88.1 |
| Total | 100.0 | 100.0 | 100.0 |

TABLE 39

PERCENTAGE DISTRIBUTION OF RESPONDENTS BY SEX AND ACCORDING TO WHETHER DIETING OR NOT

| Dieting | Sex: Male | Female | Total(1) |
| --- | --- | --- | --- |
| | % | % | % |
| On a diet | 10.0 | 38.1 | 27.8 |
| Not on a diet | 90.0 | 61.9 | 72.2 |
| Total | 100.0 | 100.0 | 100.0 |
| No. of respondents | 110 | 216 | 299 |

(1) This information was not collected for the 12 control respondents

PA and Health Surveys

Despite these differences between the two surveys, the results of both have been pooled for analytical purposes. The combined data represent a broader spread of observation than might have been obtained from an examination of the results of one survey only, and it is considered that for most variables this offsets any disadvantages resulting from different interviewing techniques or analytical procedures.

(3) Consumption of Fish

The 299 survey respondents consumed an average of 601 grams of fish and seafood weekly. About half of all persons interviewed in both surveys ate less than 500 grams weekly and 13% consumed more than 1000 grams (see Table 40).

Respondents in the PA survey had a lower average consumption than those in the Health survey - 540 grams weekly compared with 662 grams.

Some 55% of PA respondents consumed less than 500 grams compared with 44% in the Health survey. The Health survey also had a higher proportion of very heavy fish eaters.

Generally there was a very close relationship between the quantity of fish and seafood consumed and frequency of consumption. This is illustrated in Table 41 which relates respondents' usual consumption frequency to their consumption in the survey week. Just over 80% of persons usually eating one or two fish meals a week consumed less than 500 grams during the survey period. At the other end of the scale 47% of persons eating seven to eight fish meals in a typical week ate more than 1000 grams in the survey week.

(4) Species Consumed

Heavy fish consumers reported eating a wide range of fish and seafood. In all the 299 respondents claimed to have eaten over 50 species of fish in the diary week and this did not include other species which may have been included under such general descriptions as take-away fish, smoked fish, fish cutlets, fish cakes and so on. Some illustration of this diversity of species is provided in Tables 42 and 43. About 30% of average fish consumption was classed under 'other' and this comprised species or categories of fish whose average consumption per person during the week did not exceed 10 grams and in most instances were under 5 grams. As with the general population canned tuna was the principal species eaten - an average of 51 grams per person (8% of average consumption). Whiting, snapper, flounder and bream were the main species of fresh fish eaten and each averaged between 30 and 35 grams per person.

TABLE 40

PERCENTAGE DISTRIBUTION OF DIARY RESPONDENTS:
BY TOTAL FISH CONSUMPTION IN SURVEY WEEK

PA Consulting Services and Department of Health Surveys

| Quantity (grams per week) | PA Survey % | Health Department Survey % | Total % |
|---|---|---|---|
| Less than 249 | 29.1 | 20.8 | 25.1 |
| 250 to 499 | 25.8 | 18.8 | 22.4 |
| 500 to 749 | 22.5 | 30.9 | 26.8 |
| 750 to 999 | 10.6 | 14.1 | 12.4 |
| 1000 to 1999 | 9.3 | 10.1 | 9.7 |
| 2000 to 2999 | 2.0 | 4.7 | 3.3 |
| 3000 to 3999 | 0.7 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 |
| | grams | grams | grams |
| Average Consumption per person | 540 | 662 | 601 |
| | no. | no. | no. |
| Number of respondents | 151 | 148 | 299 |

PA and Health Surveys

## TABLE 41

## PERCENTAGE DISTRIBUTION OF RESPONDENTS BY TOTAL WEEKLY FISH CONSUMPTION AND BY USUAL CONSUMPTION FREQUENCY

| Weekly Consumption (grams) | Usual Frequency of Consumption per week | | | | | | |
|---|---|---|---|---|---|---|---|
| | less than 1 % | 1 to 2 % | 3 to 4 % | 5 to 6 % | 7 to 8 % | 9 to 12 % | Total % |
| 249 and under | 100.0 | 54.0 | 16.7 | 6.3 | 0.0 | 0.0 | 25.1 |
| 250 to 499 | 0.0 | 27.6 | 25.4 | 14.3 | 6.7 | 20.0 | 22.4 |
| 500 to 749 | 0.0 | 16.1 | 33.3 | 31.7 | 20.0 | 20.0 | 26.8 |
| 750 to 999 | 0.0 | 0.0 | 15.1 | 20.6 | 26.7 | 20.0 | 12.4 |
| 1000 to 1999 | 0.0 | 2.3 | 8.7 | 22.2 | 13.3 | 0.0 | 9.7 |
| 2000 to 2999 | 0.0 | 0.0 | 0.8 | 4.8 | 26.7 | 40.0 | 3.3 |
| 3000 to 3999 | 0.0 | 0.0 | 0.0 | 0.0 | 6.7 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| No. of respondents | 3 | 87 | 126 | 63 | 15 | 5 | 299 |

Cramer's V = 0.36 Significant at 5% level

PA and Health Surveys

## TABLE 42

## AVERAGE CONSUMPTION OF SELECTED SPECIES IN SURVEY WEEK

294 respondents (excluding Aborigines)

grams per person

| | |
|---|---|
| Bream | 27 |
| Flake | 17 |
| Flathead | 11 |
| Flounder | 37 |
| Garfish | 6 |
| Snapper | 32 |
| Whiting | 35 |
| Canned Tuna | 54 |
| Canned Salmon | 52 |
| Canned Sardines | 14 |
| Canned Other | 6 |
| Mackerel | 18 |
| Mullet | 13 |
| Gemfish | 8 |
| Barramundi | 11 |
| Herring | 8 |
| Cod | 13 |
| Haddock | 11 |
| Prawns | 29 |
| Lobster | 9 |
| Shellfish-Other | 21 |
| Other | 116 |
| TOTAL | 548 |

PA and Health Surveys

# TABLE 43

## AVERAGE CONSUMPTION OF SELECTED SPECIES BY ALL RESPONDENTS AND OCCUPATIONAL GROUPS

| | All Respondents | OCCUPATION | | | | |
|---|---|---|---|---|---|---|
| | | Domestic duties | Student | Fishing Industry | Aborigine | Other |
| | Grams per person in survey week | | | | | |
| Bream | 32 | 31 | 8 | 30 | 118 | 36 |
| Flake | 16 | 5 | 18 | 48 | - | 18 |
| Flathead | 10 | 13 | 1 | 66 | - | 7 |
| Flounder | 35 | 28 | 9 | 81 | - | 52 |
| Garfish | 6 | 4 | 3 | 66 | - | 2 |
| Snapper | 35 | 9 | 30 | 98 | 99 | 37 |
| Whiting | 33 | 30 | 24 | 63 | - | 41 |
| Canned Tuna | 51 | 85 | 35 | 52 | - | 48 |
| Canned Salmon | 49 | 69 | 40 | 24 | - | 53 |
| Canned Sardines | 13 | 16 | 10 | 3 | - | 16 |
| Canned Other | 6 | 1 | - | 7 | - | 13 |
| Mackerel | 17 | 28 | 15 | - | - | 17 |
| Mullet | 15 | 20 | 12 | 11 | 53 | 10 |
| Gemfish | 8 | 31 | 2 | - | - | - |
| Barramundi | 10 | 17 | 7 | - | - | - |
| Herring | 8 | 9 | 16 | 3 | - | 5 |
| Cod | 12 | 15 | 3 | 20 | - | 16 |
| Haddock | 10 | 8 | - | - | - | 20 |
| Prawns | 28 | 27 | 19 | 67 | - | 32 |
| Lobster | 9 | 9 | - | 23 | - | 13 |
| Shellfish Other | 21 | 9 | 2 | 114 | 18 | 26 |
| Other | 175 | 96 | 80 | 258 | 1392 | 117 |
| Total | 599 | 560 | 334 | 1034 | 1680 | 586 |
| No. of respondents | 299 | 71 | 70 | 18 | 15 | 123 |

PA and Health Surveys

(5) Consumption by Occupation

There were considerable differences in the amount of fish consumed between respondents according to occupation (Table 44) but, with a few exceptions, occupation appeared to have little influence on the species of fish eaten (Tables 42 and 43).

Over 85% of aborigines in the survey consumed more than 1000 grams and ate an average of almost 1700 grams per person. They ate a wide range of species including bluebone, bream, mullet, mackerel and snapper.

Persons connected with the fishing industry also ate above average quantities of fish. Their average consumption was some 1000 grams weekly and close to 40% ate more than 1000 grams. In total they tended to eat less canned fish then average and more of certain species such as flathead and garfish.

As a group, students (12-16 years old) had the lowest average consumption of some 330 grams and more than half of them ate less than 250 grams in the survey week.

(6) Consumption by Persons Dieting

Persons on a diet had an average consumption of 607 grams in the survey week compared with 596 grams for those not on a diet (Table 45). The difference between this table and Table 33 is that in the latter, persons on a diet were being compared with the average not the extreme consumer. Generally persons on a diet ate a significant quantity of fish during the survey week and only 10% ate less than 250 grams. However, dieters rarely ate very large quantities of fish - 6% ate more than 1000 grams compared with 16% for persons not on a diet. Dieters also ate a much higher percentage of canned fish compared with other heavy fish eaters (Table 46).

(7) Consumption by Country of Origin

Migrant groups surveyed had a higher average consumption than persons born in Australia or New Zealand, excepting the aboriginal group (Table 47). To a large extent this reflects the differences already observed in occupational groupings. For example, almost 90% of students visited were born in Australia and their low consumption had an important influence on the results shown for Australian born respondents. Also, about half the Mediterranean born respondents were connected with the fishing industry and it will be recalled that individuals in this latter grouping had a relatively high average consumption.

TABLE 44

PERCENTAGE DISTRIBUTION OF RESPONDENTS:
BY TOTAL WEEKLY FISH CONSUMPTION AND BY OCCUPATION

| Weekly Consumption (grams) | Domestic | Student | Fishing Industry | Aboriginal Reserve | Other | Total |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| 249 and under | 21.1 | 52.9 | 11.1 | 6.7 | 16.3 | 25.3 |
| 250 to 499 | 25.4 | 21.4 | 11.1 | 0.0 | 26.0 | 22.6 |
| 500 to 749 | 28.2 | 15.7 | 27.8 | 6.7 | 33.3 | 26.3 |
| 750 to 999 | 16.9 | 5.7 | 11.1 | 0.0 | 15.4 | 12.5 |
| 1000 to 1999 | 8.5 | 4.3 | 22.2 | 46.7 | 7.3 | 9.8 |
| 2000 to 2999 | 0.0 | 0.0 | 16.7 | 40.0 | 0.8 | 3.4 |
| 3000 to 3999 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | grams | grams | grams | grams | grams | grams |
| Average per person | 560 | 334 | 1034 | 1680 | 586 | 601 |
| | no. | no. | no. | no. | no. | no. |
| No. of respondents | 71 | 70 | 18 | 15 | 123 | 297 |

PA and Health Surveys

## TABLE 45

## AVERAGE CONSUMPTION OF SELECTED SPECIES BY WHETHER DIETING OR NOT

| Species | Respondents Dieting grams per person | Respondents not Dieting grams per person |
|---|---|---|
| Bream | 18 | 37 |
| Flake | 9 | 18 |
| Flathead | 4 | 13 |
| Flounder | 72 | 21 |
| Garfish | 4 | 7 |
| Snapper | 12 | 44 |
| Whiting | 46 | 29 |
| Canned Tuna | 92 | 35 |
| Canned Other | 105 | 53 |
| Shellfish | 50 | 62 |
| Other | 195 | 275 |
| Total | 607 | 596 |
| No. of respondents | 83 | 216 |

PA and Health Surveys

## TABLE 46

### PERCENTAGE DISTRIBUTION OF RESPONDENTS: BY TOTAL WEEKLY FISH CONSUMPTION AND ACCORDING TO WHETHER DIETING OR NOT

| Weekly Consumption (grams) | On a Diet | Not on a Diet | Total |
|---|---|---|---|
| | % | % | % |
| 249 and under | 9.6 | 31.0 | 25.1 |
| 250 to 499 | 27.7 | 20.4 | 22.4 |
| 500 to 749 | 38.6 | 22.2 | 26.8 |
| 750 to 999 | 18.1 | 10.2 | 12.4 |
| 1000 to 1999 | 4.8 | 11.1 | 9.7 |
| 2000 to 2999 | 0.0 | 4.6 | 3.3 |
| 3000 to 3999 | 1.2 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 |
| | grams | grams | grams |
| Average per person | 607 | 596 | 601 |
| | no | no | no |
| No. of respondents | 83 | 216 | 299 |

PA and Health Surveys

## TABLE 47

### PERCENTAGE DISTRIBUTION OF RESPONDENTS: BY TOTAL WEEKLY FISH CONSUMPTION AND BY COUNTRY OF ORIGIN

| Weekly Consumption (grams) | Aust./N.Z. Aboriginal % | Aust./N.Z. Other % | Mediterranean % | Other % | Not Known % | Total |
|---|---|---|---|---|---|---|
| 249 and under | 6.7 | 30.8 | 22.7 | 26.5 | 0.0 | 25.1 |
| 250 to 499 | 0.0 | 24.0 | 22.7 | 18.4 | 0.0 | 22.4 |
| 500 to 749 | 6.7 | 27.1 | 22.7 | 22.4 | 75.0 | 26.8 |
| 750 to 999 | 0.0 | 11.8 | 13.6 | 16.3 | 0.0 | 12.4 |
| 1000 to 1999 | 46.7 | 5.4 | 13.6 | 12.2 | 25.0 | 9.7 |
| 2000 to 2999 | 40.0 | 0.5 | 4.5 | 4.1 | 0.0 | 3.3 |
| 3000 to 3999 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | grams | grams | grams | grams | grams | grams |
| Average per person | 1680 | 500 | 726 | 638 | 735 | 601 |
| | no. | no. | no. | no. | no. | no. |
| No. of respondents | 15 | 211 | 22 | 47 | 4 | 299 |

PA and Health Surveys

(8) Consumption by Leisure Fishermen

Generally the consumption of fish by leisure fishermen surveyed was not as high as other groups; their average consumption in the survey week was 513 grams compared with 610 grams for all other persons surveyed (see Table 48).

3.2(iv) Frequency of fish consumption by extreme consumers

The broad-brush survey, which was designed to collect information from random samples of consumers during four periods of the year, can be expected to provide reasonable indices of equilibrium fish consumption during the year. By contrast, the two surveys of heavy fish consumers by PA and by the Department of Health, provide detailed information for only the one week of the survey.

Quantitative information on the persistence of fish eating at the extreme level is, however, also available from additional questions asked in the PA survey on the frequency of fish consumption during the past week and during a typical week, and by the Health Department survey on frequency of consumption during a typical week. The replies showed differences between PA and Health surveys in addition to those outlined in section 3.2(iii)(c)(2).

The average frequency of fish consumption, in terms of numbers of meals, during the PA survey week was 3.6 times, compared with 6.9 and 6.3 times recalled from the previous week and a typical week respectively; in the survey by the Health Department fish consumption at 3.8 times during the survey week was very similar to that of the PA survey week, but typical consumption was recalled at 3.4 times weekly.

The fact that frequencies recalled from previous weeks by the PA survey were overstated is suggested by the distribution of frequencies which included maxima of 32 and 30 times weekly for previous and typical weeks respectively compared with 19 times during the survey week; responses which allege more than 4 meals daily are clearly suspect. Claims for typical consumption in the Health survey did not exceed 7 times weekly compared with 10 times during the survey week.

While re-emphasising the inaccuracies inherent in unsupervised recall data, the above indicates that little reliance can be placed on such records as indicators of sustained consumption, a knowledge of which is of vital importance to mercury toxicology.

A similar situation seems to have been experienced by Lindsay (in press) (see also Section 2.5) who found a discrepancy between the consumption data actually recorded in a duplicate diet study and those from interviews - consumers who had reported up to 400g/day during interview did not exceed 225g/day in the subsequent diet study.

## TABLE 48

## PERCENTAGE DISTRIBUTION OF LEISURE FISHERMEN: BY TOTAL WEEKLY FISH CONSUMPTION

| Weekly Consumption (grams) | Leisure Fishermen % | All Respondents % |
|---|---|---|
| 249 and under | 29.7 | 25.1 |
| 250 to 499 | 24.3 | 22.4 |
| 500 to 749 | 24.3 | 26.8 |
| 750 to 999 | 16.2 | 12.4 |
| 1000 to 1999 | 2.4 | 9.7 |
| 2000 to 2999 | 2.7 | 3.3 |
| 3000 to 3999 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 |
| | grams | grams |
| Average per person | 513 | 601 |
| | no. | no. |
| No. of respondents | 37 | 299 |

PA and Health Surveys

Notwithstanding these comments, individual records of fish consumption as determined during the survey week provided the most reliable data available to the Working Group and on which to base analyses of fish consumption patterns by populations in the cities that were sampled.

3.2(v) Comparison with other Australian studies

It is not possible to make valid comparisons between the results of the survey of capital city households conducted for the Working Group and other surveys reported in Section 2.6(v) which were primarily carried out to ascertain the fish eating habits of Australians; for example the surveys by the Morgan Research Centre and the James Cook University. Differences between the surveys can be discussed under two broad headings namely coverage and methodology.

Coverage: The location, timing and nature of the questionnaire of each of the studies differed from the others. For example the study by the Morgan Research Centre was nation-wide whereas the PA study for the Working Group was confined to capital cities and the survey in Townsville was of a highly localised nature. Again, the Morgan study was based on data collected in one month of 1976 whereas the PA survey was conducted over a year. The nature of survey questions clearly varied between studies since few directly comparable statistics are available.

Methodology: Many aspects of the planning and conduct of the studies referred to were dissimilar and this makes comparisons invalid. For example, the Morgan study was based on respondents' diaries of fish intake whereas the PA survey was conducted through interviews. The sample size and method of sampling also differs, for example the Penington survey and the two conducted wholly in WA were purposive in nature whereas the Morgan and PA broad-brush surveys were, as far as possible, random. Some of the studies were based on households and some on individuals.

Each study of fish consumption must therefore be considered separately and any comparisons be drawn only with full account of survey coverage and methodology.

## 3.3 Mercury Ingestion by Australian Consumers

### 3.3(i) Mercury ingestion from foods other than fish

Mercury ingested from fish was compared with that from meat and eggs for high, medium and low fish consumers who were respondents in the PA purposive survey. The results are shown in Table 49.

The figures refer to the average mercury intake in the survey week of ten consumers at each consumption level. Mercury ingestion is calculated from concentrations found in foods during the 1976 Market Basket survey. In the case of fish it is assumed that consumption comprised 90% fish and 10% seafood - a composition which approximates that found for respondents in the PA and Health purposive surveys (Tables 42 and 43, Section 3.2).

The information in the table is necessarily approximate since mercury concentration data were available only from certain kinds of meat. However, the table does illustrate the generally wide margin between the intake of mercury in fish and in meat and eggs.

These results are generally in accord with those of Lindsay (in press) for the United Kingdom, but appear to be in conflict with those of the 1976 Market Basket Survey (NH & MRC 1978) (Section 2.6(iv). Lindsay concluded that the contribution to the total intake of mercury from the non-fish component of the diet was very low, with ranges of mercury generally in the range 0.001 to 0.002 mg/kg. The 1976 Market Basket survey (Appendix XV - men 20-34 years) concluded that the non-fish component accounted for around 75% of total mercury ingested. The apparent anomaly can however be explained by the inclusion of Market Basket survey results in Table 49. This demonstrates the presence of another component of mercury intake from foodstuffs over and above fish, meat and eggs, accounting for nearly three times the amount from fish, meat and eggs. Moreover, it can be seen that where this component appears to be relatively important to the average consumer of fish, the same quantity of mercury (56 mcg/week), if consumed by high and medium fish eaters, would constitute a smaller proportion, in the case of high fish eaters around 14%. The proportion of this mercury which is methylmercury is not known.

## TABLE 49

### INTAKE OF MERCURY FROM FISH AND OTHER FOODS
(PA Purposive Survey)

| Consumption | High | Medium | Low | 1976 Market Basket Survey |
|---|---|---|---|---|
| Average fish consumption in survey week (g) | 1 910 | 535 | 0 | 125 |
| Average mercury intake from fish in survey week (mcg) | 349 | 96 | 0 | 14 |
| Average meat consumption in survey week (g) | 1 631 | 949 | 1 028 | 1 320 |
| Average number of eggs consumed in survey week | 5.3 | 2.5 | 2.7 | (275g) |
| Average mercury intake from meat and eggs in survey week (range)(mcg) | 6.6 (2.5-11.5) | 3.4 (1.7-6.8) | 3.5 (0.3-5.3) | 6 |
| Average total mercury intake in survey week from fish, meat & eggs (mcg) | 355.6 | 99.4 | 3.5 | 20 |
| Average weekly total mercury intake from all other foods (mcg) | NA | NA | NA | 56 |

NA - not available

### 3.3(ii) Mercury ingestion by the average fish consumer

The amount of mercury ingested by the average consumer was estimated using:

(1) the quantity of fish eaten by the average consumer,

(2) information provided from the broadbrush survey on the frequency with which fish and seafood species were eaten by the average consumer,

(3) the weight of average servings, and

(4) estimates of mercury concentration by species.

It was found that the average mercury ingestion equivalent to the average annual consumption of 193.7 g/week (Figure 4) was 1.45 mg from fish and 0.1 mg from shellfish, totalling 1.55 mg during the year, or 0.03 mg in a week.

If it was assumed, as by WHO (1976), that the average body weight per person was 70 kg, this would give the equivalent of 0.06 mcg/kg body weight/day. However, the PA broadbrush survey was based on family groups, including children, for which the more appropriate average body weight was estimated (Appendix 4A) to be 56 kg. (The equivalent average weight of participants in the PA purposive survey was 63 kg.) Using the 56 kg value, the average mercury ingestion would become 0.08 mcg/kg body weight/day.

In Table 51, and subsequently, the provisional tolerable intake has been expressed in two ways based on (a) Joint FAO/WHO Expert Committee (1972) which suggested a weekly maximum of 0.3 mg (0.61 mcg/kg body weight/day for a 70 kg person) of which no more than 0.2 mg (0.41 mcg/kg body weight/day) should be methylmercury, and (b) WHO (1976) which relates long term daily intake of methylmercury (3-7 mcg/kg body weight/ day for a 70 kg person) to the earliest effects in approximately 5% of the most sensitive group in the adult population. Applying the usual FAO/WHO safety factor of x10 this would be equivalent to a provisional tolerable intake of 0.3-0.7 mcg/kg body weight/day for a 70 kg person. Clearly the value of 0.08 mcg/kg body weight/day obtained for the average consumer is well below the figures suggested for provisional tolerable intake.

The weighted average mercury concentration in the fish and seafood species consumed was 0.15 mg/kg.

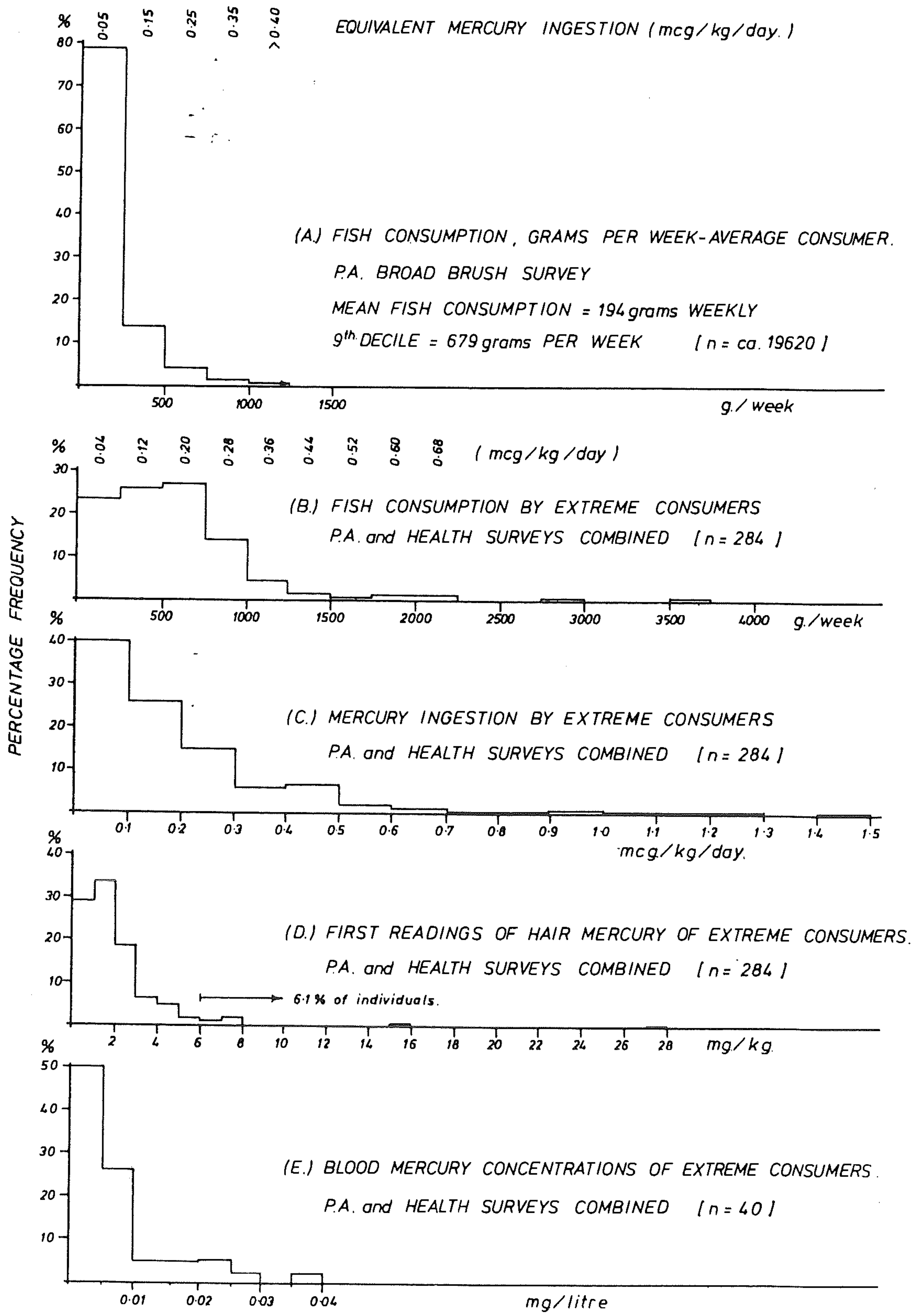


FIGURE 4

FREQUENCY DISTRIBUTION OF FISH CONSUMPTION BY CONSUMERS FROM THE P.A. BROAD BRUSH SURVEY

Histograms also show fish consumption, calculated mercury ingestion, hair and blood mercury concentrations from P.A. and Health Department survey extreme consumers combined.

### 3.3(iii) Definition of the extreme consumer

If a survey week is a typical week - which could be judged to some extent in the present surveys from the participant's statement of consumption during the previous week and in a typical week (but noting the reservations in Section 3.2) - it may be assumed that this level has been sustained over a long enough period, i.e. about 200 days, for the body burden of mercury to attain equilibrium. However, the tendency for extreme consumption levels to be closer to the average at subsequent interviews in these and overseas studies must also be taken into account and an attempt made to estimate the consumption levels consistently achieved by respondents.

Various yardsticks have been employed as reference points for extreme consumption, and these will be discussed in the following paragraphs (1)-(3), and in paragraphs (1)-(3) of sections (iv) and (v) which follow.

(1) The extreme consumers in the Working Group's survey have been identified as:-

A. The individual consuming the maximum total weight of fish, and

B. the individual having the maximum ingestion of mercury, computed from a knowledge of the quantities of fish and the average mercury concentration in each species consumed during the survey week.

Consumers A. and B. are not necessarily the same person.

(2) Margolin (unpublished report) used data from three major fish consumption studies involving 56,942 persons in the United States to support the WHO/FAO (1967) "rule of thumb" that the consumption of a foodstuff exceeded by the upper 10%, i.e. above the 9th decile, of a population will fall within 1½ to 3½ times the average intake. He used the higher figure of 3½ times to identify extreme (top 10%) consumption from estimates of average consumption in various countries and situations; those with consumption greater than 3½ times the average were judged to be extreme consumers. Comparative calculations can be made using the results of current Australian studies, from which however the proportion of individuals with fish consumption exceeding a certain quantity should also be predictable with more precision from a knowledge of the frequency distribution of a random sample of consumers (PA's broadbrush survey). (See Table 50(a).)

(3) Shepherd (1975) has proposed a quantitative method to be used as the basis for determining the dimensions of the "critical group" i.e. the population group to which the International Commission on Radiological Protection recommended that its dose limits should be applied. The method proposes a "reference level" of consumption which can be used together with the relevant dose limit to calculate derived working limits. The choice of a reference level instead of the most extreme consumer for this purpose acknowledges that it would be unreliable to use data from the highest consumer in the exposed group, since that individual may be widely atypical. The reference level was considered to more reliably reflect the time-weighted average consumption of the most extreme consumers. Shepherd's approach was adopted in a study of fish consumption and mercury ingestion in localised populations of fishermen and their families (Lindsay, in press; see also Section 2.5) and is being used as a basis for the evaluation and control of emission standards in the United Kingdom. A summary is given of Shepherd's method in Appendix 4B but the interested reader is recommended to read the full text carefully. Shepherd's method seems to have been devised for emission standards involving a small community from which it was practicable to sample most of the individuals. The Working Group therefore had some difficulty in assessing the relevance of this method to the Australian data, and in selecting the appropriate number of individuals on which to base Shepherd's calculations. For these reasons the Working Group has conducted analysis based on Shepherd's technique using a range of sample numbers to derive estimates of the reference level.

3.3(iv) Fish Consumption by extreme consumers

(a) Introduction

The frequency distribution of fish consumption of 19,620 consumers in the PA broadbrush survey is described in Figure 4(A). This demonstrates that 6.4% of consumers ate in excess of 500g during the survey week, and 0.9% more than 1000g. Further information on the distribution of persons eating fish has been obtained from the two purposive studies of extreme consumers (Figure 4(B)). However, because only 39 (27 excluding Aboriginals) of these ate more than 1000g, it is possible to obtain only limited information on the eating habits of the extreme consumers, particularly given the reservations about sustained consumption expressed in Section 3.2.

It can be said, however, that very few eat more than 1000g per week, and only 4 of the sample of 284 ate in excess of 2000g. All indications point to the fact that consumption at the latter level is rare and unlikely to be maintained consistently. Maximum fish consumption recorded from the PA data was 3580 grams during the survey week, compared with 2680 grams by an Aboriginal (2000 grams by a non-aboriginal) in the Health survey.

(b) 9th decile estimates

Prediction of maximal consumption by the WHO/FAO (1967) "rule of thumb" is not essential in the present study since a representative frequency distribution from which the 9th decile can be computed directly, was obtained through PA's randomly designed survey. However, it is useful both to compare the result obtained with that predicted by the FAO/WHO method and to compare both results with those for other situations as calculated by Margolin (i.e. from 3½ times the average). Figures used for average Australian consumption were obtained both from official statistics and from the PA broadbrush survey.

The observed 9th decile of 397g, which is about twice the average consumption, is well within the range of 1½-3½ times (i.e. 291-679 g/week) suggested by FAO/WHO.

(c) Reference level

For the Working Group's purpose the reference level devised by Shepherd has been based on a range of selected values, e.g. fifth highest, tenth highest, etc. of the 284 extreme consumers from the PA and Health surveys. These are tabulated (together with equivalent mercury intakes which will be referred to again under paragraph (c) below) in Table 50(b).

For comparison, Shepherd calculated the reference level for fish consumption by fishermen's families on the N.E. Irish Sea coast as 400 g/day (2800 g/week) which was about half that of the most extreme identified there, of 820 g/day, which at 5740g/week is greatly in excess of any person identified in Australia.

TABLE 50

## FISH CONSUMPTION AND MERCURY INGESTION

(a) Overseas and Australian Fish Consumption

| Population | Average per week (g) | Maximal per week (9th decile) = 3½ x average |
|---|---|---|
| United States | 116 | 406 |
| Canada | 119 | 417 |
| Great Britain | 140 | 490 |
| Finland | 210 | 735 |
| Sweden | 392 | 1 372 |
| Japan | 588 | 2 058 |
| Australia (official statistics) | 135 | 472 |
| Australia (consumer survey) | 194 | 679 |
| " " " | 194 | 397 (observed 9th decile) |

(b) Reference levels of Fish Consumption and Mercury Ingestion

| (i) Ranking of consumer by fish consumption or mercury ingestion | (ii) Reference level of fish consumption based on (i) (i.e. x 1.4) (g/week) | Reference level of mercury ingestion, mcg/kg body wt/day (1) based on reference level * | (2) direct from observed level |
|---|---|---|---|
| 5 highest consumers | 2800 | 0.97 | 1.33 |
| 10 " " | 2100 | 0.72 | 0.91 |
| 20 " " | 1574 | 0.54 | 0.69 |
| 30 " " | 1372 | 0.47 | 0.61 |

* 63 kg body weight (Appendix 4A)

3.3(v) Mercury ingestion by extreme consumers

Mercury ingestion by extreme consumers was calculated using the same principle employed in the calculation of ingestion by average consumers.

(a) Individual records of quantities of named fish consumed during one week by 151 persons interviewed in the PA survey and 133 persons in the Health survey were used in conjunction with mercury concentrations allocated by species and by State, using size-weighted averages where available. These data are far too numerous to present here. Body weights of persons interviewed had been recorded and were used to give individual estimates of total mercury (in mcg) consumed/kg body weight/day during the survey week.

The data on mercury concentrations in the species of fish (and turtles) eaten by Aboriginals were inadequate to provide reliable estimates of mercury ingestion and for this reason was generally not included for correlation purposes (except for hair/blood relationships - Section 3.4 - which do not require a knowledge of mercury ingestion). In any case it appears that the Aboriginal group studied (at One Arm Point, WA) was unusual in having high fish consumption with apparently low mercury concentrations in hair and blood, which, from the few data available, seems to have resulted from low mercury concentrations in their fish diet (English 1978).

Mercury ingestion did not necessarily correlate directly with fish consumption because of differences in mercury concentration in species consumed. Highest ingestion of total mercury from the PA data of 1.205 mcg/kg body weight/day corresponded to 2840 grams of fish consumed, with 1.486 mcg/kg/day from 1440 grams in the Health survey week. Highest consumption of fish of 3580g, during the PA survey week, was equivalent to a mercury ingestion of only 0.47 mcg/kg/day.

That consumption at these levels is a rare event was demonstrated by the frequency distribution in Figure 4 (A), in which the mercury intake from fish consumption of 1000g weekly corresponds closely to the FAO/WHO provisional tolerable intake. Consumption in excess of this was identified in only 0.9% of consumers.

Figure 4 (B) similarly shows that levels of fish consumption greater than 1000 grams weekly are the extreme cases of frequency of distributions even where there has been a deliberate search to find heavy fish consumers.

(b) The equivalent total mercury intake, based on average consumption of species and their mercury concentrations (which together gave an average concentration of 0.15 mg/kg in fish consumed (para (ii) above) for the two 9th decile estimates, would be 0.26 mcg/kg/day (3½ x average) and 0.16 (observed).

(c) Shepherd's reference level for mercury ingestion can be calculated in two ways; firstly by combining the reference level for fish consumption estimated in para (iv) (c) with the average concentration of mercury in fish consumed, i.e. 0.15 mg/kg; and secondly, directly from the appropriate values of the distribution of mercury ingestion in Figure 4 (C). The derived values were given in Table 50(b) in (iv) (c) above, under (1) and (2) respectively. The values obtained (2) directly were slightly higher than those from (1).

3.3(vi) Conclusions

The quantity of total mercury ingested with foods other than fish appears from the evidence both of Market Basket Surveys and consumer surveys to be small, and to contribute a small proportion of total mercury consumed by heavy fish eaters (See Section 2.6(iv)). The average Australian capital city consumer has been shown to eat less than 200 grams of fish and seafood weekly, giving an average mercury intake of 0.08 mcg total mercury/kg body weight/day for an average 56 kg person which is well below the FAO/WHO provisional tolerable intake.

However, it is recognised that this average encompasses individuals with fish consumption and mercury ingestion which are significantly higher than the average, and a special search was made for such extreme consumers.

In terms of the long term exposure of an extreme consumer of fish the sustained intake of mercury will depend on the average amount of fish eaten over a period together with the types of fish consumed and their mercury content. The maximum consumption identified was 3580 grams eaten during 19 occasions in the survey week. The subject was on a medical diet and claimed typical consumption of 12 times per week (13 during the previous week). However, the calculated mercury intake of this person, who ate eight different types of fish and seafood during the survey week, at 0.47 mcg/kg body weight/day was considerably less than the maximum estimate of mercury ingested. This was 1.49 mcg/kg/day by a person who ate seven meals totalling 1440g.

It is significant that the greatest consumers of fish from the PA survey included, in order of consumption, (1) a person on a medical diet, (2) a Greek fish shop proprietor, (3) a fish wholesaler, (4) a Laotian restaurant employee, (5) a Greek fish and chip shop owner, (6) a Chinese cook, (7) a Greek salesman, (8) an Australian housewife, (9) a Greek housewife, (10) a German female clerk, (11) a fish salesman, (12) a Greek (unemployed) and (13) a German lady on a slimming diet.

The predominance of ethnic groups, individuals on a diet and persons associated with the fishing industry can be clearly seen. The long term habits of such consumers will be of vital importance when examining the need for a mercury standard. In the present study the only indicators of sustained consumption of fish are the records of previous and typical frequency which, for the PA survey at least (Section 3.2), contain anomalies; other indicators of sustained mercury ingestion are sought in the mercury content of hair and blood of the consumer (see Section 3.4).

The PA survey which, since it surveyed different individuals over four quarters of the year, is more representative of sustained consumption by the population as a whole, indicated that only 0.9% of consumers in Australian capital cities ate more than 1000g of fish weekly which is equivalent to 0.39 mcg/kg/day for an average 56 kg person. The surveys of extreme consumers showed that this 0.9% is likely to include the maxima identified above, but that also on re-interview there is a likelihood of the individual eating less.

The methods of FAO/WHO and Shepherd provide lower, and quite different, indicators of extreme fish consumption and mercury ingestion for use as reference levels when considering the need for a standard. Estimates of the fish consumption and mercury ingestion for the various definitions of extreme consumer are given in Table 51.

From this can be seen the wide range of choice of estimates of extreme mercury (as total mercury) ingestion, i.e. from FAO/WHO 9th decile estimates of 0.11-0.26, through estimates by Shepherd's (United Kingdom) method, to the most extreme individual identified as consuming 1.49 mcg/kg body weight/day during one survey week.

Clearly conclusions on whether the Australian fish consumer is at risk from mercury ingestion will depend heavily on the yardstick chosen to describe the extreme consumer. While recalling why the mercury ingestion by the extreme consumer is most likely to overestimate sustained ingestion by the extreme group, the value obtained of 1.49 mcg total mercury/kg body weight/day will be (assuming 90% methylmercury) equivalent to 1.34 mcg methylmercury. To this must be added the small amount of methylmercury derived from foods other than fish. This figure, while more than the FAO/WHO provisional tolerable intake, is still well below the WHO (1976) threshold (minimum symptom) level of 3-7 mcg. 9th decile estimates are however, all less than 0.3 mcg, while the relationship of Shepherd estimates to provisional tolerable intake levels depends on the number of extreme consumers used in the analysis.

TABLE 51

ESTIMATES OF TOTAL MERCURY INGESTION BASED ON VARIOUS DEFINITIONS OF CONSUMER AS REFERRED TO IN THE TEXT.

| Consumer | Fish Consumption g/week | Weight of Consumer | Calculated intake of mercury mcg/week. | Calculated intake of mercury mcg/kg body wt/day |
|---|---|---|---|---|
| PA purposive survey, person with highest fish consumption | 3580* | 73.1 | 239 | 0.47 |
| PA purposive survey, person with highest mercury ingestion | 2840* | 74.7 | 630 | 1.21 |
| Health survey, person with highest fish consumption | 2000* | 95.4 | 478 | 0.72 |
| Health survey, person with highest mercury ingestion | 1440* | 54.5 | 603 | 1.49 |
| Broadbrush survey, average consumer | 194 | 56 | 30 | 0.08 |
| Broadbrush survey, level exceeded by 0.9% of consumers | G.T.1000 | 56 | G.T.157 | G.T.0.39 |
| Broadbrush survey, level (9th decile) exceeded by 10% of consumers | G.T.397 | 56 | G.T.59 | G.T.0.16 |
| FAO/WHO 9th decile yardstick - 1½ times the average consumption | 291 | 56 | 39 | 0.11 |
| FAO/WHO 9th decile yardstick 3½ times the average consumption | 679 | 56 | 103 | 0.26 |
| Shepherd's reference level based on | | | | |
| 10 extreme consumers | 2100* | * | 446 | 0.91 |
| 30 extreme consumers | 1372* | * | 299 | 0.61 |
| FAO/WHO provisional 'tolerable' intake (WHO 1976) | | | | |
| (a) FAO/WHO 1972 | - | 70.0 | 300 (or 200 MeHg) | 0.61 (0.41 MeHg) |
| (b) WHO 1976 | - | 70.0 | (147-343 MeHg) | (0.3-0.7 MeHg) |

*Figures for these consumers are based on actual fish species eaten by the individual and his actual body weight. The remainder are average consumption (Table 43 Section 3.2) and body weight assumed to be 70 kg or otherwise based on Appendix 4A.

## 3.4 Mercury in Australian Human Tissues

### 3.4(i) Introduction

The Working Group has some reservations about the value and precision of hair and blood mercury analyses as indicators of mercury intake and body burden, the reasons for which have been expressed in Sections 2.7 and 3.1(ii). These should be borne in mind when considering the results summarised in the following paragraphs.

Data on mercury in tissues were collected in the two consumption surveys of heavy fish eaters referred to in Section 3.2. An analysis of the results is presented below together with a discussion on some of the relationships observed for the individuals sampled with respect to mercury in hair and blood, survey readings and selected characteristics of the sample, and mercury and selenium levels.

### 3.4(ii) Total Mercury in Hair and Blood

About 6% of respondents (18 individuals) were estimated to have total mercury in hair of six milligrams per kilogram (mg/kg) or more at the time the hair samples were taken (Table 52). Six mg/kg is the equivalent of the provisional tolerable weekly intake (benchmark) established by a joint Food and Agriculture Organisation/World Health Organisation Committee. Of the 18 individuals exceeding six mg/kg:

(1) one had a reading of 27 mg/kg
(2) two had readings of 15 mg/kg
(3) two had between 10 and 14 mg/kg
(4) 13 had between 6 and 9.9 mg/kg

Most of the respondents with the higher mercury readings were found in the PA survey. In fact, the average mercury in hair in PA survey respondents was estimated at almost twice that of the Health survey - 2.8 as against 1.6 mg/kg (see Table 52), and PA survey respondents had consistently higher mercury readings even when account is taken of other factors such as differences in sample selection and species of fish eaten which might be expected to influence mercury levels. It will also be recalled that persons interviewed in the PA survey had lower average fish consumption. In order to assess the comparability of the techniques used by the two laboratories to analyse mercury in hair, duplicate hair samples were prepared and analysed. A paired 't' test at the 5% level applied to the logarithms of the two resulting sets of data did not find a significant difference between the results from the two laboratories. However, the hair samples used were not those collected in the course of the PA and Health surveys and they covered only low (L.T. 3mg/kg) mercury concentrations.

TABLE 52

PERCENTAGE DISTRIBUTION OF DIARY RESPONDENTS: BY TOTAL MERCURY IN HAIR

PA Consulting Services and Department of Health Surveys

| Total Mercury (mg/kg) | PA Survey % | Health Department Survey % | Total % |
|---|---|---|---|
| Less than 0.99 | 23.2 | 34.5 | 28.8 |
| 1 to 1.99 | 29.8 | 39.2 | 34.4 |
| 2 to 3.99 | 27.8 | 21.6 | 24.7 |
| 4 to 5.99 | 9.3 | 2.7 | 6.0 |
| 6 to 6.99 | 1.3 | 1.6 | 1.3 |
| 7 to 27 | 8.6 | 0.7 | 4.7 |
| Total | 100.0 | 100.0 | 100.0 |
| Average mercury in hair (mg/kg) | 2.8 | 1.6 | 2.2 |
| No. of respondents | 151 | 148 | 299 |

One factor which may have contributed to the difference in hair mercury results between the PA and Health surveys was the larger number of Melbourne residents involved in the former. The average hair mercury level of all Melbourne respondents was 3.6 mg/kg compared with 1.7 mg/kg for other respondents tested. Of the 151 PA hair samples taken, 60 were from Melbourne residents while only 18 of the 148 Health respondents came from that city. The effect of this difference can be seen by calculating the average mercury levels of non-Melbourne respondents. These were 2.0 mg/kg for those in the PA survey and 1.5 mg/kg for Health data.

However, the exclusion of Melbourne respondents does not explain all the difference between the two survey averages. After excluding Melbourne residents the PA average was still 30% higher than that of Health. Further, the average hair mercury level of PA Melbourne respondents was almost double that of Health Melbourne residents at 4.1 mg/kg and 2.1 mg/kg respectively. Thus the Melbourne contribution to the higher overall PA result was due not only to the number of respondents in that city but also to a generally higher mercury level in their hair.

It should be noted that the small size of the samples used in the above comparisons precludes the drawing of definitive conclusions. Factors other than residence in Melbourne are clearly influencing the results but these cannot be explained or are due to chance.

Blood samples were obtained from 43 Health survey respondents. Two respondents had a blood mercury level greater than 0.02 mg/kg. This level is analagous to the value of six mg/kg of mercury in hair, being equivalent to the provisional tolerable intake recommended by the FAO/WHO Committee.

Of the 43 individuals tested:

(1) one had a reading of 0.038 mg/kg
(2) one had a reading of 0.025 mg/kg
(3) three had between 0.01 and 0.02 mg/kg
(4) 34 had 0.005 mg/kg or less.

### 3.4(iii) Relationship between Mercury in Hair and Fish Consumption

#### (a) Introduction

Table 53 illustrates the relationship between average fish consumption in the survey week and mercury in hair. Generally, there was a tendency for higher mercury values to be associated with greater fish consumption. For example two thirds of persons with a hair mercury reading below one mg/kg ate less than 250 grams in the survey week and 5% consumed more than 1000 grams. At the other end of the scale 21% of those with a mercury reading of 7 or more consumed less than 510 grams but 29% ate more than 1000 grams.

## TABLE 53

### PERCENTAGE DISTRIBUTION OF RESPONDENTS: BY TOTAL WEEKLY FISH CONSUMPTION AND BY MERCURY IN HAIR

| Weekly Consumption (Grams) | Mercury in hair - mg/kg | | | | | |
|---|---|---|---|---|---|---|
| | 0 to .99 % | 1 to 1.99 % | 2 to 3.99 % | 4 to 6.99 % | 7 to 27 % | Total % |
| and under | 30.2 | 29.1 | 16.2 | 18.2 | 21.4 | 25.1 |
| 250 to 499 | 31.4 | 28.2 | 10.8 | 13.6 | 0.0 | 22.4 |
| 500 to 749 | 24.4 | 16.5 | 41.9 | 27.3 | 35.7 | 26.8 |
| 750 to 999 | 8.1 | 12.6 | 14.9 | 18.2 | 14.3 | 12.4 |
| 1000 to 1999 | 4.7 | 9.7 | 10.8 | 22.7 | 14.3 | 9.7 |
| 2000 to 2999 | 1.2 | 2.9 | 5.4 | 0.0 | 14.3 | 3.3 |
| 3000 to 3999 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | no. | no. | no. | no. | no. | no. |
| No. of Respondents | 86 | 103 | 74 | 22 | 14 | 299 |

Cramer's V = 0.21 Significant at 5% level

Some aspects of the relationship between species of fish consumed and mercury in the hair are presented in Table 54. For each survey and for the two surveys combined the table shows the average mercury level in the hair of respondents eating more than 200g of the relevant species shown in the survey week. Results in the three left hand columns refer to all people eating more than 200g of the species regardless of their total fish intake. Those in the right hand columns include only respondents whose total fish consumption in the week was at least 500g. For example, in the survey week, 21 respondents (15 Health survey, 6 PA survey) ate more than 200g of bream and had an average hair mercury level of 2.1 mg/kg. Seventeen of these respondents also had a total fish consumption of 500g or more in the week and had an average hair mercury level of 2.4 mg/kg.

It will be observed that for each species examined, respondents covered by the PA survey had higher hair mercury readings than those in the Health survey. Also, respondents eating more than 200 grams of flathead, flake, snapper and whiting had higher mercury readings than those eating canned fish.

It is also noticeable that in all cases but one the average hair mercury reading of respondents eating 500g or more of fish in the week was as high or higher than of all those eating 200g or more of fish.

However, it is important to note the small sample sizes on which some of the average mercury readings are based. Figures may be greatly influenced by very large or small individual readings.

(b) Mercury in Hair by Occupation

A feature of the analysis of mercury reading by occupational grouping was the low readings found among the original group (Table 55). It will be recalled that this group had the highest average consumption of fish among the groups surveyed. None of the aborigines surveyed had a mercury in hair reading above four and the overall average of 1.6 mg/kg was the lowest of all the groups. One reason for this is the relatively low total mercury readings in the fish eaten by those aborigines. Of their fish diet, the highest concentration of mercury was 0.13 mg/kg in spanish mackerel. Other species had readings of 0.08 mg/kg or less. In addition a significantly higher level of selenium was observed in the blood samples taken from aborigines. Their blood samples had an average selenium level of 0.22 mg/kg compared with 0.14 mg/kg for the other respondents for which selenium readings were obtained.

TABLE 54

RELATIONSHIP OF
AVERAGE MERCURY LEVEL IN HAIR AND SPECIES CONSUMED

| Species | Unit | Respondents Eating More than 200g of Species shown | | | Respondents Eating More than 200g of Species shown and more than 500g of all Species | | |
|---|---|---|---|---|---|---|---|
| | | PA Survey | Health survey | All Respondents | PA Survey | Health survey | All Respondents |
| Bream | mg/kg | 3.4 | 1.6 | 2.1 | 4.5 | 1.7 | 2.4 |
| | no | 6 | 15 | 21 | 4 | 13 | 17 |
| Flake | mg/kg | 4.5 | 2.3 | 3.3 | 5.4 | 2.0 | 3.7 |
| | no | 4 | 5 | 9 | 3 | 3 | 6 |
| Flathead | mg/kg | 4.8 | 3.0 | 4.2 | 4.8 | 3.0 | 4.2 |
| | no | 5 | 3 | 8 | 5 | 3 | 8 |
| Flounder | mg/kg | 2.0 | 1.8 | 1.9 | 2.2 | 1.9 | 2.1 |
| | no | 13 | 7 | 20 | 11 | 6 | 17 |
| Snapper | mg/kg | 5.2 | 1.8 | 3.4 | 5.3 | 1.9 | 3.5 |
| | no | 9 | 10 | 19 | 8 | 9 | 17 |
| Whiting | mg/kg | 4.5 | 1.7 | 3.0 | 5.6 | 1.9 | 3.3 |
| | no | 10 | 11 | 21 | 6 | 10 | 16 |
| Canned Tuna | mg/kg | 3.2 | 1.1 | 1.9 | 3.6 | 1.2 | 2.3 |
| | no | 12 | 20 | 32 | 10 | 11 | 21 |
| Canned Salmon | mg/kg | 2.3 | 1.8 | 2.0 | 2.4 | 2.6 | 2.5 |
| | no | 12 | 14 | 26 | 13 | 12 | 25 |

'no' refers to number of respondents in each classification.

TABLE 55

PERCENTAGE DISTRIBUTION OF RESPONDENTS:
BY TOTAL MERCURY IN HAIR AND BY OCCUPATION

| Mercury in Hair (mg/kg) | Occupation | | | | | |
|---|---|---|---|---|---|---|
| | Domestic % | Student % | Fishing % | Aboriginal % | Other % | Total % |
| 0 to 0.99 | 35.2 | 32.9 | 0.0 | 13.3 | 29.3 | 29.0 |
| 1 to 1.99 | 29.6 | 34.3 | 16.7 | 60.0 | 36.6 | 34.3 |
| 2 to 3.99 | 26.8 | 24.3 | 33.3 | 26.7 | 22.0 | 24.6 |
| 4 to 6.99 | 7.0 | 4.3 | 27.8 | 0.0 | 7.3 | 7.4 |
| 7 to 27 | 1.4 | 4.3 | 22.2 | 0.0 | 4.9 | 4.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Average mercury level (mg/kg) | 1.8 | 2.0 | 5.3 | 1.6 | 2.0 | 2.2 |
| Number of respondents | 71 | 70 | 18 | 15 | 123 | 297 |

The highest mercury readings were found among those persons connected with the fishing industry who also had a high consumption of fish. However, all the group came from the PA survey and as will be noted later a further sampling of those individuals with readings of 6 mg/kg or more gave generally lower results.

Other occupational groups had mercury readings close to the average and about 4% had readings of 6 or more.

(c) Mercury in Hair by Persons Dieting

Generally there was little difference in mercury hair readings between persons who were on a diet and the rest of the sample. Both groups had the same average reading of 2.1 mg/kg and their distributions about that average were broadly similar (Table 56). It will be recalled that there was relatively little difference in average fish consumption between persons dieting and the rest of the sample.

(d) Mercury in Hair by Country of Origin

Persons born in Mediterranean countries had a significantly higher average mercury reading (4.7 mg/kg) than groups of individuals born elsewhere (Table 57). This reflects the relatively high proportion of persons connected with the fishing industry among respondents from Mediterranean countries. Also, nearly all persons in this group were in the PA survey whose hair mercury readings tended to be higher than the average.

The low mercury readings found among the aboriginal group have been discussed earlier.

(e) Mercury in Hair by Leisure Fishermen

Average mercury readings in hair for leisure fishermen were the same as for the total sample although it will be recalled their fish consumption was lower than the overall average (Table 58).

3.4(iv) Mathematical Relationships

A number of mathematical models were formulated in order to examine the relationship between mercury readings in hair, fish consumption and other characteristics of the sample. The approach used and results obtained are described in Appendix 5A.

Briefly, the study showed that for the sample surveyed there was a positive relationship between the amount of fresh and frozen fish consumed and the hair mercury readings. No such relationship was found for other fish products (mainly canned fish).

## TABLE 56

### PERCENTAGE DISTRIBUTION OF RESPONDENTS BY TOTAL MERCURY IN HAIR AND BY WHETHER DIETING OR NOT

| Mercury in Hair (mg/kg) | On a Diet % | Not on a Diet % | Total % |
|---|---|---|---|
| 0 to 0.99 | 24.1 | 30.6 | 28.8 |
| 1 to 1.99 | 33.7 | 34.7 | 34.4 |
| 2 to 3.99 | 28.9 | 23.1 | 24.7 |
| 4 to 6.99 | 9.6 | 6.5 | 7.4 |
| 7 to 27 | 3.6 | 5.1 | 4.7 |
| Total | 100.0 | 100.0 | 100.0 |
| Average mercury level (mg/kg) | 2.2 | 2.2 | 2.2 |
| Number of respondents | 83 | 216 | 299 |

# TABLE 57

## PERCENTAGE DISTRIBUTION OF RESPONDENTS BY TOTAL MERCURY IN HAIR AND BY COUNTRY OF ORIGIN

| Mercury in Hair (mg/kg) | Australia/N.Z. Aboriginal % | Australia/N.Z. Other % | Mediterranean % | Other % | Not Known % | Total % |
|---|---|---|---|---|---|---|
| 0 to 0.99 | 13.3 | 32.7 | 9.1 | 27.7 | 0.0 | 28.8 |
| 1 to 1.99 | 60.0 | 34.1 | 22.7 | 34.0 | 25.0 | 34.4 |
| 2 to 3.99 | 26.7 | 22.7 | 27.3 | 31.9 | 25.0 | 24.7 |
| 4 to 6.99 | 0.0 | 7.1 | 18.2 | 6.4 | 0.0 | 7.4 |
| 7 to 27 | 0.0 | 3.3 | 22.7 | 0.0 | 50.0 | 4.7 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Average mercury level (mg/kg) | 1.6 | 2.0 | 4.7 | 1.8 | 4.9 | 2.2 |
| Number of respondents | 15 | 211 | 22 | 47 | 4 | 299 |

## TABLE 58

## PERCENTAGE DISTRIBUTION OF LEISURE FISHING RESPONDENTS BY TOTAL MERCURY IN HAIR

| Mercury in Hair (mg/kg) | Respondents Fishing for Leisure % | Respondents Not Fishing for Leisure % | All Respondents % |
|---|---|---|---|
| 0 to 0.99 | 18.9 | 30.2 | 28.8 |
| 1 to 1.99 | 32.4 | 34.7 | 34.4 |
| 2 to 3.99 | 37.8 | 22.9 | 24.7 |
| 4 to 6.99 | 8.1 | 7.3 | 7.4 |
| 7 to 27 | 2.7 | 5.0 | 4.7 |
| Total | 100.0 | 100.0 | 100.0 |
| Average mercury level (mg/kg) | 2.2 | 2.2 | 2.2 |
| Number of respondents | 37 | 262 | 299 |

There was a strong positive relationship between fish consumption of respondents working in the fishing industry and their hair mercury readings. Little relationship was found between consumption and mercury readings of students and persons whose main occupation was household duties.

Of the five classifications of country of origin, that of persons born in Mediterranean countries showed the strongest relationship between fish consumption and hair mercury readings. This variable was fairly closely related to the occupational group of persons working in the fishing industry. It was notable that aborigines were the only group studied to have a negative relationship between fish consumption and mercury readings although the relationship was not particularly significant.

Further linear regression tests were conducted to determine the relationships between mercury in human tissues, fish consumption and mercury intake. The method and the results obtained are described in Appendix 5B.

There was a good correlation between fish consumption and mercury intake, the relationship was highly significant and the equation specified explained a reasonably high proportion of the relationship between the two variables.

Highly significant correlations were also found in all relationships between

(1) mercury in hair and fish consumption (already noted above),

(2) hair mercury and mercury intake, and

(3) blood mercury and both fish consumption and mercury intake.

However, the equations involving hair mercury readings explained a relatively small percentage of the variation observed between the variables.

There did not appear to be a significant relationship between mercury in the hair and mercury in the blood. (NB. Lindsay (in press) concluded that his results were in excellent agreement with the linear regressions found in other studies where constant ratios were found of mercury in hair to mercury in blood close to a value of 250).

A more detailed examination was undertaken of the relationship between hair mercury and mercury intake and fish consumption, taking into consideration such factors as differences between cities, occupation and country of origin of respondents. The addition of these variables increased the percentage of mercury in hair explained by mercury ingestion and fish consumption from 4 to 6 per cent in the simple regression equations to 23 per cent using multiple regression. Residence or otherwise in Victoria was the most significant variable in these equations, being significant at the 0.1 per cent level. Also significant, at the 1 per cent level in explaining differences in hair mercury levels were membership of the fishing industry and Mediterranean country of origin. Mercury intake was also significant at the 1 per cent level but fish consumption was only significant at the 5 per cent level.

Selenium readings were obtained for 134 individuals in the Health Department study. Appendix 5C describes a regression test carried out to determine the relationship between selenium in the hair and mercury in the hair.

Some positive relationship was observed between mercury and selenium readings in hair, however the readings of mercury and selenium were clustered in the lower range of observations and no conclusion could be drawn as to relationship at higher intake levels.

3.4(v) Follow-up Surveys

The sixteen individuals in the PA survey who had hair mercury readings of 6 mg/kg or more were further investigated in March-April 1977 some six months after the initial purposive study. Twelve of them were interviewed by officers of the Victorian Department of Health, three by interviewers employed by PA consulting services and one refused to co-operate. Also five persons in the Department of Health survey were re-interviewed, three of whom had hair mercury readings greater than 6 mg/kg and two had blood mercury readings in excess of 0.02 mg/kg.

These investigations were undertaken to:

(1) establish whether there was any health risk to the individuals concerned.

(2) verify the initial hair and blood readings.

In the second interview some samples of blood and further samples of hair were collected. In addition, information was collected on changes in respondents' fish consumption between the two survey periods. The results are summarised in Table 59.

TABLE 59

CHANGES IN RESPONDENTS' HAIR MERCURY LEVELS BETWEEN SURVEYS

| Respondent Number | Mercury level mg/kg | | | | Comments |
|---|---|---|---|---|---|
| | First Survey Hair | Follow-up Study Hair: Close to scalp | Follow-up Study Hair: Rest including tips | Follow-up Study Blood | |
| 1 | 11.0 | 0.74 | 2.5 | 0.003 | |
| 2. | 7.0 | 3.1 | 2.7 | 0.008 | |
| 3. | 15.0 | 0.25 | 0.46 | 0.004 | |
| 5. | 7.4 | 0.67 | 0.98 | 0.001 | Eating less tinned tuna at time of follow-up study |
| 6. | 6.6 | 2.4 | 2.4 | 0.008 | Eating less tinned tuna at time of follow-up study |
| 7. | 7.4 | 7.2 | - | 0.021 | |
| 8. | 8.0 | 7.3 | 6.8 | 0.022 | |
| 9. | 9.8 | 2.1 | - | 0.007 | |
| 10. | 7.2 | 0.56 | - | 0.002 | Eating less tinned tuna at time of follow-up study |
| 11. | 15.0 | 2.3 | - | 0.005 | Eating less fish at time of follow-up study |
| 12. | 27.0 | 6.0 | - | 0.018 | Eating less flake at time of follow-up study |
| 13. | 7.8 | 0.1 | | NA | Eating less fish at time of follow-up study |
| 14. | 7.4 | 3.8 | | NA | Eating less fish at time of follow-up study |
| 15. | 6.4 | 3.9 | | NA | |
| 16.* | 7.0 | 5.0 | | NA | |
| 17.* | 0.5 | 0.4 | | NA | |
| 18.* | 6.8 | 4.6 | | NA | Eating less fish at time of follow-up study. |
| 19.* | 2.8 | 1.5 | | NA | Eating less fish at time of follow-up study. |
| 20.* | 6.6 | 8.3 | | NA | |

* Department of Health survey respondents.

Generally, the hair mercury readings of respondents were lower at the time of the follow-up study than they had been previously. A factor which contributed to this in some cases was a change in diet between surveys. Dietary information was collected for 15 respondents in the follow-up study and seven were eating less fish since the time of the initial survey and none were eating more. There is however no satisfactory explanation for the wide discrepancies in other cases, for example Respondent 3 (Table 59), unless external contamination (Section 2.7(xi)) was a cause.

3.4(vi) Comparison with other relevant studies

The study by Penington referred to in Section 2.6(v) collected data on mercury in the tissues of some respondents. This section compares the results with those of the PA and Health purposive studies. It will be recalled that the Penington survey was also purposive, being directed at people onsidered to be 'at risk' from possible mercury ingestion.

Hair samples were obtained by Penington from about 350 people and the highest reading recorded was 37 mg/kg compared with 27 mg/kg in the PA and Health surveys. Both the Penington and the PA and Health studies found about 6% of respondents with a hair mercury level greater than 6 mg/kg.

The Penington study obtained blood samples from about 100 respondents and 3 of these had a blood mercury level greater than 0.02 mg/kg. In the Health study, analysis of 43 samples found 2 exceeding 0.02 mg/kg.

Whereas no relationship between hair and blood mercury levels was observed in the 43 people sampled in the Health study, the Penington survey calculated a correlation coefficient for the two values of 0.66 from their results from 89 people.

3.4(vii) Comparison of Australian blood mercury/mercury intake data with those from overseas studies

Lindsay (in press) compared the results he obtained from duplicate diet studies (Section 2.5) with those from other overseas studies. The data from his United Kingdom study showed a regression of blood mercury levels against mercury intake with a lower (about 8 times) slope than that based on the FAO/WHO Study Group on metabolic data from tracer studies on human volunteers (Miettinen 1973). The conclusion from Miettinen's studies was that blood methylmercury concentrations (expressed in mcg/litre) and mercury intake (in mcg/70 kg body wt/day) were linearly related with a slope (coefficient of x) of unity and intercept of zero. Lindsay concluded that the United Kingdom data did not support the assumption of linearity, but the form of the relationship was too complex to interpret.

In Figure 5, Lindsay's data have been compared with other studies cited by him, which were referred to also in WHO (1976). Australian data have been converted to the same units and included for comparison in Figure 5, which is based on Table 60.

WHO (1976) concluded that, excluding United Kingdom and Australian data, although the coefficient of x of 0.5-0.8 from field studies was lower than the predicted (Miettinen) value of unity from tracer studies, it was likely that these differences were not real, given the difficulties in the accurate measurement of dietary intake and the uncertainty in tracer studies based on counting blood samples. Lindsay however concluded that the United Kingdom data indicated that the consumption of methylmercury at the level of the tolerable weekly intake of 0.2 mg of methylmercury per week recommended by FAO/WHO would not be likely to result in levels in excess of 0.5 mcg/100 ml whole blood as organic mercury and 2 mg/kg in hair (c.f. 2 mcg/100 ml and 6 mg/kg respectively expected by FAO/WHO 1972)

It has been noted (Appendix 5B) that the Australian results while being significantly correlated, explain a relatively small proportion of the variation in blood concentration. Moreover reference to Figure 3 of Appendix 5B shows that the linear regression does not provide a very convincing fit. Before discussing the implications of this further the following points should be noted

(1) mercury intake refers only to total mercury, but since the methylmercury component of this in fish approaches 100%, this should not affect the result greatly,

(2) mercury intake is based only on mercury derived from fish consumed during the survey week (Lindsay's data refer to total diet, excluding beverages, during the survey week),

(3) blood mercury was recorded as total mercury,

(4) mercury intake data (like Lindsay's) represent only the extreme lower end of the range of overseas data represented in Figure 5.

Australian mercury intake figures therefore do not include the amount consumed with foods other than fish. Lindsay concluded that the contribution to the total intake of mercury from the non-fish component of the diet was very low, considering that the ranges of mercury found were generally in the range 0.001 to 0.002 mg/kg. However, figures from the 1976 Australian Market Basket Survey (Section 2.6 (iii) and (iv)) indicated that although foods other than fish contained similar concentrations of total mercury to those recorded in the

## TABLE 60

## RELATIONSHIP BETWEEN WHOLE BLOOD CONCENTRATION AND DAILY INTAKE OF MERCURY

(Partly after Lindsay (in press) which was based on WHO (1976) Table 3)

| Number of Subjects | Average Hg intake (x) mcg/70kg body wt/day | Whole blood conc. (y) mg/litre | $R^2$ | Reference |
|---|---|---|---|---|
| 32 | 0-800 | y = 0.7x + 1 | | Birke et al, 1967 |
| 165 | 0-400 | y = 0.3x + 5 | | Tejning, 1970 |
| 20 | 0-800 | y = 0.8x + 1 | | Birke et al, 1972 |
| 22 | 0-800 | y = 0.5x + 10 | 0.92 | Skerfring, 1974 |
| 119 | 1-69 | y = 0.15x + 2.3 | 0.25 | Lindsay, in press |
| (NE Irish Sea) 55 | L.T. 1-80 | y = 0.04x + 3.0 | 0.06 | Lindsay, in press |
| (SE English Channel) 174 | L.T. 1-80 | y = 0.12x + 2.5 | 0.21 | Lindsay, in press |
| (Total) 29 | L.T. 0-104 | y = 0.24x + 2.4 | 0.15 | Present Study |
| Department of Health Survey Australia 15 Tracer Studies | | y = 1.0x | | Miettinem, 1973 |

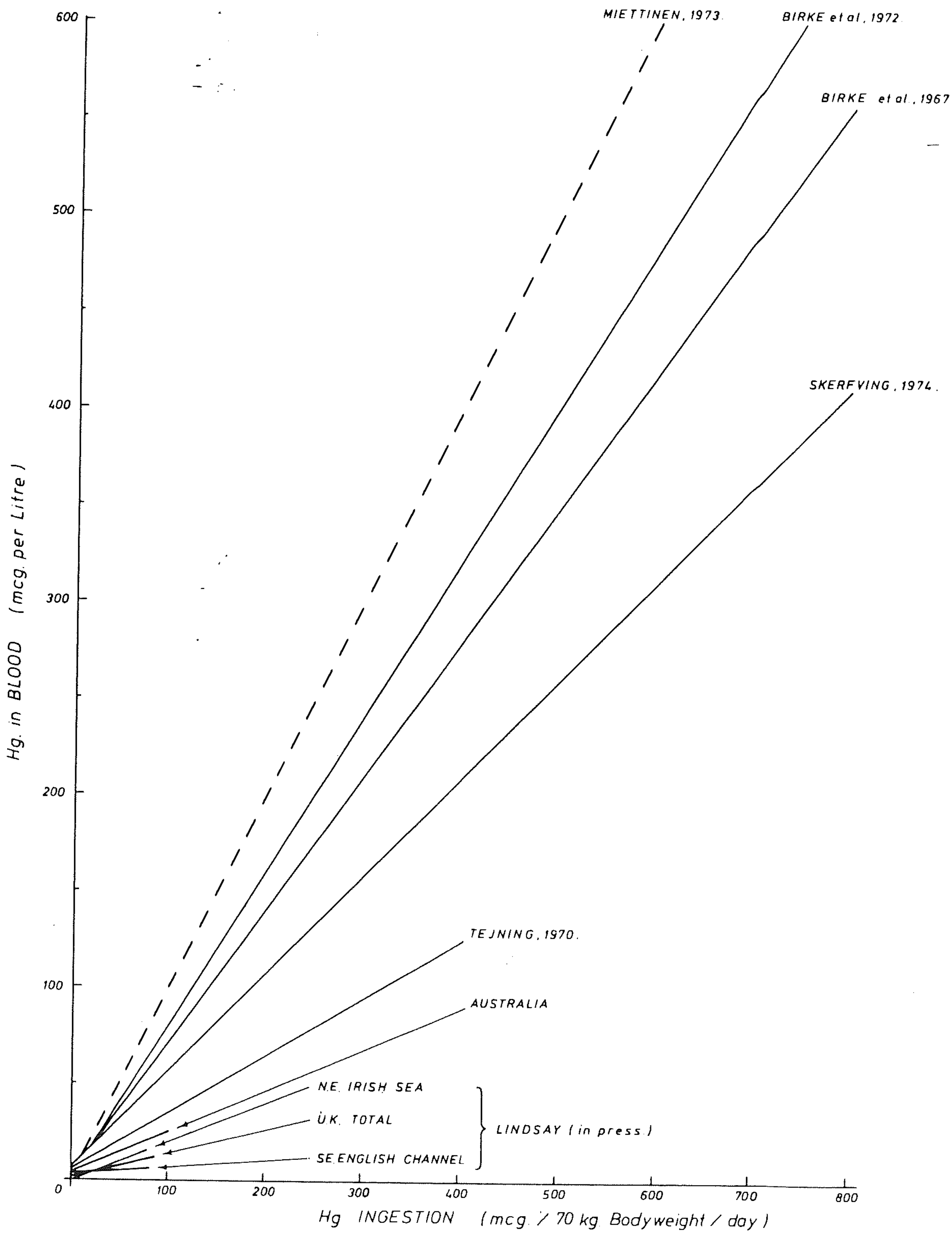


FIGURE 5

RELATIONSHIPS BETWEEN MERCURY IN BLOOD AND MERCURY INGESTION

Based on data provided in Table 60

United Kingdom, they accounted for approximately 75% (0.006 out of 0.008 mg daily) of the total intake - the proportion which was methylmercury is not known. In Section 3.3 (i) it was noted that while this high proportion of mercury intake from foods other than fish, meat and eggs referred to the average diet, the same quantity would represent a smaller proportion of the total mercury ingested in a high fish diet.

The addition of any mercury derived from foods other than fish to mercury intakes recorded in Figure 5 and in Appendix 5B, Figure 3 would cause an even greater deviation (below) the Miettinen relationship. While the linear regression does not give a convincing fit to the data, it is still evident from Appendix 5B Figure 3 that almost all of the data points are below Miettinen's regression line.

These results and other work into the relationships between blood mercury concentrations and mercury intake have therefore all been below the Miettinen regression line and suggest that more mercury can be ingested before reaching symptom level than indicated by the FAO/WHO based on Miettinen.

A major deficiency in the United Kingdom and Australian data is, however, the fact that data derived from a single survey week may not represent sustained consumption, which is a requirement of the FAO/WHO relationships.

## 4. ALTERNATIVES FOR CONTROL AND THEIR CONSEQUENCES

### 4.1 Alternatives for controlling levels of mercury in fish consumed

The Working Group has examined the various alternatives for controlling the quantity of mercury consumed in fish by the general public, and has attempted to evaluate the social and economic consequences of some of them. Reference will be made to precedents for administrative action in Australia (Sections 1 and 2.6 (vii)) and overseas (Section 2.3).

(1) No controls - as for example in the UK where continuing evaluation has failed to convince Government of the need for regulatory action, though monitoring is being continued. Clearly the application of any controls, which are designed to protect human health at the cost both to the producer and of a valuable source of protein, will require justification in terms of known, or at least probable, danger to health. The application of controls would certainly result in the reduction of fish supplied and consumed, both directly from restriction on landings or sales of fish and indirectly through public disquiet. They affect the capital investment and livelihood of the fishermen and involve administration costs. The Working Group's activities have centred on providing information relevant to such an assessment by the NH&MRC, which recognises the associated costs.

(2) Warnings - Warnings may be aimed (a) at reducing the capture of fish of named species or sizes or from designated areas, e.g. sand flathead from Port Phillip Bay in Victoria, in certain lake areas of Sweden and Denmark (Section 2.3) and (b) at reducing mercury ingestion by specific groups of the general public, e.g. pregnant women, etc., for which there are several Australian examples (Section 2.2).

Warnings (and prohibitions, see below) are among the few possible approaches to controlling fish consumption by amateur fishermen, other groups such as isolated communities which do not rely on established markets for their supply of fish, and perhaps those connected with the fishing industry and their families who are prominent among high fish consumers.

Experience suggests that warnings to individuals, for example through specific organisations, are more likely to be effective than general public warnings. The latter may cause initial over-reaction by members of the public not directly affected, later to be forgotten unless regularly reinforced.

(3) *Prohibition of capture of fish from designated (polluted) areas* - e.g. in certain freshwater lakes in Sweden. This approach has special relevance to amateur fishermen who would not be covered by restrictions on marketed fish.

(4) *Prohibition of capture, landing or sale of designated species of fish* e.g. marlin other than for non-commercial purposes in New South Wales, and in Canada where swordfish and bluefin tuna are automatically placed under detention.

(5) *Restrictions on capture, landing or sale of individual fish with mercury levels in excess of a prescribed standard*, e.g. the standard prescribed in many countries specifies a permissible maximum concentration of mercury in the fish, which may be rigidly implemented by inspection, as was proposed for Australia under the Trade Practices Act. It should be noted that although a standard specifies a maximum for inspection purposes it is often based on calculations of average ingestion of mercury.

(6) *Restrictions on capture, landing or sale of fish containing average levels in excess of a prescribed standard*, e.g. for school shark in Victoria where legal minimum and maximum landing sizes have been adjusted to ensure that the *average* mercury level in the marketed catch does not exceed the standard. A similar approach has been applied to market receivals in WA.

Administration of the standard in this way is more properly identified with calculations of provisional tolerable intake (Joint FAO/WHO Expert Committee 1972 and NH & MRC 1973), and would allow blending of sizes and species of fish to an average concentration not exceeding the standard.

The US action level is administered on the basis of the average concentration in twelve samples from a consignment (Appendix 6), and similarly New Zealand and Canadian inspection quires the average level in a consignment of fish not to exceed the standard.

(7) *Exemptions from controls and differential controls*, e.g. in Japan where tuna and shark are exempted from the general control level on the basis of natural accumulation of mercury. In the US, the NMFS (1978) recently argued that no control should be placed on fish other than swordfish which is uniformly high in mercury, and freshwater fish which are particularly subject to local mercury contamination. The USSR has a sliding scale of limits according to origin, processing and type of fish, similar in effect to the differential limits in foods recommended by the NH & MRC for trace elements, including mercury, from different sources. The NH & MRC recommended limit for mercury in foods other than fish is 0.03 mg/kg.

(8) Control of imports. The standard for imported fish may be the same as the domestic standard, as in Australia; it may be more stringent, e.g. Sweden, Denmark, while some countries with no domestic standard are reported to, at least unofficially, exercise control of imports. The Australian imports standard specifies a maximum permissible mercury concentration and inspection is administered accordingly. It was claimed at the time that one of the reasons for proposing to apply the Trade Practices Act to the Australian standard was the complaint by countries importing into Australia that they were being discriminated against because of Australia's failure to implement its own domestic standard in the same manner.

(9) Blending of Fish. One way of using fish containing mercury concentrations above permissible levels could be to blend it with other foods or other fish species with low mercury levels. Such blending could ensure that the resultant product has an average mercury level less than the permissible maximum for fish and fish products (currently 0.5 mg/kg).

Fish blending has been an acceptable procedure overseas. For example, in the United States canneries have been permitted to blend the high mercury tuna species such as yellowfin with lower mercury species to obtain a canned product having an average mercury content not exceeding 0.5 mg/kg.

There are limited opportunities to adopt such practices in Australia under present NHMRC definitions of fish and fish products and the draft revised standard for metals in food (NHMRC June 1979).

Under the draft standard the fish content of fish products may not contain mercury exceeding 0.5 mg/kg, the same level for fish generally. A fish product is not explicitly defined but must contain more than 51 percent fish and would appear to cover products such as fish balls, fish rissoles, fish cakes and fish fingers, as well as breaded fish and fish cooked in batter.

The draft standard does not appear to preclude the blending of two or more fish species provided the resultant blend does not exceed 0.5 mg/kg of mercury, this blend could then be used to constitute the fish component in fish products.

However such blending would not appear to be possible for canned fish. The standard for canned fish products states that such products must be prepared from "fish properly prepared and fit for human consumption". It is understood that there is some doubt as to whether fish with a mercury content in excess of 0.5 mg/kg, for use in blending with lower mercury fish, would be considered fit for human consumption. If this interpretation is correct there would appear to be strong grounds for clarifying and reviewing the standard because there would not seem to be any logical ground for discriminating against canned fish of less than the permissible mercury level, irrespective of how that level was achieved. Also there would seem to be a dual standard in the present treatment of blends in fish products and in canned fish.

(10) <u>Control of mercury emissions</u> have been effective in reducing mercury concentrations in freshwater fish, e.g. in Sweden and Canada, and in marine fish, e.g. in the UK. Control of mercury emissions is now being implemented throughout Australia (Section 2.6 (vii)).

In the following sections an evaluation is made of the alternatives listed under paragraphs (5), (6) and (8) above.

## 4.2 Analysis

### 4.2(i) Data analysis and statistical method

Mercury concentration data are available for most of the important Australian commercial fish in the form of a range of individual analyses for each species. (Table 19, Section 3.1 (iii)). The unweighted mean * which can be calculated in each case does not always (Table 62) give a representative figure to which to refer a selected health standard, or which may be used in computing dietary ingestion of mercury (Section 3.3). Various authors in Australia (Section 2.6 (ii)) and overseas (Section 2.4 (iii)b) have sought a correlation between mercury and some measurement of catch size of fish. This relationship can be used in conjunction with catch size composition data, and the length/weight relationship of the species, first to calculate a more realistic (weighted) average mercury level of the catch and second to examine the consequences, in terms of losses from the marketable catch, of exercising various alternatives for controlling the level of mercury in fish reaching the consumer.

The Working Group consulted with a number of statisticians from Commonwealth and State instrumentalities on the relationship between size and mercury levels in Australian fish species, and found that they are not in agreement as to whether the relationships are sufficiently precise for predicting mercury concentration from a measurement of size. However, this posed the dilemma that without some yardstick for separating the catch into acceptable and unacceptable fractions, based on size, the only present regulatory alternatives would be to retain or reject all fish of a species containing any fish with mercury in excess of the standard, or to issue warnings to the public, or place prohibition on designated areas.

The data processing procedure finally agreed upon by the Working Group was that formulated by Mr N. Caputi of the Western Australian Department of Fisheries and Wildlife, details of which are set out in Appendix 7. In summary the Group proceeded as follows:-

(1) For species in which adequate (about 30) samples were analysed for mercury with accompanying individual records of size, semi-log and log-log regressions were attempted. These were chosen to provide <u>a priori</u> a more realistic relationship than a linear one. Figures 6 and 7 give examples of regressions which were (a) well correlated (gemfish) and (b) marginally correlated (leatherjacket) (Table 62).

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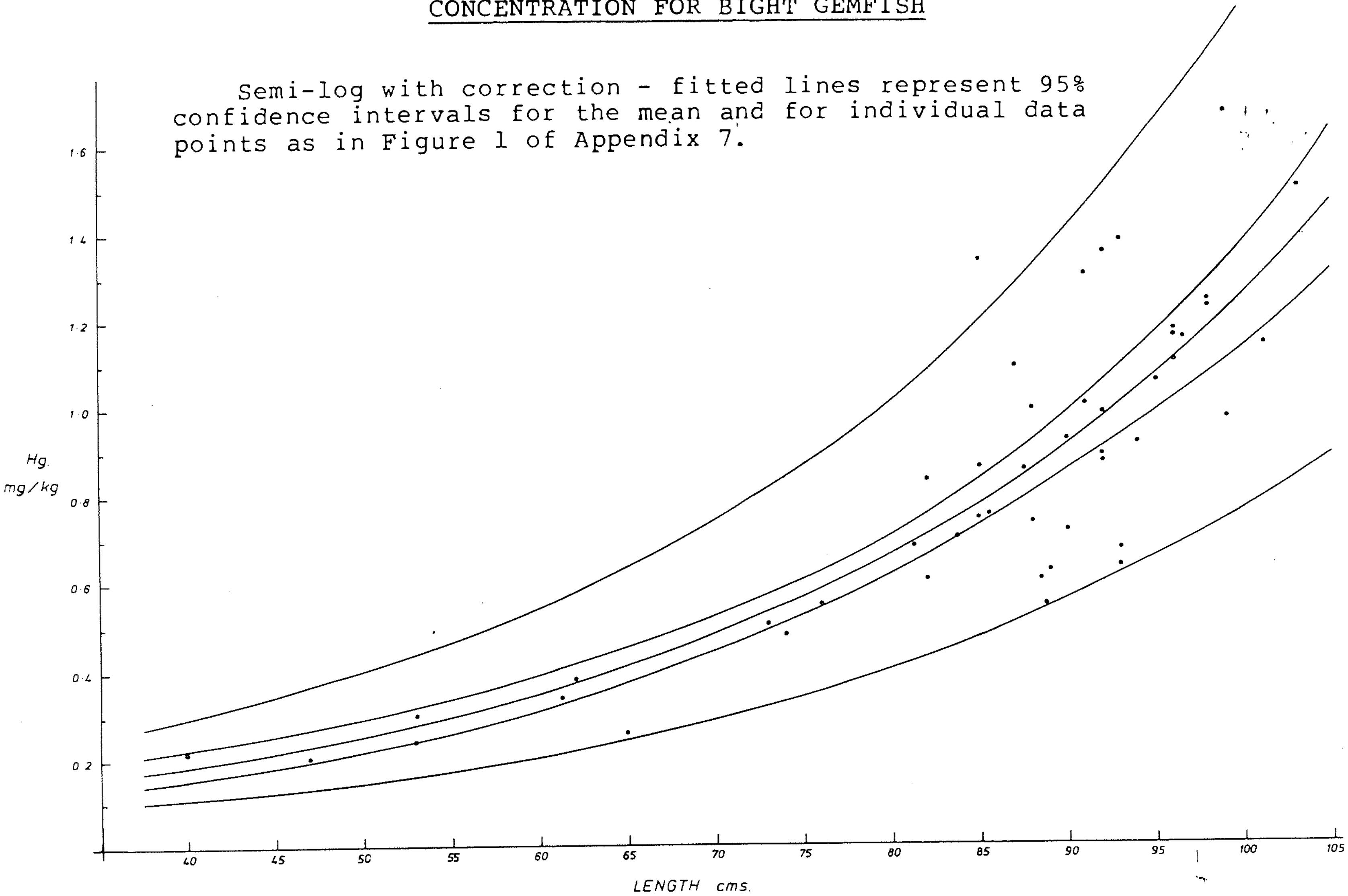
* An <u>unweighted</u> mean is the mean of the samples analysed; a <u>weighted</u> mean is the mean obtained after adjusting for the size composition representative of fish in the commercial catch.

FIGURE 6

## RELATIONSHIP BETWEEN LENGTH AND MERCURY CONCENTRATION FOR BIGHT GEMFISH

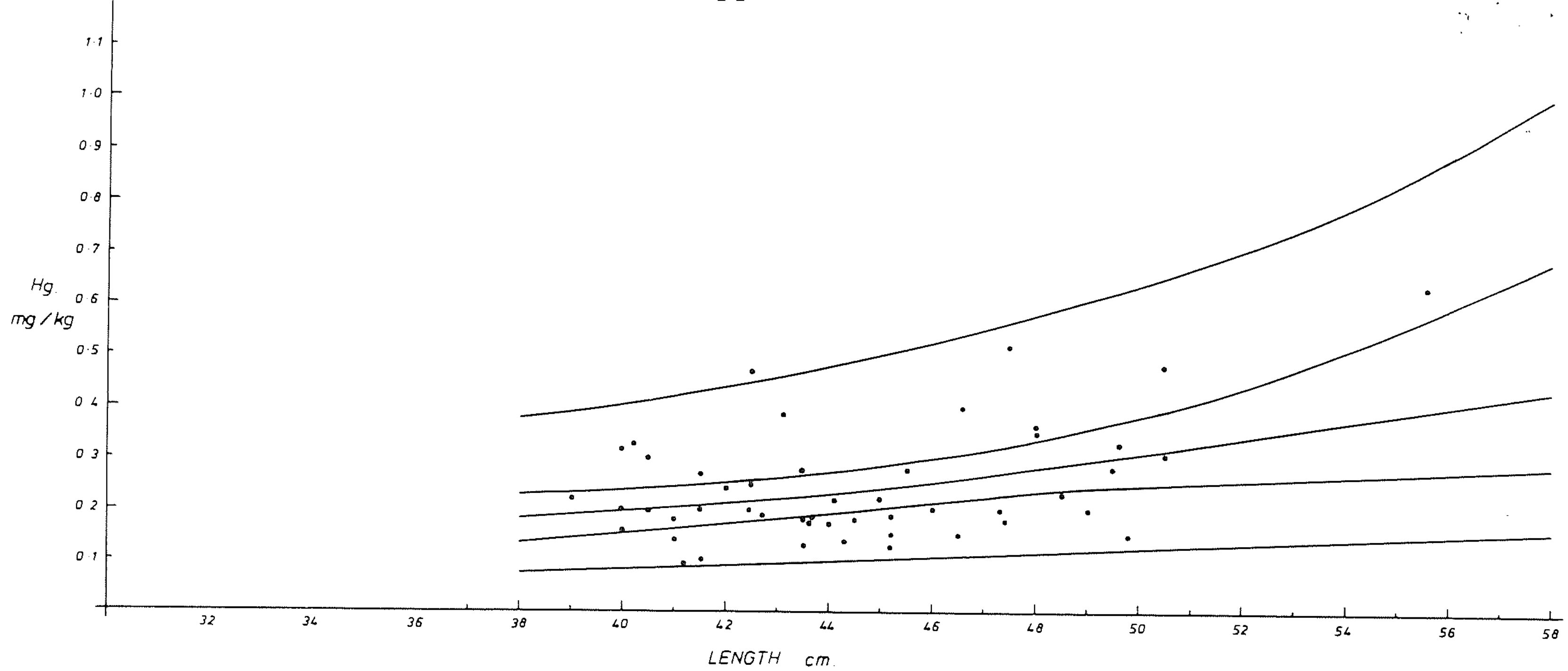



Semi-log with correction - fitted lines represent 95% confidence intervals for the mean and for individual data points as in Figure 1 of Appendix 7.

FIGURE 7

RELATIONSHIP BETWEEN LENGTH AND MERCURY CONCENTRATION FOR BIGHT LEATHER JACKET

Semi-log with correction - fitted lines represent 95% condifence intervals for the mean and for individual data points as in Figure 1 of Appendix 7.



(2) Significance of regression equations was judged on the F-value which was required to be at least 4 times greater than the selected percentage point (F-table value) (Appendix 7). In a few instances (e.g. morwong, Table 62) where the F-value did not exceed 4 times, the regression was used if the correlation was significant at the 0.05 level. The choice of semi-log or log-log for further computation was based on the higher multiple correlation value in the two equations.

(3) Where correlation significance at the 95% level was obtained, data from species with accompanying size composition of the catch and length/weight relationship were analysed to provide values for the parameters listed under para. 5 below.

(4) Where <u>no</u> significant correlation was obtained for a species in which the maximum mercury concentration exceeded one of the chosen standards, or where no catch composition data had been supplied to the Group, e.g. South Australian tuna, it was necessary to calculate the 95% confidence intervals of the unweighted mean and of the individual mercury analyses. It was not possible to predict percentages lost as in 3, above; instead it had to be assumed that since mercury concentration could not be related to size it would, if any fish exceeded the standard, be necessary to reject the entire catch to ensure that no fish with mercury in excess of a required standard would reach the consumer.

(5) One objective of the data analysis was to attempt to predict the effects on the catches of selected species of fish of the application of legal maximum sizes appropriate to various alternatives for control. The alternatives examined here were maximum permitted mercury levels of 0.25, 0.5, 0.75, 1.0, 1.25 and 1.5 mg/kg, and the parameters predicted included:-

a. a legal maximum length ($L_1$ in Figure 1 Appendix 7) at which the mean mercury level would equal the maximum permitted,

b. a legal maximum length ($L_2$) at which the upper 95% confidence limit of the mean would equal the maximum permitted,

c. a legal maximum length ($L_3$) at which the upper 95% confidence limit of the individual data would equal the maximum permitted - this would be the situation envisaged under the Trade Practices Act (Section 1),

d. a legal maximum length ($L_4$) below which the weighted mean mercury level of fish remaining would equal the maximum permitted - this option would identify with the basis for selecting a standard, i.e. from calculations of average levels of mercury ingested,

e. the weighted mean and maximum (from the 95% confidence interval of individual data) mercury level in the permitted catch, i.e. below the legal maximum size.

f. the weight of fish rejected from the catch which contains mercury less than the maximum permitted, expressed both as (i) a percentage of the rejected catch and (ii) as a percentage of the total catch.

The results obtained were used to attempt to estimate the total loss expected from the ten species of greatest importance to the Australian 1976/77 catch (Table 64). This was computed by calculating separately the losses for each State for each of the ten species. Where a "species" in fact comprised a number of different fish species, separate estimates for each were used and subsequently combined (for example school shark and gummy shark, school whiting and King George whiting, etc.).

In addition those species comprising the most important ten species for each State, where not represented in the top ten Australia-wide were examined to provide a view of the situation for each State. To obtain an overall picture a certain amount of combination and extrapolation was necessary, including combining mercury levels for various States, and occasionally employing losses for the same species from another State or more rarely from another closely related species. Sources of data have been given in Table 61.

Available data on species of emerging importance in developing fisheries have been examined in a similar manner to the above, or where this has not been possible some commentary has been provided from the knowledge available.

It must be re-emphasised that the results of the above procedures are intended only to provide an approximate guide to the likely effects of controls based on data supplied to or acquired by the Working Group. A more precise analysis would require:-

(1) Mercury analyses using a standarised method.

(2) Mercury/size data fully representative of each area for each species.

(3) Size composition and length/weight data representative of each area for each species.

Since these were not available for many species and because in any case individual mercury data usually have a wide confidence interval, too much emphasis should not be placed on lost tonnages and values for individual species (Tables 62-64); rather the overall figure for Australia, and for each State, expressed as percentage losses in weight and value (Table 66) should be used, although only as a basis for preliminary conclusions at the present time. The data have been presented in such a form that, if required, estimates can be revised as additional, more precise data, become available.

TABLE 61

INFORMATION USED FOR ECONOMIC ASSESSMENT

- giving source

| :CIES )UP* | IMPORTANCE TO STATES* | SPECIES | HG/LENGTH | LENGTH/ WEIGHT | SIZE COMPOSITION | ASSESSMENT POSSIBLE? |
|---|---|---|---|---|---|---|
| ıa (1) | SA (1) | S. bluefin+ | | Hg only | NA | NA |
| .s "no correlation" | | | | | | |
| | WA (4) | | (SA) | NA | NA | " |
| | NSW (11) | | (SA) | NA | NA | " |
| ;hark (2) | Vic (1) | | Vic | Vic | Vic | yes |
| | SA (2) | | Vic | Vic | SA | yes |
| | Tas (1) | | (Vic) | (Vic) | (Vic) | (use Vic) |
| | WA (5) | | WA | WA | WA | yes |
| | NSW (2) | | NA | NA | NA | (use Aust. mean) |
| lul' (3) | NSW (1) | Sea | Hg only | NA | NA | no losses |
| | Qld (1) | Y. eye | (Vic) | (cubic) | (Vic) | (use Vic) |
| | WA (2) | Y. eye | (Vic) | (Vic) | (Vic) | (use Vic) |
| | | Sea | Hg only | NA | NA | no losses |
| | SA (5) | Y. eye | (Vic) | (cubic) | (Vic) | (use Vic) |
| | Vic (7) | Y. eye | Vic | cubic | Vic | yes |
| ı. salmon (4) | WA (1) | | Vic/WA nc | na | na | as nc |
| | SA (4) | | (") | " | " | (as nc) |
| | Tas (2) | | (NSW) | " | " | (as nc) |
| | NSW (8) | | NSW/Vic/WA nc | " | " | as nc |
| | Vic (6) | | Vic/WA nc | " | " | as nc |
| /hiting (5) | SA (3) | K. G | Hg only | NA | NA | no losses |
| | Vic (2) | School | NA | NA | NA | (use NSW sand) |
| | | K. G | Hg only | NA | NA | no losses |
| | Qld (3) | G. lined | NA | NA | NA | (use NSW sand) |
| | | Sand | NA | NA | NA | (use NSW sand) |
| | NSW (10) | Sand | NSW | NSW | NSW | yes |
| | | K. G | (Vic/SA) | NA | NA | no losses |
| | WA (7) | W. sand | NA | NA | NA | (use NSW sand) |
| | | K. G | (Vic/SA) | NA | NA | (no losses) |
| ;napper (6) | NSW (7) | auratus | NSW/Vic/SA | NSW | NSW | yes |
| | SA (6) | " | " | (Vic) | SA | yes |
| | Vic (5) | " | " | Vic | Vic | yes |
| | Qld (8) | | NA | NA | NA | (use NSW) |
| | WA (3) | unicolor | WA | WA | WA | yes |

ͺotnote: NA = not available; nc = no correlation; na = not applicable;

Source: Australian Bureau of Statistics 1976/77

Scientifc names given in Table 15

Iumbers in parenthesis in the first column indicate the order of importance to ``stralia, and in the second column the order of importance for each State.

TABLE 61 (cont)

| SPECIES GROUP* | IMPORTANCE TO STATES* | SPECIES | HG/LENGTH | LENGTH/ WEIGHT | SIZE COMPOSITION | ASSESSMENT POSSIBLE? |
|---|---|---|---|---|---|---|
| Gemfish (7) | NSW (2) | ("hake") | NSW | NSW | NSW | yes |
| Flathead (8) | NSW (6) | Tiger | NSW/Vic/Tas | NSW | NSW | yes |
| | | Dusky | Hg only | NA | NA | no losses |
| | | N. sand | NA | NA | NA | (use Vic sand) |
| | Vic (3) | Tiger | NSW/Vic/Tas | Vic | Vic | yes |
| Morwong (9) | NSW (3) | Jackass | NSW/Vic/SA | NSW | NSW | yes |
| | Vic (8) | " | " | Vic | Vic | yes |
| Giant Perch (10) | NT (1) | Barramundi | Hg only | NA | NA | as nc |
| | Qld (4) | | " | " | " | as nc |
| Redfish (11) | NSW (4) | Nannygai | NA | NA | NA | (use WA) |
| Mackerel (12) | Qld (2) | | NA | NA | NA | (use Taiwanese) |
| Bream (13) | NSW (12) | Black | NSW/Vic | (WA) | (Vic) | (yes) |
| | Qld (5) | Y. fin | NA | NA | NA | (use NSW, nc) |
| | Vic (9) | Black | NSW/Vic | Vic | Vic | yes |
| | SA (10) | Black | (NSW/Vic) | (Vic) | (Vic) | (use Vic) |
| Ruff (14) | WA (6) | A. herring | WA | WA | WA | yes |
| | SA (7) | | Vic | (WA) | Vic | yes |
| Snoek (15) | Vic (4) | Barracoota | Vic/Tas | Vic | Vic | yes |
| Luderick | NSW (9) | | Hg only | NA | NA | no losses |
| Pike | SA (8) | | NA | NA | NA | no |
| Mulloway | SA (10) | | (NSW Hg only) | NA | NA | (as nc) |
| Giant threadfin | Qld (6) | | NA | NA | NA | no |
| Tailor | Qld (7) | | NA | NA | NA | (use NSW, nc) |
| Emperor | Qld (9) | | NA | NA | NA | no |
| Cod | Qld (10) | | NA | NA | NA | no |
| Cobbler | WA (8) | Catfish | Hg only | NA | NA | no losses |

ABLE 61 (cont)

| ECIES roup* | IMPORTANCE TO STATES* | SPECIES | HG/LENGTH | LENGTH/ WEIGHT | SIZE COMPOSITION | ASSESSMENT POSSIBLE? |
|---|---|---|---|---|---|---|
| ewfish | WA (9) | Dhufish | NA | NA | NA | no |
| ght edfish | WA (10) | | WA (Bight) | WA | WA | yes |
| epsea evalla | Developing | | NSW | Vic | Vic | yes |
| ie kerel | Developing | | WA (Bight) | WA | WA | yes |

tes:

G t Australian Bight species for which information for assessment is available - Bight redfish, leatherjacket, deepsea flathead, latchet, yellow spot boarfish, gemfish, queen snapper, hapuku.
Species with maximum Hg less than 0.25 mg/kg - jackass morwong, jack mackerel, ruby fish, knifejaw
Species with mean Hg less than 0.25 mg/kg - trevally, barracouta, yellow spot boarfish, Australian tusk
Species with Hg data only - saw shark, angel shark.

TABLE 62

PREDICTED LOSSES FROM EXERCISING VARIOUS ALTERNATIVES FOR CONTROL OF MERCURY
- predicted percentage losses

Note: Throughout Tables 61-69 brackets indicate where calculations have been based on information extrapolated from different States or species.

| Species group | State | Species | Semi-log or log-log | $R^2$ | F | Sigt. | WT'D mean | U/W mean | Max. Hg. | % Loss 0.25 | | | | % Loss 0.5 | | | | % Loss 0.75 | | | | % Loss 1.0 | | | | % Loss 1.25 | | | | % Loss 1.50 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ |
| (1) TUNA | SA(1) | S.bluefin | NA | NA | NA | NA | n.a. | 0.22 | 0.63 | | | | | | | | | | | | | | | | | | | | | | | | |
| | WA(4) | " | (SA) | | | | | | | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NSW(11) | " | (SA) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (2) SHARK | Vic(1) | gummy | log-log | .12 | 7.12 | YES | 0.41 | 0.42 | 2.40 | 82 | 92 | 100 | 65 | 22 | 34 | 91 | 0 | 4 | 8 | 62 | 0 | 1 | 2 | 38 | 0 | 0 | 1 | 21 | 0 | 0 | 0 | 11 | 0 |
| | | school | log-log | .80 | 584.95 | YES | 0.96 | 0.89 | 3.30 | 94 | 97 | 100 | 88 | 69 | 76 | 94 | 46 | 52 | 57 | 82 | 20 | 41 | 46 | 69 | 4 | 30 | 38 | 61 | 0 | 18 | 31 | 46 | 0 |
| | SA(2) | school | | | | | 1.25 | 1.17 | 2.74 | 100 | 100 | 100 | 99 | 98 | 98 | 100 | 96 | 94 | 95 | 100 | 85 | 76 | 87 | 98 | 43 | 39 | 58 | 95 | 3 | 16 | 35 | 90 | 0 |
| | Tas(1) | gummy | | | | | | 0.42 | 3.04 | (82) | (92) | (100) | (65) | (22) | (34) | (91) | (0) | (4) | (8) | (62) | (0) | (1) | (2) | (38) | (0) | (0) | (1) | (21) | (0) | (0) | (0) | (11) | (0) |
| | | school | | | | | | 0.53 | 2.13 | (94) | (97) | (100) | (88) | (69) | (76) | (94) | (46) | (52) | (57) | (82) | (20) | (41) | (46) | (69) | (4) | (30) | (38) | (61) | (0) | (18) | (31) | (46) | (0) |
| | WA(5) | gummy | log-log | .29 | 43.94 | YES | 0.46 | 0.44 | 2.10 | 98 | 100 | 100 | 95 | 35 | 46 | 100 | 0 | 0 | 8 | 86 | 0 | 0 | 0 | 54 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 10 | 0 |
| | | whiskery | " | .28 | 46.13 | YES | 0.66 | 0.59 | 1.70 | 100 | 100 | 100 | 99 | 87 | 94 | 100 | 70 | 22 | 36 | 99 | 0 | 0 | 8 | 97 | 0 | 0 | 0 | 87 | 0 | 0 | 0 | 61 | 0 |
| | | Bronze Whaler | " | .59 | 207.33 | YES | 1.05 | 0.73 | 2.60 | 100 | 100 | 100 | 99 | 89 | 93 | 100 | 75 | 66 | 70 | 99 | 37 | 48 | 55 | 93 | 5 | 31 | 40 | 86 | 0 | 19 | 28 | 75 | 0 |
| | NSW(5) | mixed spp. | | | | | | | | (91) | (96) | (100) | (83) | (60) | (67) | (94) | (43) | (43) | (47) | (80) | (26) | (33) | (38) | (66) | (11) | (20) | (28) | (56) | (1) | (11) | (20) | (45) | (0) |
| (3) MULLET | NSW(1) | sea | NA | NA | NA | NA | NA | 0.03 | 0.20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(7) | y.eye | semi | .28 | 18.73 | YES | 0.05 | 0.07 | 0.45 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SA(5) | " | (Vic) | | | | | | | (0) | (0) | (5) | (0) | 0 | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | Q(1) | " | (Vic) | | | | | | | (0) | (0) | (5) | (0) | 0 | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | WA(2) | " | (Vic) | | | | | | | (0) | (0) | (5) | (0) | 0 | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | " | sea | (NSW) | – | – | – | – | 0.01 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. SALMON | WA(1) | | n.c. | – | – | NO | | 0.21 | 0.30 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(6) | | " | – | – | NO | | 0.11 | 0.33 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SA(4) | | " | – | – | NO | | | | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | NSW(5) | | " | – | – | NO | | 0.23 | 0.62 | 0 | 100 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tas(2) | | " | – | – | NO | | 0.17 | 0.37 | (0) | (100) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) WHITING | SA(3) | K.G. | NA | NA | NA | NA | NA | 0.05 | 0.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NSW(10) | K.G. | NA | NA | NA | NA | NA | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | sand | semi | .78 | 79.82 | YES | 0.15 | 0.30 | 0.66 | 10 | 18 | 43 | 0 | 0 | 1 | 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(2) | school | (NSW sand) | | | | | | | (10) | (18) | (43) | (0) | (0) | (1) | (10) | (0) | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | K.G. | NA | NA | NA | NA | NA | 0.07 | 0.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | WA(7) | w.sand | (NSW sand) | | | | | | | (10) | (18) | (43) | (0) | (0) | (1) | (10) | (0) | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | K.G. | NA | NA | NA | NA | NA | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Q(3) | G.lined | (NSW sand) | | | | | | | (10) | (18) | (43) | (0) | (0) | (1) | (10) | (0) | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | sand | (NSW sand) | | | | | | | (10) | (18) | (43) | (0) | (0) | (1) | (10) | (0) | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) SNAPPER | NSW(7) | auratus | log-log | .62 | 164.69 | YES | 0.23 | 0.34 | 1.94 | 33 | 40 | 100 | 0 | 3 | 6 | 46 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 0 |
| | Q(5) | " | (NSW) | | | | | | | (33) | (40) | (100) | (0) | (3) | (6) | (46) | (0) | (0) | (0) | (21) | (0) | (0) | (0) | (10) | (0) | (0) | (0) | (3) | (0) | (0) | (0) | (1) | (0) |
| | Vic(5) | " | log-log | | 164.69 | YES | 0.44 | 0.44 | 1.50 | 82 | 88 | 100 | 65 | 48 | 59 | 92 | 0 | 0 | 6 | 73 | 0 | 0 | 0 | 64 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 10 | 0 |
| | SA(6) | " | log-log | | 164.69 | YES | 0.46 | 0.58 | 1.30 | 69 | 76 | 100 | 40 | 36 | 38 | 84 | 0 | 24 | 31 | 51 | 0 | 4 | 16 | 41 | 0 | 0 | 3 | 36 | 0 | 0 | 0 | 32 | 0 |
| | WA(3) | unicolor | log-log | | 73.05 | YES | 0.27 | 0.20 | 1.25 | 47 | 62 | 98 | 5 | 3 | 16 | 83 | 0 | 0 | 1 | 52 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 5 | 0 |

TABLE 62 Cont.

| Species group | State | Species | Semi-log or log-log | $R^2$ | F | Sigt. | WT'D mean | U/W mean | Max. Hg. | % Loss 0.25 | | | | % Loss 0.5 | | | | % Loss 0.75 | | | | % Loss 1.0 | | | | % Loss 1.25 | | | | % Loss 1.50 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ |
| (7) GEMFISH | NSW(2) | | semi | | 551.13 | YES | 0.60 | 0.68 | 3.07 | 99 | 100 | 100 | 97 | 52 | 61 | 99 | 14 | 19 | 23 | 81 | 0 | 8 | 8 | 52 | 0 | 4 | 5 | 31 | 0 | 2 | 3 | 19 | [illegible] |
| (8) FLATHEAD | NSW(3) | Tiger | semi | - | 37.49 | YES | 0.24 | 0.24 | 0.75 | 27 | 43 | 100 | 0 | 5 | 9 | 57 | 0 | 0 | 4 | 27 | 0 | 0 | 1 | 14 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 4 | |
| | | Dusky | NA | NA | NA | NA | NA | 0.13 | 0.22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | (Vic sand) | (NA) | (NA) | (NA) | (NA) | (NA) | | | (0) | (100) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| | Vic(3) | Tiger | semi | | 37.49 | YES | 0.17 | (0.29) | (1.81) | 6 | 9 | 100 | 0 | 4 | 4 | 19 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 2 | |
| (9) MORWONG | NSW(3) | Jackass | log-log | | 16.17 | 4F | 0.18 | 0.27 | 0.49 | 8 | 16 | 82 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Vic(8) | " | " | | 16.17 | 4F | 0.16 | 0.21 | 0.37 | 1 | 5 | 62 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| (10) GIANT | NT(1) | | NA | NA | NA | NA | NA | 0.21 | 0.60 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| PERCH | Q(4) | | | | | | | | | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| (11) REDFISH | NSW(4) | | (WA) | - | - | - | | (0.38) | (0.56) | (100) | (100) | (100) | (100) | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| (12) MACKEREL | Q(2) | Spanish School | | NO DATA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (13) BREAM | Vic(9) | Black | log-log | | 30.41 | YES | 0.22 | 0.25 | 1.17 | 7 | 47 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| | NSW(12) | " | (Vic) | | | | | 0.22 | 0.81 | (7) | (47) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (23) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| | Q(5) | Y/Fin | (NSW) | (NA) | (NA) | (NA) | (NA) | (0.23) | (0.81) | (0) | (100) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| | SA(10) | Black | (Vic) | | | | | (0.15) | (0.27) | (7) | (47) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (23) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| (14) RUFF | WA(6) | | log-log | 0.31 | 53.73 | YES | 0.14 | 0.12 | 0.74 | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| | SA(7) | | (WA/Vic) | | | | | 0.11 | 0.14 | (0) | (0) | (56) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| (15) SNOEK | Vic(4) | | Semi | | 5.83 | 4F* | 0.06 | 0.07 | 0.22 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| MULLOWAY | SA(9) | | (NSW/nc) | (NA) | (NA) | (NA) | (NA) | (0.22) | (0.82) | (0) | (100) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0 |
| LUDERICK | NSW(9) | | | | | | | 0.05 | 0.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| TAILOR | Q(7) | | (NSW) | NA | NA | NA | NA | | | (0) | (0) | (100) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| COBBLER | WA(8) | | | | | | | 0.03 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | [illegible] |
| BIGHT REDFISH | WA(10) BIGHT | | log-log | 0.09 | 4.70 | 4F* | 0.49 | 0.52 | 1.32 | 100 | 100 | 100 | 100 | 33 | 93 | 100 | 0 | 0 | 0 | 98 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 62 Cont.

| Species group | State | Species | Semi-log or log-log | $R^2$ | F | Sigt. | WT'D mean | U/W mean | Max. Hg. | % Loss 0.25 $L_1$ | $L_2$ | $L_3$ | $L_4$ | % Loss 0.5 $L_1$ | $L_2$ | $L_3$ | $L_4$ | % Loss 0.75 $L_1$ | $L_2$ | $L_3$ | $L_4$ | % Loss 1.0 $L_1$ | $L_2$ | $L_3$ | $L_4$ | % Loss 1.25 $L_1$ | $L_2$ | $L_3$ | $L_4$ | % Loss 1.50 $L_1$ | $L_2$ | $L_3$ | $L_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D/S TREVALLA | NSW/Vic | - | log-log | - | 24.86 | YES | 0.33 | 0.47 | 1.23 | 83 | 100 | 100 | 71 | 0 | 2 | 98 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BLUE MACKEREL | BIGHT | | n.c. | - | - | NO | n.a. | 0.15 | 0.37 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LEATHER JACKET | " | | Semi-log | 0.15 | 8.28 | YES | 0.25 | 0.25 | 0.64 | 26 | 65 | 100 | 0 | 0 | 2 | 26 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D/S FLATHEAD | " | | log-log | 0.61 | 77.56 | YES | 0.41 | 0.43 | 0.77 | 91 | 98 | 100 | 86 | 18 | 27 | 86 | 0 | 3 | 5 | 37 | 0 | 1 | 1 | 10 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 |
| LATCHET | " | | log-log | 0.81 | 230.65 | YES | 0.24 | 0.55 | 1.39 | 15 | 19 | 84 | 0 | 5 | 6 | 12 | 0 | 2 | 2 | 6 | 0 | 1 | 1 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Y. SPOTTED BOARFISH | " | | log-log | 0.19 | 10.95 | YES | 0.34 | 0.34 | 0.87 | 83 | 100 | 100 | 70 | 3 | 21 | 100 | 0 | 1 | 3 | 98 | 0 | 0 | 2 | 83 | 0 | 0 | 2 | 48 | 0 | 0 | 0 | 15 | 0 |
| GEMFISH | " | | semi-log | 0.85 | 264.67 | YES | 0.71 | 0.83 | 1.67 | 98 | 99 | 100 | 95 | 73 | 80 | 92 | 40 | 46 | 49 | 76 | 0 | 12 | 19 | 54 | 0 | 0 | 5 | 39 | 0 | 0 | 0 | 7 | 0 |
| QUEEN SNAPPER | " | | log-log | 0.40 | 32.17 | YES | 0.22 | 0.20 | 0.61 | 25 | 49 | 98 | 0 | 0 | 0 | 52 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HAPUKU | " | | log-log | 0.33 | 24.57 | YES | 0.51 | 0.48 | 0.95 | 93 | 99 | 100 | 88 | 40 | 63 | 97 | 2 | 9 | 20 | 87 | 0 | 0 | 7 | 53 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 13 | 0 |
| SAW SHARK ) ANGEL SHARK) | | REFER TABLE 3.1(iii) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Footnote: NA = not available, n.c. = no correlation, n.a. = not applicable.
* Significant at 0.05 level but less than 4F
Species with Max 0.25 i.e. no losses at 0.25
Jackass Morwong, Jack Mackerel, Ruby Fish & Knife Jaw (Squid).
Species with Mean 0.25 Max 0.5
Trevally, Barracouta (= Snoek), Yellow Spotted Boarfish, Australian Tusk.

TABLE 63

PREDICTED LOSSES FROM EXERCISING VARIOUS ALTERNATIVES FOR CONTROL OF MERCURY

- predicted losses in tonnes

| Species Group | State | Species | Catch t. | Total for State | Proportion of State | Proportion of Australia | Loss at 0.25 | | | | Loss at 0.5 | | | | Loss at 0.75 | | | | Loss at 1.0 | | | | Loss at 1.25 | | | | Loss at 1.5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ |
| (1) Tuna | SA(1) | S.bluefin | 8941 | 8941 | 1.0 | 9813 | | | | | | | | | | | | | | | | | | | | | | | |
| | WA(4) | | 492 | 492 | 1.0 | 9941 | 0 | 0 | 9813 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NSW(11) | | 380 | 380 | 1.0 | = 0.99 | | | | | | | | | | | | | | | | | | | | | | | |
| Loss | | | | | | | | | 9813 | | | | | | | | | | | | | | | | | | | | |
| Adjusted Loss | | | | | | | | | 9941 | | | | | | | | | | | | | | | | | | | | |
| (2) Shark | Vic(1) | gummy | 1239* | 2816 | 0.95 | 6931 | 1069 | 1200 | 1304 | 848 | 287 | 443 | 1187 | 0 | 52 | 104 | 809 | 0 | 13 | 26 | 496 | 0 | 0 | 13 | 274 | 0 | 0 | 0 | 143 |
| | | school | 1436 | | 0.95 | 6961 | 1421 | 1466 | 1512 | 1330 | 1043 | 1149 | 1421 | 695 | 786 | 862 | 1240 | 302 | 620 | 696 | 1043 | 60 | 454 | 574 | 922 | 0 | 272 | 469 | 695 |
| | SA(2) | school | | 1200 | 1.0 | = 1.0 | 1200 | 1200 | 1200 | 1188 | 1176 | 1176 | 1200 | 1152 | 1128 | 1140 | 1200 | 1020 | 912 | 1044 | 1176 | 516 | 468 | 696 | 1140 | 36 | 192 | 420 | 1080 |
| | Tas(1) | gummy | 542 | 1130 | 0.95 | | (468) | (524) | (571) | (371) | (126) | (194) | (520) | (0) | (23) | (46) | (354) | (0) | (6) | (11) | (217) | (0) | (0) | (6) | (120) | (0) | (0) | (0) | (63) |
| | | school | 531 | | 0.95 | | (525) | (542) | (559) | (492) | (386) | (425) | (525) | (257) | (291) | (319) | (458) | (112) | (229) | (257) | (386) | (22) | (168) | (212) | (341) | (0) | (101) | (173) | (257) |
| | WA(5) | gummy | 42 | 468 | 0.73 | | 56 | 58 | 58 | 55 | 20 | 27 | 58 | 0 | 0 | 5 | 50 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 6 |
| | | whiskery | 184 | | 0.73 | | 252 | 252 | 252 | 249 | 219 | 237 | 252 | 176 | 55 | 91 | 249 | 0 | 0 | 20 | 244 | 0 | 0 | 0 | 219 | 0 | 0 | 0 | 154 |
| | | b.whaler | 117 | | 0.73 | | 160 | 160 | 160 | 159 | 142 | 149 | 160 | 120 | 106 | 112 | 158 | 59 | 77 | 88 | 149 | 8 | 50 | 64 | 138 | 0 | 30 | 45 | 120 |
| | NSW(5) | mixed | | 1317 | 1.0 | | (1202) | (1261) | (1317) | (1095) | (793) | (886) | (1242) | (560) | (570) | (625) | (1054) | (348) | (433) | (500) | (873) | (141) | (266) | (365) | (740) | (8) | (139) | (258) | (590) |
| | | spp. | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 |
| Total exc NSW | | | | | | | 5151 | 5402 | 5616 | 4692 | 3399 | 3800 | 5323 | 2400 | 2441 | 2679 | 4518 | 1493 | 1857 | 2142 | 3742 | 606 | 1140 | 1565 | 3171 | 36 | 595 | 1107 | 2518 |
| Loss/adjusted | | | | | | | 6353 | 6663 | 6933 | 5787 | 4192 | 4686 | 6565 | 2960 | 3011 | 3304 | 5572 | 1841 | 2290 | 2642 | 4615 | 747 | 1406 | 1930 | 3911 | 44 | 734 | 1365 | 3108 |
| Loss | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (3) Mullet | NSW(1) | sea | 2199 | 2596 | 0.85 | 5882 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(7) | y.eye | ? | 245 | 1.0 | 5892 | 0 | 0 | 12.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SA(5) | " | 320 | 427 | 0.75 | = 1.0 | (0) | (0) | (21.4) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | Q(1) | " | ? | 1358 | 1.0 | | (0) | (0) | (67.9) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | WA(2) | " | 638 | 1256 | 0.88 | | (0) | (0) | (62.8) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | " | sea | 468 | | 0.88 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Loss=adjusted Loss | | | | | | | 0 | 0 | 164.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. salmon | WA(1) | | 1400 | 1400 | 1.0 | 4056 | 0 | 0 | 1400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(6) | | 275 | 275 | 1.0 | 4057 | 0 | 0 | 275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SA(4) | | 985 | 985 | 1.0 | = 1.0 | (0) | (0) | (985) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | NSW(8) | | 613 | 613 | 1.0 | | 0 | 613 | 613 | 0 | 0 | 0 | 613 | 0 | 0 | 0 | 613 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Tas(2) | | 783 | 783 | 1.0 | | (0) | (783) | (783) | (0) | (0) | (0) | (783) | (0) | (0) | (0) | (783) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Loss | | | | | | | 0 | 1396 | 4056 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| adjusted loss | | | | | | | 0 | 1396 | 4057 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Whiting | SA(3) | K.G. | 590 | 991 | 0.60 | 3000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NSW(10) | K.G. | 229 | 400 | 0.89 | 3001 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Sand | 128 | | 0.89 | = 1.0 | 14.3 | 25.9 | 61.8 | 0 | 0 | 1.4 | 14.3 | 0 | 0 | 0 | 1.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(2) | school | 668 | 890 | 1.0 | | (66.8) | (120.2) | (287.2) | (0) | (0) | (6.7) | (66.8) | (0) | (0) | (0) | (6.7) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | K.G. | 222 | | 1.0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | WA(7) | w.sand | 187 | 313 | 0.82 | | (22.8) | (41.0) | (98.0) | (0) | (0) | (2.3) | (22.8) | (0) | (0) | (0) | (2.3) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | K.G. | 71 | | 0.82 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Q(3) | g.lined | ? | 406 | 1.0 | | (40.6) | (73.1) | (174.6) | (0) | (0) | (4.7) | (40.6) | (0) | (0) | (0) | (4.7) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | | sand | ? | | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| loss/adjusted loss | | | | | | | 144.5 | 260.2 | 621.6 | 0 | 0 | 15.1 | 144.5 | 0 | 0 | 0 | 15.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE 63 cont.

| Species Group | State | Species | Catch t. | Total for State | Proportion of State | Proportion of Australia | Loss at 0.25 | | | | Loss at 0.5 | | | | Loss at 0.75 | | | | Loss at 1.0 | | | | Loss at 1.25 | | | | Loss at 1.5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ |
| (6) Snapper | NSW(7) | auratus | 840 | 840 | 1.0 | 2125/2125 = 1.0 | 277.2 | 336.0 | 840 | 0 | 25.2 | 50.4 | 386.4 | 0 | 0 | 0 | 176.4 | 0 | 0 | 0 | 84.0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 8 |
| | Q(5) | " | 158 | 158 | 1.0 | | (52.1) | (63.2) | (158) | (0) | (4.7) | (9.5) | (72.7) | (0) | (0) | (0) | (33.2) | (0) | (0) | (0) | (15.8) | (0) | (0) | (0) | (5) | (0) | (0) | (0) | (2) |
| | Vic(5) | " | 289 | 289 | 1.0 | | 237.0 | 254.3 | 289 | 187.9 | 138.7 | 170.5 | 265.9 | 0 | 0 | 17.3 | 211.0 | 0 | 0 | 0 | 185.0 | 0 | 0 | 0 | 66 | 0 | 0 | 0 | 30 |
| | SA(6) | " | 307 | 307 | 1.0 | | 211.8 | 233.3 | 307 | 122.8 | 110.5 | 116.7 | 257.9 | 0 | 73.7 | 95.2 | 156.6 | 0 | 12.3 | 49.1 | 125.9 | 0 | 0 | 9 | 111 | 0 | 0 | 0 | 98 |
| | WA(3) | unicolor | 531 | 531 | 1.0 | | 249.6 | 329.2 | 520.4 | 0 | 15.9 | 85.0 | 440.7 | 0 | 0 | 5.3 | 276.1 | 0 | 0 | 0 | 191.2 | 0 | 0 | 0 | 85 | 0 | 0 | 0 | 27 |
| loss/adjusted loss | | | | | | | 1027.7 | 1216.0 | 2114.4 | 310.7 | 295.0 | 432.1 | 1423.6 | 0 | 73.7 | 117.8 | 853.3 | 0 | 12.3 | 49.1 | 602 | 0 | 0 | 9 | 292 | 0 | 0 | 0 | 165 |
| (7) Gemfish | NSW(2) | | 2109 | 2109 | 1.0 | 2109/2112 = 1.0 | 2088 | 2109 | 2109 | 2046 | 1097 | 1286 | 2088 | 295 | 401 | 485 | 1708 | 0 | 169 | 169 | 1097 | 0 | 84 | 105 | 654 | 0 | 42 | 63 | 401 |
| (8) Flathead | NSW(3) | tiger | 647 | 1223 | 1.0 | 1881/2020 = 0.93 | 175 | 278 | 647 | 0 | 32 | 58 | 369 | 0 | 0 | 26 | 175 | 0 | 0 | 6 | 91 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 26 |
| | | dusky | 214 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | n.sand | 360 | | | | (0) | (360) | (360) | (0) | (0) | (0) | (360) | (0) | (0) | (0) | (360) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| | Vic(3) | tiger | ? | 658 | 1.0 | | 39 | 59 | 658 | 0 | 26 | 26 | 125 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 13 |
| total | | | | 1881 | | | 214 | 697 | 1665 | 0 | 58 | 84 | 854 | 0 | 0 | 26 | 581 | 0 | 0 | 6 | 124 | 0 | 0 | 0 | 71 | 0 | 0 | 0 | 39 |
| adjusted total | | | | | | | 230 | 749 | 1790 | 0 | 62 | 90 | 918 | 0 | 0 | 28 | 625 | 0 | 0 | 6 | 133 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 42 |
| (9) Morwong | NSW(3) | jackass | 1453 | 1453 | 1.0 | 1653/1752 = 0.94 | 116 | 232 | 1191 | 0 | 0 | 0 | 73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Vic(8) | " | 200 | 200 | 1.0 | | 2 | 10 | 124 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | | | | | | | 118 | 242 | 1315 | 0 | 0 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| adjusted total | | | | | | | 126 | 257 | 1399 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) Giant Perch | NT(1) | | 1163 | 1163 | 1.0 | 1544/1568 = 0.98 | 0 | 0 | 1163 | 0 | 0 | 0 | 1163 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Q(4) | | 381 | 381 | 1.0 | | 0 | 0 | 381 | 0 | 0 | 0 | 381 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| loss | | | | | | | 0 | 0 | 1544 | 0 | 0 | 0 | 1544 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| adjusted loss | | | | | | | 0 | 0 | 1568 | 0 | 0 | 0 | 1568 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTES

*44 and 51% (Walker 1976)
( ) - based on data from another State on species.

TABLE 64

TOP (TEN) SPECIES BY STATE AND AUSTRALIA-WIDE
- predicted losses in tonnes and percentages

| Species Group | Catch | 0.25 $L_1$ | 0.25 $L_2$ | 0.25 $L_3$ | 0.25 $L_4$ | 0.5 $L_1$ | 0.5 $L_2$ | 0.5 $L_3$ | 0.5 $L_4$ | 0.75 $L_1$ | 0.75 $L_2$ | 0.75 $L_3$ | 0.75 $L_4$ | 1.0 $L_1$ | 1.0 $L_2$ | 1.0 $L_3$ | 1.0 $L_4$ | 1.25 $L_1$ | 1.25 $L_2$ | 1.25 $L_3$ | 1.25 $L_4$ | 1.5 $L_1$ | 1.5 $L_2$ | 1.5 $L_3$ | 1.5 $L_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New South Wales - total catch 18673t, total in top 10 species 12549t or 67% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Mullet | 2596 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Gemfish | 2109 | 2088 | 2109 | 2109 | 2046 | 1097 | 1286 | 2088 | 295 | 401 | 485 | 1708 | 0 | 169 | 169 | 1097 | 0 | 84 | 105 | 654 | 0 | 42 | 63 | 401 | 0 |
| (3) Morwong | 1453 | 116 | 232 | 1191 | 0 | 0 | 0 | 73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) Redfish | 1421 | (1421) | (1421) | (1421) | (1421) | (0) | (0) | (1421) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Shark | 1317 | (1202) | (1261) | (1317) | (1095) | (793) | (886) | (1242) | (560) | (570) | (625) | (1054) | (348) | (433) | (500) | (873) | (141) | (266) | (365) | (740) | (8) | (139) | (258) | (590) | (0) |
| (6) Flathead | 1223 | 175 | 278 | 647 | 0 | 32 | 58 | 369 | 0 | 0 | 26 | 175 | 0 | 0 | 6 | 91 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 26 | 0 |
| (7) Snapper | 840 | 277 | 336 | 840 | 0 | 25 | 50 | 386 | 0 | 0 | 0 | 176 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 8 | 0 |
| (8) A. Salmon | 613 | 0 | 613 | 613 | 0 | 0 | 0 | 613 | 0 | 0 | 0 | 613 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (9) Luderick | 577 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) Whiting | 400 | 14 | 26 | 62 | 0 | 0 | 1 | 14 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 5293 | 6276 | 8200 | 4562 | 1947 | 2281 | 6206 | 855 | 971 | 1136 | 3727 | 348 | 602 | 675 | 2145 | 141 | 350 | 470 | 1464 | 8 | 181 | 321 | 1025 | 0 |
| % | | 42 | 50 | 65 | 36 | 16 | 18 | 49 | 7 | 8 | 9 | 30 | 3 | 5 | 5 | 17 | 1 | 3 | 4 | 12 | 0.1 | 1 | 3 | 8 | 0 |
| South Australia - total catch 14499t, total in top 10 species 13304t or 92% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Tuna | 8941 | 0 | 0 | 8941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Shark | 1200 | 1200 | 1200 | 1200 | 1188 | 1176 | 1176 | 1200 | 1152 | 1128 | 1140 | 1200 | 1020 | 912 | 1044 | 1176 | 516 | 468 | 696 | 1140 | 36 | 192 | 420 | 1080 | 0 |
| (3) Whiting | 991 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. Salmon | 995 | (0) | (0) | (985) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Mullet | 427 | (0) | (0) | (21) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) Snapper | 307 | 212 | 233 | 307 | 123 | 110 | 117 | 258 | 0 | 74 | 95 | 157 | 0 | 12 | 49 | 126 | 0 | 0 | 9 | 111 | 0 | 0 | 0 | 98 | 0 |
| (7) Ruff | 228 | (0) | (0) | (128) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Pike | 120 | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| (9) Mulloway | 87 | (0) | (87) | (87) | (0) | (0) | (0) | (87) | (0) | (0) | (0) | (87) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (10) Bream | 13 | (1) | (8) | (18) | (0) | (0) | (0) | (18) | (0) | (0) | (0) | (4) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 1413 | 1528 | 11687 | 1311 | 1286 | 1293 | 1563 | 1152 | 1202 | 1235 | 1448 | 1020 | 924 | 1093 | 1302 | 516 | 468 | 705 | 1251 | 36 | 192 | 420 | 1178 | 0 |
| % | | 11 | 12 | 88 | 10 | 10 | 10 | 12 | 9 | 9 | 9 | 11 | 8 | 7 | 8 | 10 | 4 | 4 | 5 | 9 | 0.2 | 1 | 3 | 9 | 0 |
| Victoria total-catch 10089t, total in top 10 species 5968t or 59% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Shark | 2816 | 2490 | 2666 | 2816 | 2178 | 1330 | 1592 | 2608 | 695 | 838 | 966 | 2049 | 302 | 633 | 721 | 1539 | 60 | 454 | 574 | 922 | 0 | 272 | 469 | 838 | 0 |
| (2) Whiting | 890 | (67) | (120) | (297) | (0) | (0) | (7) | (67) | (0) | (0) | (0) | (7) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Flathead | 658 | 39 | 59 | 658 | 0 | 26 | 26 | 125 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 13 | 0 |
| (4) Snoek | 335 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Snapper | 289 | 237 | 254 | 289 | 188 | 139 | 171 | 266 | 0 | 0 | 17 | 211 | 0 | 0 | 0 | 185 | 0 | 0 | 0 | 66 | 0 | 0 | 0 | 0 | 0 |
| (6) A. Salmon | 275 | 0 | 0 | 275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (7) Mullet | 245 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (8) Morwong | 200 | 2 | 10 | 124 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (9) Bream | 185 | 13 | 87 | 185 | 0 | 0 | 0 | 185 | 0 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) Tuna | 75 | (0) | (0) | (75) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 2848 | 3196 | 4768 | 2366 | 1495 | 1796 | 3253 | 695 | 838 | 983 | 2356 | 302 | 633 | 721 | 1757 | 60 | 454 | 574 | 1014 | 0 | 272 | 469 | 851 | 0 |
| % | | 48 | 54 | 80 | 40 | 25 | 30 | 55 | 12 | 14 | 16 | 39 | 5 | 11 | 12 | 29 | 1 | 8 | 10 | 17 | 0 | 5 | 8 | 14 | 0 |

TABLE 64 cont.

| Species Group | Catch | 0.25 L$_1$ | 0.25 L$_2$ | 0.25 L$_3$ | 0.25 L$_4$ | 0.5 L$_1$ | 0.5 L$_2$ | 0.5 L$_3$ | 0.5 L$_4$ | 0.75 L$_1$ | 0.75 L$_2$ | 0.75 L$_3$ | 0.75 L$_4$ | 1.0 L$_1$ | 1.0 L$_2$ | 1.0 L$_3$ | 1.0 L$_4$ | 1.25 L$_1$ | 1.25 L$_2$ | 1.25 L$_3$ | 1.25 L$_4$ | 1.5 L$_1$ | 1.5 L$_2$ | 1.5 L$_3$ | 1.5 L$_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Western Australia - total catch 7575t, total in top 10 species 5381 or 71% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) A. Salmon | 1400 | 0 | 0 | 1400 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Mullet | 1256 | 0 | 0 | (63) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (3) Snapper | 531 | 250 | 329 | 520 | 0 | 16 | 85 | 441 | 0 | 0 | 5 | 276 | 0 | 0 | 0 | 191 | 0 | 0 | 0 | 85 | 0 | 0 | 0 | 27 | 0 |
| (4) Tuna | 492 | (0) | (0) | (492) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Shark | 468 | 468 | 470 | 470 | 463 | 381 | 412 | 468 | 296 | 161 | 208 | 457 | 59 | 77 | 108 | 424 | 8 | 50 | 64 | 374 | 0 | 30 | 45 | 280 | 0 |
| (6) Ruff | 437 | 0 | 0 | 249 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (7) Whiting | 313 | (23) | (41) | (98) | (0) | (0) | (2) | (23) | (0) | (0) | (0) | (2) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Cobbler | 246 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (9) Jewfish | 155 | | | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | |
| (10) Bight Redfish | 83 | 83 | 83 | 83 | 83 | 27 | 77 | 83 | 0 | 0 | 0 | 81 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 824 | 923 | 3375 | 547 | 424 | 576 | 1015 | 296 | 161 | 213 | 816 | 59 | 77 | 108 | 617 | 8 | 50 | 64 | 459 | 0 | 30 | 45 | 307 | 0 |
| % | | 16 | 18 | 65 | 10 | 8 | 11 | 19 | 6 | 3 | 4 | 15 | 1 | 1 | 2 | 12 | 0.2 | 1 | 1 | 9 | 0 | 0.6 | 0.9 | 6 | 0 |
| Queensland - total catch 5425t, total in top 10 species 4365t or 80% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Mullet | 1358 | (0) | (0) | (68) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (2) Mackerel | 1068 | (0) | (0)+ | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Whiting | 406 | (41) | (73) | (175) | (0) | (0) | (5) | (41) | (0) | (0) | (0) | (5) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (4) G. Perch | 381 | 0 | 0 | 381 | 0 | 0 | 0 | 381 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Bream | 280 | (0) | (280) | (280) | (0) | (0) | (0) | (280) | (0) | (0) | (0) | (280) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) G. Threadfin | 221 | | | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | |
| (7) Tailor | 202 | (0) | (0) | (202) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Snapper | 158 | (52) | (63) | (158) | (0) | (5) | (10) | (73) | (0) | (0) | (0) | (33) | (0) | (0) | (0) | (16) | (0) | (0) | (0) | (5) | (0) | (0) | (0) | (2) | (0) |
| (9) Emperor | 150 | | | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | |
| (10) Cod | 141 | | | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | |
| Total | | 93 | 416 | 1264 | 0 | 5 | 15 | 775 | 0 | 0 | 0 | 318 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 2 | 0 |
| % | | 2 | 11 | 33 | 0 | 0.1 | 0.4 | 20 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 | 0 |
| Tasmania - total catch 2363t, total in top 5 species 2063t or 87% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Shark | 1130 | (993) | (1067) | (1130) | (863) | (512) | (619) | (1045) | (257) | (314) | (365) | (812) | (112) | (235) | (268) | (603) | (22) | (168) | (218) | (461) | (0) | (101) | (173) | (320) | (0) |
| (2) A. Salmon | 783 | (0) | (783) | (783) | (0) | (0) | (0) | (783) | (0) | (0) | (0) | (783) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Morwong | 59 | (4) | (9) | (47) | (0) | (0) | (0) | (3) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (4) D. Sea Trevalla | 54 | (45) | (54) | (54) | (28) | (0) | (1) | (53) | (0) | (0) | (0) | (21) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Snoek | 37 | (0) | (0) | (5) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 1042 | 1913 | 2043 | 901 | 512 | 620 | 1884 | 257 | 314 | 365 | 1616 | 112 | 235 | 268 | 603 | 22 | 168 | 218 | 461 | 0 | 101 | 173 | 320 | 0 |
| % | | 51 | 93 | 99 | 44 | 25 | 30 | 91 | 12 | 15 | 18 | 78 | 5 | 11 | 13 | 29 | 0 | 8 | 11 | 22 | 0 | 5 | 8 | 16 | 0 |

+ using Taiwanese data (Sun and Chang 1972)

TABLE 64 Cont.

| Species Group | Catch | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.50 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L$ | $L_2$ | $L_3$ | $L_4$ |
| Northern Territory - total catch 1483t, total in top 2 species 1378t or 93% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Giant Perch | 1163 | 0 | 0 | 1163 | 0 | 0 | 0 | 1163 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Threadfin | 215 | | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | |
| Total | | 0 | 0 | 1163 | 0 | 0 | 0 | 1163 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | |
| % | | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUSTRALIA - total catch 60111t, total in top 10 species 3942t or 66% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Tuna | 9941 | 0 | 0 | 9941 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Shark | 6961 | 6353 | 6663 | 6933 | 5787 | 4192 | 4686 | 6565 | 2960 | 3011 | 3304 | 5572 | 1841 | 2290 | 2642 | 4615 | 747 | 1406 | 1930 | 3911 | 44 | 734 | 1365 | 3108 | 0 |
| (3) Mullet | 5892 | 0 | 0 | 164 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. Salmon | 4057 | 0 | 1396 | 4057 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 1396 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Whiting | 3001 | 145 | 260 | 622 | 0 | 0 | 15 | 145 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (6) Snapper | 2125 | 1028 | 1216 | 2114 | 311 | 295 | 432 | 1424 | 0 | 74 | 118 | 853 | 0 | 12 | 49 | 602 | 0 | 0 | 9 | 292 | 0 | 0 | 0 | 165 | 0 |
| (7) Gemfish | 2112 | 2086 | 2109 | 2109 | 2046 | 1097 | 1286 | 2088 | 295 | 401 | 485 | 1708 | 0 | 169 | 169 | 1097 | 0 | 84 | 105 | 654 | 0 | 42 | 63 | 401 | 0 |
| (8) Flathead | 2020 | 230 | 749 | 1790 | 0 | 62 | 90 | 918 | 0 | 0 | 28 | 625 | 0 | 0 | 6 | 133 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 42 | 0 |
| (9) Morwong | 1752 | 126 | 257 | 1399 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) G. Perch | 1568 | 0 | 0 | 1568 | 0 | 0 | 0 | 1568 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total loss | | 9970 | 12650 | 30697 | 8144 | 5646 | 6509 | 14184 | 3255 | 3486 | 3935 | 10169 | 1841 | 2471 | 2866 | 6447 | 747 | 1490 | 2044 | 4933 | 44 | 776 | 1428 | 3716 | 0 |
| % loss | | 25 | 29 | 78 | 21 | 14 | 17 | 36 | 8 | 9 | 10 | 26 | 5 | 6 | 7 | 16 | 2 | 4 | 5 | 13 | 0.1 | 2 | 4 | 9 | 0 |

TABLE 65
TOP (TEN) SPECIES BY STATE AND AUSTRALIA-WIDE
- predicted losses in value ($'000) and percentages
* DPI estimates; otherwise ABS

| Species Group | Value - $'000 | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ |
| New South Wales - total catch $12,509,000;total in top 10 species $7,523,000 or 60% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Mullet | 998 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Gemfish | 780 | 772 | 780 | 780 | 757 | 406 | 476 | 772 | 109 | 148 | 179 | 632 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (3) Morwong | 1209 | 97 | 193 | 991 | 0 | 0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 62 | 62 | 406 | 0 | 31 | 39 | 242 | 0 | 16 | 23 | 148 | 0 |
| (4) Redfish | 412 | ( 412) | ( 412) | ( 412) | ( 412) | (0) | (0) | ( 412) | (0) | (0) | (0) | (0) | (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Shark | 529 | ( 481) | ( 508) | ( 529) | ( 439) | (317) | (354) | ( 497) | (227) | (227) | (249) | ( 423) | (138) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) Flathead | 1037 | 145 | 539 | 850 | 0 | 31 | 52 | 622 | 0 | 0 | 21 | 451 | 0 | (175) | (201) | (349) | ( 58) | (106) | (148) | (296) | (5) | ( 58) | (106) | (238) | (0) |
| (7) Snapper | 1763 | 582 | 705 | 1763 | 0 | 53 | 106 | 811 | 0 | 0 | 0 | 370 | 0 | 0 | 5 | 73 | 0 | 0 | 0 | 41 | 0 | 0 | 0 | 21 | 0 |
| (8) A. Salmon | 153 | 0 | 153 | 153 | 0 | 0 | 0 | 153 | 0 | 0 | 0 | 153 | 0 | 0 | 0 | 176 | 0 | 0 | 0 | 53 | 0 | 0 | 0 | 18 | 0 |
| (9) Luderick | 167 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) Whiting | 475 | 19 | 33 | 71 | 0 | 0 | 1 | 19 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 2508 | 3323 | 5549 | 1608 | 807 | 989 | 3346 | 336 | 375 | 449 | 2035 | 138 | 237 | 268 | 1004 | 58 | 137 | 187 | 632 | 5 | 74 | 129 | 425 | 0 |
| % | | 33 | 44 | 74 | 21 | 11 | 13 | 44 | 4 | 5 | 6 | 27 | 2 | 3 | 4 | 13 | 1 | 2 | 2 | 8 | 0 | 1 | 2 | 6 | 0 |
| South Australia - total catch $9,113,000;total in top 9 species $7,929,000 or 87% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Tuna | 3961 | 0 | 0 | 3961 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Shark | 528 | 528 | 528 | 528 | 523 | 517 | 517 | 528 | 507 | 496 | 502 | 528 | 449 | 401 | 459 | 517 | 227 | 195 | 306 | 502 | 16 | 84 | 185 | 475 | 0 |
| (3) Whiting | 2169 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. Salmon | 328 | (0) | (0) | (328) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Mullet | 215 | (0) | (0) | (11) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) Snapper | 432 | 298 | 328 | 432 | 173 | 156 | 164 | 363 | 0 | 104 | 134 | 220 | 0 | 17 | 69 | 177 | 0 | 0 | 13 | 156 | 0 | 0 | 0 | 138 | 0 |
| (7) Ruff | 114 | (0) | (0) | ( 64) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Pike | | NOT CALCULATED | | | | | | | | | | | | | | | | | | | | | | | |
| (9) Mulloway | 157 | (0) | (157) | (157) | (0) | (0) | (0) | (157)) | (0) | (0) | (0) | (157) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (10) Bream | 25 | (2) | (12) | (25) | (0) | (0) | (0) | (25) | (0) | (0) | (0) | (6) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 828 | 1025 | 5506 | 696 | 673 | 681 | 1073 | 507 | 600 | 636 | 911 | 449 | 418 | 528 | 694 | 227 | 195 | 319 | 658 | 16 | 84 | 185 | 613 | 0 |
| % | | 10 | 13 | 69 | 9 | 8 | 9 | 14 | 6 | 8 | 8 | 11 | 6 | 5 | 7 | 9 | 3 | 2 | 4 | 8 | 0 | 1 | 2 | 8 | 0 |
| Victoria total-catch $9,312,000;total in top 10 species $7,136,000 or 77% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Shark | 4358 | 3835 | 4140 | 4358 | 3356 | 2048 | 2484 | 4058 | 1090 | 1307 | 1482 | 3181 | 479 | 959 | 1133 | 2397 | 87 | 697 | 915 | 1830 | 0 | 436 | 741 | 1307 | 0 |
| (2) Whiting | 864 | (69) | (112) | (276) | (0) | (0) | (9) | (69) | (0) | (0) | (0) | (9) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Flathead | 405 | 24 | 24 | 405 | 0 | 16 | 16 | 77 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 8 | 0 |
| (4) Snoek | 241 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Snapper | 608 | 499 | 535 | 608 | 395 | 292 | 359 | 559 | 0 | 0 | 36 | 444 | 0 | 0 | 0 | 389 | 0 | 0 | 0 | 140 | 0 | 0 | 0 | 61 | 0 |
| (6) A. Salmon | 183 | 0 | 0 | 183 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (7) Mullet | 155 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (8) Morwong | 142 | 1 | 7 | 88 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (9) Bream | 135 | 9 | 63 | 135 | 0 | 0 | 0 | 135 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) Tuna | 45 | (0) | (0) | (45) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 4437 | 4881 | 6140 | 3751 | 2356 | 2868 | 4894 | 1090 | 1307 | 1518 | 3693 | 479 | 959 | 1133 | 2806 | 87 | 697 | 915 | 1986 | 0 | 436 | 741 | 1376 | 0 |
| % | | 62 | 68 | 86 | 53 | 33 | 40 | 69 | 15 | 18 | 21 | 52 | 7 | 13 | 16 | 39 | 1 | 10 | 13 | 28 | 0 | 6 | 10 | 19 | 0 |

TABLE 65 cont.

| Species Group | Value - $'000 | 0.25 L1 | 0.25 L2 | 0.25 L3 | 0.25 L4 | 0.5 L1 | 0.5 L2 | 0.5 L3 | 0.5 L4 | 0.75 L1 | 0.75 L2 | 0.75 L3 | 0.75 L4 | 1.0 L1 | 1.0 L2 | 1.0 L3 | 1.0 L4 | 1.25 L1 | 1.25 L2 | 1.25 L3 | 1.25 L4 | 1.5 L1 | 1.5 L2 | 1.5 L3 | 1.5 L4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Western Australia - total catch $4,226,000;total in top 10 species $3,572,000 or 85% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) A. Salmon | 378 | 0 | 0 | 378 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Mullet | 682 | (0) | (0) | (34) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Snapper | 407 | 191 | 252 | 399 | 20 | 12 | 65 | 338 | 0 | 0 | 4 | 212 | 0 | 0 | 0 | 147 | 0 | 0 | 0 | 65 | 0 | 0 | 0 | 2 | 0 |
| (4) Tuna | 201 | (0) | (0) | (201) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Shark | 356 | 356 | 356 | 356 | 352 | 288 | 313 | 356 | 224 | 121 | 157 | 349 | 46 | 57 | 82 | 324 | 7 | 39 | 50 | 285 | 0 | 21 | 36 | 214 | 0 |
| (6) Ruff | 92 | 0 | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (7) Whiting | 335 | (23) | (44) | (104) | (0) | (0) | (2) | (23) | (0) | (0) | (0) | (2) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Cobbler | 492* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (9) Jewfish | 574* | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| (10) Bight Redfish | 55 | 55 | 55 | 55 | 55 | 18 | 51 | 55 | 0 | 0 | 0 | 54 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 625 | 707 | 1579 | 427 | 318 | 431 | 772 | 224 | 121 | 161 | 617 | 46 | 57 | 82 | 472 | 7 | 39 | 50 | 350 | 0 | 21 | 36 | 234 | 0 |
| % | | 21 | 24 | 55 | 14 | 11 | 14 | 26 | 7 | 4 | 5 | 21 | 2 | 2 | 3 | 16 | 0 | 1 | 2 | 12 | 0 | 1 | 1 | 8 | 0 |
| Queensland - total catch $5,298,000;total in top 10 species $3,888,000 or 73% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Mullet | 743 | (0) | (0) | (37) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (2) Mackerel | 1133 | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Whiting | 525 | (53) | (95) | (226) | (0) | (0) | (5) | (53) | (0) | (0) | (0) | (5) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (4) G. Perch | 354* | 0 | 0 | 354 | 0 | 0 | 0 | 354 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Bream | 284 | (0) | (284) | (284) | (0) | (0) | (0) | (284) | (0) | (0) | (0) | (284) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (6) G. Threadfin | 124* | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| (7) Tailor | 166* | (0) | (0) | (166) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (8) Snapper | 215 | (71) | (86) | (215) | (0) | (6) | (13) | (99) | (0) | (0) | (0) | (45) | (0) | (0) | (0) | (22) | (0) | (0) | (0) | (6) | (0) | (0) | (0) | (2) | (0) |
| (9) Emperor | 154* | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| (10) Cod | 190* | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| Total | | 124 | 465 | 1282 | 0 | 6 | 18 | 790 | 0 | 0 | 0 | 334 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 2 | 0 |
| % | | 4 | 14 | 37 | 0 | 0 | 1 | 23 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tasmania - total catch $1,672,000;total in top 5 species $927,000 or 55% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Shark | 664 | (584) | ( 624) | ( 664) | (505) | (299) | (365) | ( 611) | (153) | (186) | (212) | (478) | ( 66) | (139) | (159) | (352) | (13) | (100) | (126) | (272) | (0) | (60) | (100) | (186) | (0) |
| (2) A. Salmon | 190 | (0) | (190) | (190) | (0) | (0) | (0) | (190) | (0) | (0) | (0) | (190) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (3) Morwong | 16 | (1) | (2) | (13) | (0) | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (4) D. Sea Trevalla | 49 | (41) | (49) | (49) | (35) | (0) | (1) | (48) | (0) | (0) | (0) | (19) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| (5) Snoek | 8 | (0) | (0) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Total | | 626 | 865 | 917 | 540 | 299 | 366 | 850 | 153 | 186 | 212 | 687 | 66 | 139 | 159 | 352 | 13 | 100 | 126 | 272 | 0 | 60 | 100 | 186 | 0 |
| % | | 68 | 93 | 99 | 58 | 32 | 39 | 92 | 17 | 20 | 23 | 74 | 7 | 15 | 17 | 38 | 1 | 11 | 14 | 29 | 0 | 6 | 11 | 20 | 0 |

TABLE 65 cont.

| Species Group | Catch | 0.25 $L_1$ | 0.25 $L_2$ | 0.25 $L_3$ | 0.25 $L_4$ | 0.5 $L_1$ | 0.5 $L_2$ | 0.5 $L_3$ | 0.5 $L_4$ | 0.75 $L_1$ | 0.75 $L_2$ | 0.75 $L_3$ | 0.75 $L_4$ | 1.0 $L_1$ | 1.0 $L_2$ | 1.0 $L_3$ | 1.0 $L_4$ | 1.25 $L_1$ | 1.25 $L_2$ | 1.25 $L_3$ | 1.25 $L_4$ | 1.50 L | 1.50 $L_2$ | 1.50 $L_3$ | 1.50 $L_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Northern Territory - total catch $1,664,000;total in top 2 species $1,610,000 or 97% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Giant Perch | 1361 | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Threadfin | 249 | NO INFORMATION | | | | | | | | | | | | | | | | | | | | | | | |
| Total | | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| % | | 0 | 0 | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUSTRALIA - total catch $43,794,000;total in top 10 species $28,247,000 or 64% | | | | | | | | | | | | | | | | | | | | | | | | | |
| (1) Tuna | 4404 | 0 | 0 | 4404 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) Shark | 6447 | 5867 | 6189 | 6447 | 5351 | 3868 | 4319 | 6060 | 2772 | 2772 | 3030 | 5158 | 1676 | 2128 | 2450 | 4255 | 709 | 1289 | 1805 | 3610 | 64 | 709 | 1289 | 2901 | 0 |
| (3) Mullet | 2798 | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (4) A. Salmon | 1232 | 0 | 419 | 1232 | 0 | 0 | 0 | 419 | 0 | 0 | 0 | 419 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (5) Whiting | 4368 | 218 | 393 | 917 | 0 | 0 | 22 | 218 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (6) Snapper | 3425 | 1644 | 1952 | 3425 | 514 | 400 | 685 | 2295 | 0 | 103 | 206 | 1370 | 0 | 21 | 69 | 959 | 0 | 0 | 14 | 480 | 0 | 0 | 0 | 0 | 0 |
| (7) Gemfish | 835 | 827 | 835 | 835 | 810 | 434 | 509 | 827 | 117 | 159 | 192 | 676 | 0 | 67 | 67 | 4340 | 0 | 33 | 42 | 259 | 0 | 17 | 25 | 159 | 0 |
| (8) Flathead | 1547 | 170 | 572 | 1377 | 0 | 46 | 62 | 696 | 0 | 0 | 15 | 480 | 0 | 0 | 5 | 108 | 0 | 0 | 0 | 62 | 0 | 0 | 0 | 31 | 0 |
| (9) Morwong | 1380 | 97 | 207 | 1104 | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (10) G. Perch | 1811* | 0 | 0 | 1811 | 0 | 0 | 0 | 1811 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total loss | | 8823 | 10567 | 21636 | 6675 | 4828 | 5597 | 12395 | 2889 | 3034 | 3443 | 8125 | 1676 | 2216 | 2591 | 5756 | 709 | 1322 | 1861 | 4411 | 64 | 726 | 1314 | 3091 | 0 |
| % loss | | 31 | 37 | 77 | 24 | 17 | 20 | 44 | 10 | 11 | 12 | 29 | 6 | 8 | 9 | 20 | 3 | 5 | 7 | 16 | 0 | 3 | 5 | 11 | 0 |

## TABLE 66

**PREDICTED LOSSES FROM EXERCISING VARIOUS ALTERNATIVES FOR CONTROL OF MERCURY**
- in weight and value, and percentage weight and value - 1976-77 catches

| MERCURY LEVEL (mg/kg) | | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALTERNATIVES | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ |
| New South Wales | '000 tonnes (t) | 5.3 | 6.3 | 8.2 | 4.6 | 1.9 | 2.3 | 6.2 | 0.9 | 1.0 | 1.1 | 3.7 | 0.3 | 0.6 | 0.7 | 2.1 | 0.1 | 0.4 | 0.5 | 1.5 | 0 | 0.2 | 0.3 | 1.0 | 0 |
| | $000 value (v) | 2508 | 3323 | 5549 | 1608 | 807 | 989 | 3346 | 336 | 375 | 449 | 2035 | 138 | 237 | 268 | 1004 | 58 | 137 | 187 | 632 | 5 | 74 | 129 | 425 | 0 |
| 12549/18673* | % weight | 42 | 50 | 65 | 36 | 16 | 18 | 49 | 7 | 8 | 9 | 30 | 3 | 5 | 5 | 17 | 1 | 3 | 4 | 12 | 0.1 | 1 | 3 | 8 | 0 |
| | % value | 33 | 44 | 74 | 21 | 11 | 13 | 44 | 4 | 5 | 6 | 27 | 2 | 3 | 4 | 13 | 1 | 2 | 2 | 8 | 0 | 1 | 2 | 6 | 0 |
| South Australia | t | 1.4 | 1.5 | 11.7 | 1.3 | 1.3 | 1.3 | 1.6 | 1.2 | 1.2 | 1.2 | 1.4 | 1.0 | 0.9 | 1.1 | 1.3 | 0.5 | 0.5 | 0.7 | 1.2 | 0 | 0.2 | 0.4 | 1.2 | 0 |
| | v | 828 | 1025 | 5506 | 696 | 673 | 681 | 1073 | 507 | 600 | 636 | 911 | 449 | 418 | 528 | 694 | 227 | 195 | 319 | 658 | 16 | 84 | 185 | 613 | 0 |
| | % weight | 11 | 12 | 88 | 10 | 10 | 10 | 12 | 9 | 9 | 9 | 11 | 8 | 7 | 8 | 10 | 4 | 4 | 5 | 9 | 0.2 | 1 | 3 | 9 | 0 |
| 13304/14499* | % value | 10 | 13 | 69 | 9 | 8 | 9 | 14 | 6 | 8 | 8 | 11 | 6 | 5 | 7 | 9 | 3 | 2 | 4 | 8 | 0 | 1 | 2 | 8 | 0 |
| Victoria | t | 2.8 | 3.2 | 4.8 | 2.4 | 1.5 | 1.8 | 3.3 | 0.7 | 0.8 | 1.0 | 2.4 | 0.3 | 0.6 | 0.7 | 1.8 | 0 | 0.5 | 0.6 | 1.0 | 0 | 0.3 | 0.5 | 0.9 | 0 |
| | v | 4437 | 4881 | 6140 | 3751 | 2356 | 2868 | 4894 | 1090 | 1307 | 1518 | 3693 | 479 | 959 | 1133 | 2806 | 87 | 697 | 915 | 1986 | 0 | 436 | 741 | 1376 | 0 |
| 5968/10089* | % weight | 48 | 54 | 80 | 40 | 25 | 30 | 55 | 12 | 14 | 16 | 39 | 5 | 11 | 12 | 29 | 1 | 8 | 10 | 17 | 0 | 5 | 8 | 14 | 0 |
| | % value | 62 | 68 | 86 | 53 | 33 | 40 | 69 | 15 | 18 | 21 | 52 | 7 | 13 | 16 | 39 | 1 | 10 | 13 | 28 | 0 | 6 | 10 | 19 | 0 |
| Western Australia | t | 0.8 | 0.9 | 3.4 | 0.5 | 0.4 | 0.6 | 1.0 | 0.3 | 0.2 | 0.2 | 0.8 | 0.1 | 0.1 | 0.1 | 0.6 | 0 | 0.1 | 0.1 | 0.5 | 0 | 0 | 0 | 0.3 | 0 |
| | v | 625 | 707 | 1577 | 427 | 318 | 431 | 772 | 224 | 121 | 161 | 617 | 46 | 57 | 82 | 472 | 7 | 39 | 50 | 350 | 0 | 21 | 36 | 234 | 0 |
| 5381/7575* | % weight | 16 | 18 | 65 | 10 | 8 | 11 | 19 | 6 | 3 | 4 | 16 | 1 | 1 | 2 | 12 | 0 | 1 | 2 | 9 | 0 | 0 | 0 | 6 | 0 |
| | % value | 21 | 24 | 53 | 14 | 11 | 14 | 26 | 7 | 4 | 5 | 21 | 2 | 2 | 3 | 16 | 0 | 1 | 2 | 12 | 0 | 1 | 1 | 8 | 0 |
| Queensland | t | 0.1 | 0.4 | 1.3 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | v | 124 | 465 | 1282 | 0 | 6 | 18 | 790 | 0 | 0 | 0 | 334 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 2 | 0 |
| 4365/5425* | % weight | 2 | 11 | 33 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | % value | 4 | 14 | 37 | 0 | 0 | 1 | 23 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tasmania | t | 1.0 | 1.9 | 2.0 | 0.9 | 0.5 | 0.6 | 1.9 | 0.3 | 0.3 | 0.4 | 1.6 | 0.1 | 0.2 | 0.3 | 0.6 | 0 | 0.2 | 0.2 | 0.5 | 0 | 0.1 | 0.2 | 0.3 | 0 |
| | v | 626 | 865 | 917 | 540 | 299 | 366 | 850 | 153 | 186 | 212 | 687 | 66 | 139 | 159 | 352 | 13 | 100 | 126 | 272 | 0 | 60 | 100 | 186 | 0 |
| | % Weight | 51 | 93 | 99 | 44 | 25 | 30 | 91 | 12 | 15 | 18 | 78 | 5 | 11 | 13 | 29 | 0 | 8 | 11 | 22 | 0 | 5 | 8 | 16 | 0 |
| 2063/2363* | % value | 68 | 93 | 99 | 58 | 32 | 39 | 92 | 17 | 20 | 23 | 74 | 7 | 15 | 17 | 38 | 1 | 11 | 14 | 29 | 0 | 6 | 11 | 20 | 0 |
| Australia | t | 10.0 | 12.7 | 30.7 | 8.1 | 5.6 | 6.5 | 14.2 | 3.3 | 3.5 | 3.9 | 10.2 | 1.8 | 2.5 | 2.9 | 6.4 | 0.7 | 1.5 | 2.0 | 4.9 | 0 | 0.8 | 1.4 | 3.7 | 0 |
| | v | 8823 | 10567 | 21636 | 6675 | 4828 | 5597 | 12395 | 2889 | 3034 | 3443 | 8125 | 1676 | 2216 | 2591 | 5756 | 709 | 1322 | 1861 | 4411 | 64 | 726 | 1314 | 3091 | 0 |
| 39429/60111* | % weight | 25 | 29 | 78 | 21 | 14 | 17 | 36 | 8 | 9 | 10 | 26 | 5 | 6 | 7 | 16 | 2 | 4 | 5 | 13 | 0 | 2 | 4 | 9 | 0 |
| | % value | 31 | 37 | 77 | 24 | 17 | 20 | 44 | 10 | 11 | 12 | 29 | 6 | 8 | 9 | 20 | 3 | 5 | 7 | 16 | 0 | 3 | 5 | 11 | 0 |

* Weight in top 10 species/total weight landed

4.2(ii) Procedures for individual species

It is emphasised that complete data have not always been available to the Working Group and at the time of writing it was not considered expedient to attempt the search for all the missing information. The assumptions made in the various computations and the basis for any extrapolations between States and between species, together with sources of all-data, have been carefully documented, (see Table 61 and Appendix 8). Any modifications required to the calculations can then, if required, be included at a later date. Reference to Table 19 in Section 3.1(iii) will also give information on unweighted mercury means and ranges for species both included and excluded from assessments.

4.2(iii) Locality differences in mercury concentrations

Comparisons of mercury concentration between fishing areas only become valid when identical sizes and ages of fish are compared. An unweighted mean makes no reference to size, and in a weighted mean area differences in mercury concentration may be masked by area differences in size composition. The most useful basis for comparison between areas is therefore the mercury/size relationship.

Examples of locality differences in mercury concentration, for example in North Atlantic halibut and in dogfish, have been cited in Section 2.4 (iii). A locality difference was detected for Australian shark, in particular between male gummy sharks (Walker 1976). His observation that mercury concentrations were higher in males than females, more so in gummy shark than school shark, indicates that sex differences between areas must also be taken into consideration. Data provided to the Working Group rarely distinguished between sexes so that this component of any locality differences could not be taken into account.

An obvious source of difference between localities would be the influence of polluting mercury, as demonstrated for sand flathead (Ratkowsky et al 1975; Dix et al 1975) and in data provided to the Working Group (Table 19, Section 3.1 (iii)). However, some locality differences appear to have no association with a point source of mercury emission. For example, the mercury concentrations shown in Figure 8 were from snapper samples taken from three areas within 120 km of each other, and show significantly different mercury/size relationships. Clear differences are seen between mercury concentrations in western and eastern snapper (Table 19, Section 3.1 (iii), but these are considered to be different species. However, T.I. Walker (pers. comm.) has also detected a significant difference between two stocks of eastern snapper off Victoria but without identifying the underlying cause. Area differences have also been reported for New Zealand snapper (Robertson et al 1975).

TABLE 67

LOCALITY DIFFERENCES FOR MERCURY IN AUSTRALIAN FISH

| Species | Areas | Correlation | Length* (cm) at mean mercury conc | | |
|---|---|---|---|---|---|
| | | | 0.25 | 0.5 | 0.75 |
| Sand flathead | Oceanic | log-log | 42 | 57 | G.T.60 |
| | Inlet | " " | L.T.20 | 27 | 39 |
| Snapper | WA | log-log | 55 | 66.5 | G.T.69 |
| | Eastern | " " | 38 | 61 | 80 |
| Gummy shark | WA | log-log | 53 | 73 | 89 |
| | Vic. m | " " | 72 | 89 | 99 |
| | f | " " | 72 | 101 | 122 |
| Gemfish | NSW | semi-log | 62.5 | 77 | 85 |
| | WA | " " | 50 | 71 | 84 |
| Angel shark | WA | log-log | 71 | 115 | G.T.130 |
| | NSW | " " | 91 | 127.5 | G.T.130 |

* Gummy shark - partial length, other species - Length to caudal fork.

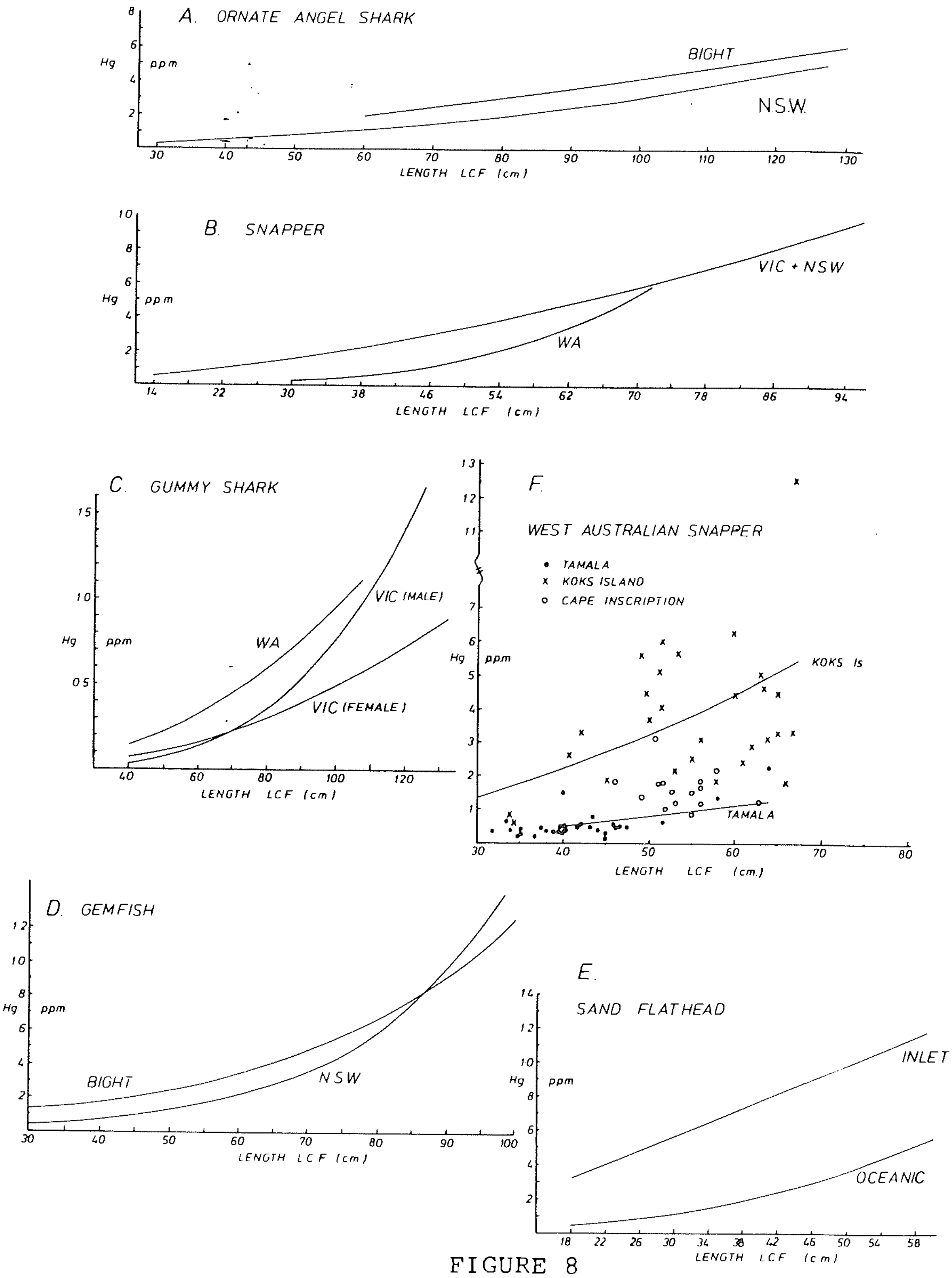



FIGURE 8

RELATIONSHIP BETWEEN TOTAL MERCURY AND LENGTH IN VARIOUS SPECIES, DEMONSTRATING AREAS DIFFERENCES

1. The choice of correlation (semi-log or log-log) is listed in the text Table 67.

2. Comparison of log-log relationships for snapper from areas within 120 km of each other in Shark Bay, W.A.

In data made available to the Working Group, convincing locality differences were identified only in 3 other species - gummy shark between WA and Victoria, gemfish between NSW and WA, and angel shark between WA and NSW, though here again two species of angel shark seem to be involved. These are given in Table 67 in which pairs of lengths predicting three mean mercury concentrations are compared using identical types of mercury/length regressions, i.e. both semi-log, or both log-log, and in Figure 8.

Although there are few examples these do nevertheless underline the need for collecting data representative of the area under consideration.

4.2(iv) Species of importance in emerging fisheries

The necessary data for detailed analyses in newly developing fisheries are generally unavailable or insufficiently representative. However, the information available is presented below to give some guide to the likely effects of a mercury standard on these developing fisheries. For brevity reference will only be made to the current standard of 0.5 mg/kg.

The fisheries will be considered under the following headings:-

(a) South-east of Australia.
(b) The Great Australian Bight.
(c) The North-West Shelf.
(d) Pelagic fisheries.
(e) Tuna fisheries.
(f) Squid.
(g) Billfish, light fish and lantern fish

(a) South-east of Australia

A number of species have shown potential for significant expansion in this area including deep sea trevalla, deep sea flathead, blue grenadier, king dory, gemfish, squid, jack mackerel, striped tuna, many shark species, etc.

Reference to Tables 19 & 20 in 3.1(iii) shows that unweighted means of gemfish and shark would exceed 0.5 mg/kg, but individuals of deep sea trevalla and deepwater flathead (Table 62) would be in this category. No data are available on king dory, but mirror dory averaged 0.16, max. 0.36 (NSW), John dory 0.13, max. 0.29 (Tas) and 0.32, max. 1.24 (Bight), and silver dory 0.05, max. 0.1 (Tas) and 0.17, max. 0.5 (Bight). Blue grenadier (NSW) averaged 0.31, max. 1.55 mg/kg. Other species will be referred to below.

(b) Great Australian Bight

A trawling venture in the Great Australian Bight from 1977 to 1979 identified the fishery potential. Major species in likely order of importance are blue mackerel, Bight redfish, leatherjacket, jackass morwong, jack mackerel, shark spp. including saw shark, ruby fish, trevally, deep sea flathead, knife jaw, swallow tail, latchet, barracouta, boarfish, gemfish, squid, Queen snapper, angel shark and hapuku.

Reference to Table 62 shows that only gemfish and sharks had average mercury levels much in excess of 0.5 mg/kg, while Bight redfish and latchet were above but close to 0.5. However, a number of other species with means of less than 0.5 had maxima in excess of 0.5 - leatherjacket, deep sea flathead, yellow spotted boarfish, Queen snapper and hapuku.

(c) North-West Shelf

The total catch from this fishery by Taiwanese pair trawlers is estimated to have reached 42,000 tonnes in 1974 (FAICOM Report 1978) although this had fallen to 10,000 tonnes in 1976. It is not known what proportion of N.W. Shelf catches will eventually be taken by Australian fishing vessels or reach Australian markets. Preliminary results of feasability fishing operations suggest that up to half of the catch from the area could be directed to the domestic market. The most important species comprising the Taiwanese catch in 1976 (FAICOM Report 1978) were in order of importance: Golden thread, lizard fish, porgies, shark, cuttlefish, amber fish, sergeant fish, grunters; followed by goatfish, pompanos, red snapper, squid, trevally, rays and lesser species.

Limited mercury data are available directly from this fishery. 48 samples from 19 species caught by a Taiwanese trawler from the north-west fishing grounds show total mercury levels of 0.1 mg/kg or less. Seven of the species listed above were represented. There are a few relevant data from other sources, (e.g. Sun and Chang 1972), for reference purposes.

(d) Pelagic Fisheries

Major species, as shown from surveys, are jack mackerel, blue mackerel and pilchard, all with low concentrations of mercury.

(e) Tuna

The Fishing and Allied Industries Committee of WA considered that the tuna fisheries of the Indian Ocean have the greatest potential for economic Australian participation in her 200 mile fishing zone (FAICOM Report 1978). That report listed the major species, some of which have relevance to other Australian waters:

Skipjack or striped tuna (Katsuwonus pelamis)
Mackerel tuna (Euthynnus affinis)
Yellowfin tuna (Thunnus albacares)
Northern bluefin tuna (Thunnus tonggol)
Southern bluefin tuna (Thunnus maccoyii)

Australian mercury data on tuna is limited to southern bluefin from SA, Tables 61 and 62 and Tables 19 & 20 in Section 3.1(iii) and striped tuna from Tasmania (20 samples averaging 0.15 mg/kg, range 0.11-0.17). 154 Taiwanese samples of yellowfin tuna averaged 0.21 (0.05-0.62) (Sun and Chang, 1972) and nine Japanese samples from Australia's east coast 0.25 (0.16-0.35). There is a considerable body of mercury analyses on tuna species from overseas which generally shows mean mercury levels of less than 0.5 mg/kg but with individuals exceeding this in some species (see Section 2.4(iii)).

(f) Squid and cuttlefish

As of 6 March 1979 (Ministerial Press Release) five feasibility fishing ventures had been approved by the Australian Government for squid, involving a total of 36 boats, and already Japanese squid vessels were taking encouraging catches in south-eastern waters within the Australian 200 mile Fishing Zone. 13 Samples of squid (Nototodarus gouldi) from Tasmania averaged 0.05 mg/kg (0.02-0.27) and two cuttlefish (Sepia spp.) 0.2. Mercury concentrations in squid, as in other invertebrates, are generally consistently low as shown by 40 samples from squid imported into WA (mean 0.02, range 0.01-0.06) and 120 samples of cuttlefish (mean 0.02, range 0.01-0.04). Squid (Loligo spp.) and cuttlefish (Sepia spp.) from the North West Shelf (para. (ii) above) and squid (Nototodarus gouldi) from the Bight therefore seem unlikely to cause problems from mercury concentrations.

(g) Billfish, light fish and lantern fish

The 1978 report of the Working Group on the 200 mile Australian Fishing Zone concluded that billfish, which include the marlins and the sailfish, are not now, nor are they likely to be in the future, of direct economic use to Australia except as the centrepiece of very valuable sports charter fisheries. Legislation in New South Wales already permits the fishing for marlin only for recreational purposes. Black marlin from Queensland have been found to contain up to 16.5 mg/kg total mercury (Table 19, Section 3.1 (iii)). Although light fish and lantern fish are said to be abundant off the Australian Coast, they will probably be more appropriate for industrial application.

## 4.3 Likely effects of controls

### 4.3(i) Existing fisheries

#### (a) The current situation

Assessment of the likely effects of controls needs to be undertaken against the background of the current Australian situation of a National recommended standard for mercury of 0.5 mg/kg, with Commonwealth and State (except for South Australia) regulations specifying the same maximum concentration. Such comments need to take account of average and maximum concentrations in fish caught and fish consumed as well as information on quantities and species eaten which was provided in Section 3. Table 19 of Section 3.1 (iii) provides current information, by species and by States, of maximum mercury concentrations. In addition, computations have been made of weighted (by quantity and where possible by size) average mercury concentrations using the best data available, as follows:

| | | | mg/kg |
|---|---|---|---|
| * | (1) | Ten most important finfish species caught in Australia | 0.31 |
| | (2) | Ten most important finfish species caught in New South Wales | 0.31 |
| | (3) | Ten most important finfish species caught in South Australia | 0.29 |
| | (4) | Ten most important finfish species caught in Victoria | 0.42 |
| + | (5) | Ten most important finfish species caught in Western Australia | 0.21 |
| * | (6) | 25 most important finfish species caught in Australia | 0.28 |
| | (7) | 20 most important fish species consumed in Australia (Section 3.1 (iii)) | 0.17 |
| | (8) | Fish and seafoods eaten by the average and extreme consumer (Section 3.3(ii)) | 0.15 |

* Data given in Table 68

\+ For remaining States there were inadequate data for computation of averages.

TABLE 68

CALCULATION OF WEIGHTED MEAN MERCURY CONCENTRATION IN MOST IMPORTANT AUSTRALIAN SPECIES

(data for 1976-77)

| | Species group | Weight landed (tonnes) | Mean mercury* | |
|---|---|---|---|---|
| 1. | Tuna | 9941 | 0.22 | |
| 2. | Shark | 6961 | 0.82* | |
| 3. | Mullet | 5892 | 0.04* | |
| 4. | A. salmon | 4057 | 0.17 | |
| 5. | Whiting | 3001 | 0.10* | |
| 6. | Snapper | 2125 | 0.30* | |
| 7. | Gemfish | 2112 | 0.60* | |
| 8. | Flathead | 2020 | 0.20* | |
| 9. | Morwong | 1752 | 0.18* | |
| 10. | Giant Perch | 1568 | 0.21 | 39429 t or 66% of total |
| 11. | Redfish | 1512 | 0.38* | |
| 12. | Mackerel | 1279 | 0.13 | |
| 13. | Bream | 881 | 0.22* | |
| 14. | Pilchard | 872° | | |
| 15. | Ruff | 704 | 0.12* | |
| 16. | Luderick | 703 | 0.05 | |
| 17. | Garfish | 509 | 0.03 | |
| 18. | Mulloway | 493 | 0.13 | |
| 19. | Threadfin | 448 | no information | |
| 20. | Snoek | 416 | 0.06* | |
| 21. | Tailor | 377 | 0.22 | |
| 22. | Kingfish | 374 | 0.13 | |
| 23. | Leatherjacket | 357 | 0.25* | |
| 24. | Trevally | 329 | 0.19 | |
| 25. | John Dory | 251 | 0.31 | |
| 26. | Cobbler | 246 | 0.03 | 49180 t or 82% of total |

Weighted mean for top ten species = 0.31 mg/kg
Weighted mean for top 25 species (excluding pilchard) = 0.28 mg/kg

* Weighted means; otherwise unweighted means of best available information.

o Few pilchard used for human consumption.

Shellfish (invertebrate) species were not included in estimates (1) - (7) because, even though they are important quantitatively, a large proportion of most species is exported. Invertebrates appeared in (8) but for the most part contained low concentrations of mercury.

Estimate (8) includes the catches of amateur fishermen - fish recorded as "caught or a gift" in the P.A. consumer survey (1978) constituted 27% of all fresh and frozen fish, including imports, consumed.

The calculations were based on data unaffected by the current 0.5 mg/kg standard, since these data pre-dated the imposition of mercury controls. The only species likely to have been affected by the latter would be eastern school shark in Victoria and the various shark species in Western Australia. This would mean that the present day average concentration of mercury in shark marketed would be less than the 0.82 mg/kg given in Table 68 and used for computing the values above.

Some data are available from the United States and the United Kingdom for comparison with the above figures. Finch (1973) calculated the weighted average of the mercury levels of all the species consumed in the United States as "below 0.20 ppm". The Working Party on Monitoring of Food Stuffs (1971) gave overall average concentrations for fish and shellfish eaten in the United Kingdom as 0.08 and 0.13 mg/kg respectively. The fish included 64% from distant waters averaging 0.06 mg/kg, 18% from middle distance waters with 0.11 mg/kg and a small percentage from coastal waters with 0.21 mg/kg - the latter included some areas with averages of 0.5 mg/kg. The arithmetic means of samples of fish obtained by Lindsay (in press) during his duplicate diet study (Section 2.5) were 0.27 mg/kg (NE Irish Sea) and 0.22 mg/kg (SW English Channel).

(b) Changes in weight and value

The results of calculations to evaluate likely losses in weight and value, by species, by State and Australia-wide, consequent on exercising the various alternatives for control discussed in Section 4.2 (i) and Appendix 7, have been presented in Tables 62-65 and summarised in Table 66. In addition Table 69 presents for those species for which adequate data were available,

(1) approximate values of maximum size

(2) Average and maximum mercury concentrations in the retained catch (upper 95% of mercury at maximum size specified), and

(3) The weights of fish containing less than the identified standard expressed both as a percentage of discarded fish and of the total catch.

TABLE 69

SUMMARY OF MAXIMUM LENGTHS, MEAN AND MAXIMUM MERCURY CONCENTRATIONS IN CATCH REMAINING AND PREDICTED WEIGHTS OF FISH CONTAINING LESS THAN THE IDENTIFIED STANDARD

expressed both as (i) a percentage of discarded fish and (ii) of the total catch calculated for alternatives $L_1$ to $L_4$ for each of the mercury standards 0.25 to 1.5 mg/kg

| State | Species | Semi-log or log-log | Parameter | | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.5 | | | | Length Measurement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | |
| Vic | Gummy shark | log-log | i) Maximum length (cm) | F | 73 | 67 | 49 | 80 | 102 | 95 | 69 | NA | 123 | 114 | 84 | NA | 130 | 126 | 95 | NA | >130 | >130 | 105 | NA | >130 | >130 | 115 | NA | PARTIAL |
| | | | | M | 72 | 68 | 55 | 79 | 89 | 85 | 67 | NA | 100 | 96 | 76 | NA | 108 | 104 | 83 | NA | 116 | 110 | 89 | NA | 122 | 115 | 94 | NA | |
| | (sexes combined) | | ii) Mean Hg remaining | | .21 | .17 | - | .25 | .34 | .30 | .17 | .41 | .38 | .36 | .25 | .41 | .40 | .40 | .32 | .41 | .41 | .41 | .35 | .41 | .41 | .41 | .41 | .41 | |
| | Weighted mean: 0.41 | | iii) Max Hg remaining | | .61 | .51 | - | .85 | 1.26 | 1.09 | .50 | M | 1.75 | >1.5 | .75 | M | >1.8 | >1.8 | 1.0 | M | >1.8 | >1.8 | 1.25 | M | >1.8 | >1.8 | 1.5 | M | |
| | Max: 2.40 | | iv) % of rejects | | 17 | 22 | 27 | 13 | 33 | 40 | 66 | NA | 40 | 49 | 82 | NA | 38 | 60 | 87 | NA | NA | 52 | 88 | NA | NA | NA | 82 | NA | |
| | | | v) % of catch | | 14 | 20 | 27 | 8 | 7 | 14 | 60 | NA | 2 | 4 | 51 | NA | 0 | 1 | 33 | NA | NA | 0 | 18 | NA | NA | NA | 9 | NA | |
| Vic | School shark | log-log | i) Maximum length (cm) | F | 64 | 61 | 54 | 68 | 80 | 77 | 67 | 95 | 90 | 88 | 75 | NA | 98 | 95 | 83 | NA | 105 | 102 | 89 | NA | 112 | 107 | 94 | NA | PARTIAL |
| | | | | M | 68 | 65 | 56 | 72 | 80 | 77 | 66 | 90 | 87 | 85 | 72 | 100 | 93 | 90 | 77 | 108 | 98 | 94 | 81 | NA | 102 | 97 | 84 | NA | |
| | (sexes combined) | | ii) Mean Hg remaining | | .21 | .19 | - | .25 | .36 | .32 | .22 | .50 | .46 | .43 | .29 | .75 | .54 | .50 | .36 | .94 | .64 | .57 | .41 | .96 | .76 | .63 | .45 | .96 | |
| | Weighted mean : 0.96 | | iii) Max Hg remaining | | .59 | .48 | - | .75 | 1.17 | .98 | .56 | 1.6 | 1.5 | 1.6 | .75 | 1.6 | 1.6 | 1.6 | 1.0 | 1.6 | 1.6 | 1.6 | 1.25 | M | 1.6 | 1.6 | 1.5 | M | |
| | Max: 3.30 | | iv) % of rejects | | 4 | 5 | 8 | 2 | 9 | 13 | 25 | 2 | 13 | 14 | 36 | 4 | 19 | 23 | 42 | 5 | 28 | 33 | 51 | NA | 33 | 45 | 60 | NA | |
| | | | v) % of.catch | | 4 | 5 | 8 | 2 | 6 | 10 | 24 | 1 | 9 | 8 | 29 | 1 | 8 | 11 | 30 | 0 | 8 | 13 | 30 | NA | 6 | 17 | 28 | NA | |
| WA | Gummy shark | log-log | i) Maximum length (cm) | | 53 | 47 | <40 | 55 | 73 | 70 | 48 | NA | 90 | 83 | 59 | NA | >100 | 92 | 68 | NA | >100 | 100 | 75 | NA | >100 | >100 | 82 | NA | PARTIAL |
| | | | ii) Mean Hg remaining | | .23 | - | - | .25 | .38 | .36 | - | .46 | .46 | .44 | .28 | .46 | .46 | .46 | .35 | .46 | .46 | .46 | .39 | .46 | .46 | .46 | .43 | .46 | |
| | Weighted mean: 0.46 | | iii) Max Hg remaining | | .61 | - | - | .65 | 1.18 | 1.07 | - | >1.7 | >1.7 | 1.56 | .75 | >1.7 | >1.7 | >1.7 | 1.01 | >1.7 | >1.7 | >1.7 | 1.24 | >1.7 | >1.7 | >1.7 | 1.52 | >1.7 | |
| | Max: 2.10 | | iv) % of rejects | | 15 | 16 | 16 | 14 | 36 | 40 | 58 | NA | NA | 55 | 80 | NA | NA | NA | 87 | NA | NA | NA | 91 | NA | NA | NA | 94 | NA | |
| | | | v) % of catch | | 15 | 16 | 16 | 14 | 12 | 18 | 58 | NA | NA | 4 | 69 | NA | NA | NA | 47 | NA | NA | NA | 26 | NA | NA | NA | 10 | NA | |
| WA | Whiskery shark | log-log | i) Maximum length (cm) | | 50 | 44 | <40 | 51 | 62 | 60 | 45 | 65 | 71 | 69 | 52 | NA | 78 | 74 | 57 | NA | 84 | 79 | 62 | NA | 89 | 83 | 66 | NA | PARTIAL |
| | | | ii) Mean Hg remaining | | - | - | - | .26 | .43 | .38 | - | .50 | .61 | .58 | .27 | .66 | .66 | .64 | .33 | .66 | .66 | .66 | .43 | .66 | .66 | .66 | .53 | .66 | |
| | Weighted mean: 0.66 | | iii) Max Hg remaining | | - | - | - | .72 | 1.28 | 1.15 | - | 1.46 | 1.9 | 1.76 | .76 | 1.9 | 1.9 | 1.9 | .99 | 1.9 | 1.9 | 1.9 | 1.28 | 1.9 | 1.9 | 1.9 | 1.54 | 1.9 | |
| | Max: 1.70 | | iv) % of rejects | | 6 | 6 | 6 | 6 | 29 | 31 | 33 | 26 | 41 | 45 | 59 | NA | NA | 55 | 76 | NA | NA | NA | 85 | NA | NA | NA | 89 | NA | |
| | | | v) % of catch | | 6 | 6 | 6 | 5 | 26 | 29 | 33 | 18 | 9 | 16 | 59 | NA | NA | 4 | 74 | NA | NA | NA | 74 | NA | NA | NA | 55 | NA | |
| WA | Bronze-whaler | log-log | i) Maximum length (cm) | | 31 | 28 | <20 | 35 | 47 | 44 | 28 | 55 | 61 | 58 | 36 | 80 | 73 | 69 | 43 | 108 | 84 | 78 | 49 | NA | 94 | 86 | 55 | NA | PARTIAL |
| | | | ii) Mean Hg remaining | | - | - | - | .24 | .42 | .39 | - | .51 | .56 | .53 | .27 | .75 | .67 | .63 | .38 | 1.0 | .79 | .72 | .44 | 1.05 | .88 | .81 | .51 | 1.03 | |
| | Weighted mean: 1.05 | | iii) Max Hg remaining | | - | - | - | .72 | 1.17 | 1.05 | - | 1.5 | >1.7 | 1.63 | .75 | >1.7 | >1.7 | >1.7 | 1.01 | >1.7 | >1.7 | >1.7 | 1.23 | >1.7 | >1.7 | >1.7 | 1.5 | >1.7 | |
| | Max: 2.60 | | iv) % of rejects | | 3 | 3 | 3 | 3 | 12 | 14 | 18 | 8 | 18 | 21 | 36 | 9 | 26 | 29 | 49 | 8 | 31 | 37 | 60 | NA | 37 | 43 | 66 | NA | |
| | | | v) % of catch | | 3 | 3 | 3 | 3 | 11 | 13 | 18 | 6 | 12 | 15 | 36 | 3 | 13 | 16 | 46 | 0 | 10 | 15 | 51 | NA | 7 | 12 | 50 | NA | |
| NSW | Snapper | log-log | i) Maximum length (cm) | | 38 | 36 | 21 | NA | 61 | 56 | 34 | NA | 79 | 71 | 44 | NA | 96 | 86 | 52 | NA | >100 | 97 | 61 | NA | >100 | >100 | 69 | NA | LCF |
| | | | ii) Mean Hg remaining | | .16 | .16 | - | .23 | .22 | .21 | .15 | .23 | .23 | .23 | .18 | .23 | .23 | .23 | .20 | .23 | .23 | .23 | .22 | .23 | .23 | .23 | .23 | .23 | |
| | Weighted mean: 0.23 | | iii) Max Hg remaining | | .62 | .54 | - | >1.8 | 1.26 | 1.09 | .50 | >1.8 | >1.8 | 1.6 | .75 | >1.8 | >1.8 | >1.8 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 1.94 | | iv) % of rejects | | 29 | 33 | 61 | NA | 40 | 48 | 79 | NA | NA | NA | 86 | NA | NA | NA | 91 | NA | NA | NA | 92 | NA | NA | NA | 94 | NA | |
| | | | v) % of catch | | 10 | 13 | 61 | NA | 1 | 3 | 37 | NA | NA | NA | 18 | NA | NA | NA | 9 | NA | NA | NA | 3 | NA | NA | NA | 1 | NA | |

M = max Hg in raw data
NA = not applicable
- = 100% loss

Table 69 (cont)

| State | Species | Semi-log or log-log | Parameter | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.5 | | | | Length Measurement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | |
| Vic | Snapper | log-log | i) Maximum length(cm) | 38 | 36 | 21 | 51 | 61 | 56 | 34 | NA | 79 | 71 | 44 | NA | 96 | 86 | 52 | NA | >100 | 97 | 61 | NA | >100 | >100 | 69 | NA | LCF |
| | | | ii) Mean Hg remaining | .19 | .18 | - | .25 | .32 | .27 | .15 | .44 | .44 | .43 | .22 | .44 | .44 | .44 | .25 | .44 | .44 | .44 | .37 | .44 | .44 | .44 | .42 | .44 | |
| | Weighted mean: 0.44 | | iii) Max Hg remaining | .61 | .54 | - | >1.9 | 1.26 | 1.09 | .50 | >1.9 | 1.86 | 1.6 | .75 | >1.9 | >1.9 | >1.9 | 1.0 | >1.9 | >1.9 | >1.9 | 1.25 | >1.9 | >1.9 | >1.9 | >1.5 | >1.9 | |
| | Max: 1.50 | | iv) % of rejects | 14 | 16 | 23 | 8 | 39 | 42 | 56 | NA | NA | 58 | 74 | NA | NA | NA | 86 | NA | NA | NA | 92 | NA | NA | NA | 94 | NA | |
| | | | v) % of catch | 11 | 14 | 23 | 5 | 19 | 24 | 52 | NA | NA | 4 | 54 | NA | NA | NA | 51 | NA | NA | NA | 45 | NA | NA | NA | 12 | NA | |
| SA | Snapper | log-log | i) Maximum length(cm) | 38 | 36 | 21 | 53 | 61 | 56 | 34 | NA | 79 | 71 | 44 | NA | 96 | 86 | 52 | NA | >100 | 97 | 61 | NA | >100 | >100 | 69 | NA | LCF |
| | | | ii) Mean Hg remaining | .20 | .19 | - | .25 | .26 | .25 | .18 | .46 | .32 | .28 | .23 | .46 | .44 | .37 | .25 | .46 | .46 | .45 | .21 | .46 | .46 | .46 | .22 | .46 | |
| | Weighted mean: 0.46 | | iii) Max Hg remaining | .62 | .53 | - | >1.9 | 1.27 | 1.09 | .50 | >1.9 | 1.86 | 1.60 | .75 | >1.9 | >1.9 | >1.9 | 1.0 | >1.9 | >1.9 | >1.9 | 1.25 | >1.9 | >1.9 | >1.9 | 1.5 | >1.9 | |
| | Max: 1.30 | | iv) % of rejects | 17 | 21 | 33 | 3 | 20 | 22 | 56 | NA | 37 | 41 | 58 | NA | 47 | 53 | 68 | NA | NA | 63 | 78 | NA | NA | NA | 85 | NA | |
| | | | v) % of catch | 12 | 16 | 33 | 1 | 7 | 9 | 47 | NA | 9 | 13 | 29 | NA | 2 | 8 | 28 | NA | NA | 2 | 28 | NA | NA | NA | 27 | NA | |
| WA | Snapper | log-log | i) Maximum length(cm) | 62 | 59 | 45 | 73 | 75 | 70 | 54 | NA | 84 | 76 | 61 | NA | 90 | 82 | 65 | NA | 96 | 86 | 70 | NA | 96 | 90 | 73 | NA | LCF |
| | | | ii) Mean Hg remaining | .18 | .15 | .07 | .25 | .26 | .23 | .11 | .27 | .27 | .27 | .17 | .27 | .27 | .27 | .21 | .27 | .27 | .27 | .23 | .27 | .27 | .27 | .25 | .27 | |
| | Weighted mean: 0.27 | | iii) Max Hg remaining | .83 | .67 | .25 | >1.7 | 1.65 | 1.25 | .50 | >1.7 | >1.7 | >1.7 | .75 | >1.7 | >1.7 | >1.7 | 1.0 | >1.7 | >1.7 | >1.7 | 1.25 | >1.7 | >1.7 | >1.7 | 1.5 | >1.7 | |
| | Max: 1.25 | | iv) % of rejects | 31 | 36 | 50 | 16 | 45 | 55 | 76 | NA | NA | 64 | 84 | NA | NA | NA | 89 | NA | NA | NA | 91 | NA | NA | NA | 92 | NA | |
| | | | v) % of catch | 15 | 22 | 49 | 1 | 1 | 9 | 63 | NA | NA | 1 | 44 | NA | NA | NA | 32 | NA | NA | NA | 14 | NA | NA | NA | 5 | NA | |
| NSW | Gemfish | semi-log | i) Maximum length(cm) | 62 | 60 | 48 | 65 | 77 | 75 | 63 | 87 | 85 | 84 | 71 | NA | 91 | 90 | 77 | NA | 96 | 94 | 82 | NA | 100 | 98 | 85 | NA | LCF |
| | | | ii) Mean Hg remaining | .22 | - | - | .25 | .39 | .37 | .23 | .50 | .48 | .47 | .32 | .60 | .52 | .52 | .39 | .60 | .55 | .54 | .45 | .60 | .57 | .56 | .48 | .60 | |
| | Weighted mean: 0.60 | | iii) Max Hg remaining | .50 | - | - | .56 | 1.01 | .91 | .50 | 1.57 | 1.52 | 1.39 | .75 | >2.0 | >2.0 | >2.0 | 1.0 | >2.0 | >2.0 | >2.0 | 1.25 | >2.0 | >2.0 | >2.0 | 1.5 | >2.0 | |
| | Max: 3.07 | | iv) % of rejects | 8 | 8 | 8 | 7 | 22 | 27 | 45 | 4 | 26 | 30 | 67 | NA | 25 | 29 | 74 | NA | 28 | 34 | 77 | NA | 31 | 38 | 79 | NA | |
| | | | v) % of catch | 8 | 8 | 8 | 7 | 11 | 17 | 45 | 1 | 5 | 7 | 54 | NA | 2 | 3 | 38 | NA | 1 | 2 | 24 | NA | 1 | 1 | 15 | NA | |
| NSW | Tiger Flathead | semi-log | i) Maximum length(cm) | 43 | 40 | 28 | NA | 52 | 49 | 38 | NA | 58 | 53 | 43 | NA | 62 | 56 | 47 | NA | >63 | 58 | 50 | NA | >63 | 61 | 53 | NA | |
| | | | ii) Mean Hg remaining | .18 | .16 | - | .24 | .22 | .21 | .14 | .24 | .24 | .23 | .17 | .24 | .24 | .23 | .20 | .24 | .24 | .24 | .21 | .24 | .24 | .24 | .22 | .24 | |
| | Weighted mean: 0.24 | | iii) Max Hg remaining | .73 | .58 | - | >1.9 | 1.46 | 1.14 | .50 | >1.9 | >1.9 | 1.58 | .75 | >1.9 | >1.9 | >1.9 | 1.0 | >1.9 | >1.9 | >1.9 | 1.25 | >1.9 | >1.9 | >1.9 | 1.5 | >1.9 | |
| | Max: 0.75 | | iv) % of rejects | 27 | 37 | 59 | NA | 36 | 46 | 79 | NA | NA | 57 | 83 | NA | NA | 62 | 86 | NA | NA | NA | 88 | NA | NA | NA | 88 | NA | |
| | | | v) % of catch | 17 | 16 | 59 | NA | 2 | 4 | 45 | NA | NA | 2 | 22 | NA | NA | 1 | 12 | NA | NA | NA | 7 | NA | NA | NA | 3 | NA | |
| VIC | Tiger Flathead | semi-log | i) Maximum length(cm) | 43 | 40 | 28 | NA | 52 | 49 | 38 | NA | 58 | 53 | 43 | NA | 62 | 56 | 47 | NA | >63 | 58 | 50 | NA | >63 | 61 | 53 | NA | |
| | | | ii) Mean Hg remaining | .14 | .14 | - | .17 | .16 | .15 | .13 | .17 | .17 | .16 | .14 | .17 | .17 | .17 | .15 | .17 | .17 | .17 | .15 | .17 | .17 | .17 | .16 | .17 | |
| | Weighted mean: 0.17 | | iii) Max Hg remaining | .73 | .58 | - | >1.8 | 1.46 | 1.14 | .50 | >1.8 | >1.8 | 1.58 | .75 | >1.8 | >1.8 | >1.8 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 1.81 | | iv) % of rejects | 19 | 30 | 77 | NA | 43 | 43 | 79 | NA | NA | NA | 76 | NA | NA | NA | 85 | NA | NA | NA | 90 | NA | NA | NA | 93 | NA | |
| | | | v) % of catch | 1 | 3 | 77 | NA | 2 | 2 | 15 | NA | NA | NA | 5 | NA | NA | NA | 5 | NA | NA | NA | 4 | NA | NA | NA | 2 | NA | |
| WA | Bight Redfish | log-log | i) Maximum length(cm) | 20 | <20 | <20 | NA | 39 | 34 | <20 | NA | >55 | 48 | 32 | NA | >55 | >55 | 44 | NA | >55 | >55 | 52 | NA | NA | NA | NA | NA | |
| | | | ii) Mean Hg remaining | - | - | - | - | .47 | .42 | - | .49 | .49 | .49 | .40 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | .49 | |
| | Weighted mean: 0.49 | | iii) Max Hg remaining | - | - | - | - | .90 | .79 | - | >1.3 | >1.3 | 1.12 | .75 | >1.3 | >1.3 | >1.3 | 1.0 | >1.3 | >1.3 | >1.3 | 1.25 | >1.3 | >1.3 | >1.3 | >1.3 | >1.3 | |
| | Max: 1.32 | | iv) % of rejects | 26 | 26 | 26 | 26 | 48 | 50 | 51 | NA | NA | NA | 65 | NA | NA | NA | 67 | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | | v) % of catch | 26 | 26 | 26 | 26 | 16 | 47 | 51 | NA | NA | NA | 64 | NA | NA | NA | 1 | NA | NA | NA | NA | NA | NA | NA | NA | NA | |

Table 69 (cont)

| State | Species | Semi-log or log-log | Parameter | 0.25 | | | | 0.5 | | | | 0.75 | | | | 1.0 | | | | 1.25 | | | | 1.5 | | | | Length Measurement |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | $L_1$ | $L_2$ | $L_3$ | $L_4$ | |
| NSW/ | Deep sea Trevalla | log-log | i) Maximum length (cm) | 62 | 55 | <55 | 64 | 75 | 72 | 58 | NA | 84 | 80 | 67 | NA | 91 | 85 | 73 | NA | 96 | 89 | 77 | NA | 103 | 110 | 81 | NA | |
| Vic | | | ii) Mean Hg remaining | .23 | - | - | .25 | .32 | .32 | .19 | .33 | .33 | .33 | .29 | .33 | .33 | .33 | .32 | .33 | .33 | .33 | .33 | .33 | .33 | .33 | .33 | .33 | |
| | Weighted mean: 0.33 | | iii) Max Hg remaining | .57 | - | - | .65 | 1.12 | .95 | .50 | >1.8 | 1.69 | 1.4 | .75 | >1.8 | >1.8 | 1.77 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 1.23 | | iv) % of rejects | 26 | 31 | 31 | 23 | NA | 58 | 81 | NA | NA | NA | 93 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| | | | v) % of catch | 21 | 31 | 31 | 16 | NA | 1 | 79 | NA | NA | NA | 35 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | |
| WA | Deep sea Flathead | log-log | i) Maximum length (cm) | 45 | 41 | <38 | 46 | 57 | 55 | 46 | NA | 66 | 63 | 53 | NA | 74 | 69 | 60 | NA | 80 | 74 | 64 | NA | 84 | 77 | 57 | NA | |
| | | | ii) Mean Hg remaining | .24 | .20 | - | .25 | .36 | .34 | .25 | .41 | .39 | .39 | .33 | .41 | .40 | .40 | .38 | .41 | .41 | .41 | .39 | .41 | .41 | .41 | .38 | .41 | |
| | Weighted mean: 0.41 | | iii) Max Hg remaining | .47 | .38 | - | >1.8 | .89 | .82 | .50 | >1.8 | 1.35 | 1.18 | .75 | >1.8 | >1.8 | 1.55 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 0.77 | | iv) % of rejects | 28 | 30 | 30 | 27 | 40 | 44 | 59 | NA | 44 | 48 | 66 | NA | 48 | 51 | 66 | NA | NA | NA | 69 | NA | NA | NA | 73 | NA | |
| | | | v) % of catch | 25 | 29 | 30 | 23 | 7 | 12 | 51 | NA | 1 | 2 | 24 | NA | NA | NA | 6 | NA | NA | NA | 2 | NA | NA | NA | 2 | NA | |
| WA | Latchet | log-log | i) Maximum length (cm) | 30 | 29 | 25 | NA | 36 | 35 | 31 | NA | 41 | 40 | 35 | NA | 45 | 44 | 38 | NA | 48 | 46 | 41 | NA | 50 | 49 | 43 | NA | |
| | | | ii) Mean Hg remaining | .19 | .18 | .14 | .24 | .21 | .20 | .19 | .24 | .22 | .22 | .20 | .24 | .22 | .22 | .21 | .24 | .24 | .24 | .21 | .24 | .24 | .24 | .22 | .24 | |
| | Weighted mean: 0.24 | | iii) Max Hg remaining | .42 | .37 | .25 | >1.8 | .85 | .79 | .50 | >1.8 | 1.28 | 1.17 | .75 | >1.8 | 1.72 | 1.55 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 1.39 | | iv) % of rejects | 21 | 26 | 58 | NA | 29 | 33 | 51 | NA | 28 | 31 | 56 | NA | 34 | 37 | 53 | NA | NA | NA | 58 | NA | NA | NA | NA | NA | |
| | | | v) % of catch | 3 | 5 | 49 | NA | 1 | 2 | 6 | NA | 1 | 1 | 3 | NA | NA | 1 | 2 | NA | NA | NA | 1 | NA | NA | NA | NA | NA | |
| WA | Gemfish | semi-log | i) Maximum length (cm) | 50 | 45 | 35 | 54 | 71 | 68 | 57 | 84 | 84 | 82 | 70 | NA | 93 | 91 | 80 | NA | 100 | 97 | 86 | NA | >100 | >100 | 95 | NA | |
| | | | ii) Mean Hg remaining | .23 | .21 | - | .25 | .38 | .34 | .27 | .50 | .50 | .49 | .37 | >1.0 | .65 | .62 | .47 | .71 | .70 | .68 | .54 | .71 | .71 | .71 | .67 | .71 | |
| | Weighted mean: 0.71 | | iii) Max Hg remaining | .40 | .34 | .25 | .45 | .77 | .70 | .50 | 1.15 | 1.15 | 1.07 | .75 | >1.7 | 1.55 | 1.45 | 1.0 | >1.7 | >1.7 | >1.7 | 1.25 | >1.7 | >1.7 | >1.7 | 1.5 | >1.7 | |
| | Max: 1.67 | | iv) % of rejects | 26 | 27 | 27 | 26 | 39 | 40 | 42 | 35 | 45 | 45 | 49 | NA | 47 | 48 | 53 | NA | 49 | 50 | 56 | NA | NA | NA | 51 | NA | |
| | | | v) % of catch | 25 | 27 | 27 | 24 | 28 | 32 | 39 | 16 | 21 | 22 | 37 | NA | 6 | 9 | 28 | NA | 1 | 2 | 22 | NA | NA | NA | 4 | NA | |
| WA | Hapuku | log-log | i) Maximum length (cm) | 63 | 55 | <50 | 68 | 78 | 75 | 60 | 94 | 88 | 84 | 69 | NA | 97 | 90 | 76 | NA | >100 | 95 | 82 | NA | >100 | 98 | 86 | NA | |
| | | | ii) Mean Hg remaining | .22 | .15 | - | .25 | .40 | .35 | .19 | .50 | .47 | .44 | .26 | .51 | .51 | .48 | .38 | .51 | .51 | .51 | .51 | .51 | .51 | .51 | .51 | .51 | |
| | Weighted mean: 0.51 | | iii) Max Hg remaining | .57 | .39 | - | .71 | 1.07 | .95 | .50 | >1.8 | 1.61 | 1.38 | .75 | >1.8 | >1.8 | 1.74 | 1.0 | >1.8 | >1.8 | >1.8 | 1.25 | >1.8 | >1.8 | >1.8 | 1.5 | >1.8 | |
| | Max: 0.95 | | iv) % of rejects | 33 | 34 | 35 | 32 | 43 | 46 | 51 | 35 | 46 | 49 | 59 | NA | NA | 52 | 62 | NA | NA | NA | 62 | NA | NA | NA | 64 | NA | |
| | | | v) % of catch | 31 | 34 | 35 | 29 | 17 | 29 | 49 | 1 | 4 | 10 | 51 | NA | NA | 4 | 33 | NA | NA | NA | 15 | NA | NA | NA | 8 | NA | |

Since the data analysed pre-date any mercury controls, the results represent the total cost to the fishing industry, rather than additional costs over and above those already experienced.

Using the current standard of 0.5 mg/kg as a reference basis, it can be seen that the most extreme losses would be for alternative $L_3$, which ensures (with 97½% confidence) that no fish will exceed 0.5 mg/kg, and which was to have been supported by a regulation under the Trade Practices Act. Under this alternative, percentage losses in weight and value (Table 66) would range from 12% (1600t) and 14% ($1,073,000) respectively in South Australia to 91% (1900t) and 92% ($850,000) in Tasmania (Table 66). It should be noted that the Tasmanian percentages represent relatively small totals, that they are dominated by shark, and that all Tasmanian calculations were extrapolated from other States. The magnitude of loss is generally determined by the relative concentration of mercury in dominant species (Table 64). Losses from Victoria (55 and 69%) and New South Wales (49 and 44%) represent large absolute losses as well as percentages. The Australian average losses would be 36% (14,200t) and 44% ($12,395,000).

The losses for $L_3$ would be greater for 0.25 mg/kg while becoming progressively less between 0.75 and 1.5 mg/kg. Percentages lost do not change markedly over the latter range. This is also true of all alternatives $L_1$ to $L_4$.

Since the above analysis uses data which pre-date any mercury controls, it does not permit quantification of the existing real situation, i.e. in which a proportion of shark landed in Victoria and Western Australia may not be marketed. The abolition of controls would be expected initially at least to increase the quantity of larger shark being landed, although the extent of any such increase would be tempered by the existence of a black market trade in large shark, especially across State borders.

(c) Further economic and social consequences of controls

The above discussion has concentrated on the short term impact of imposing different mercury levels without regard to their effects on the livelihood of fishermen and others connected with the fishing industry and for the longer term implications of such measures. These economic considerations have been discussed in some detail in a report to the Working Group by Jarzynski (1979) and are briefly considered below.

Any reduction in fish supply should result in a price rise for fish in the short term; the magnitude of this increase will depend on the size of the reduction, the demand elasticities for the various species and the readiness with which substitutes become available. In the longer term, imports should increase and consumers may switch to other fish species and non-fish items, dampening the price rise to a large extent. Thus the benefits to fishermen of a price rise will tend to be smaller than otherwise.

The short term impact on some sections of the fishing industry could be quite severe. Reductions in fish production of the order expected under certain alternatives for control and mercury standards, especially the $L_3$ alternative could have a significant adverse impact on many fishermen and fishing communities. The hardest hit fishermen would be those where gemfish, shark or snapper form a significant portion of the catch. There are few alternative fishing activities to absorb displaced fishermen in areas where such species are caught.

Generally, the small operators, part-time and estuarine fishermen would escape the impact of mercury restrictions. Plants processing gemfish would have severe financial problems in remaining viable, and seasonal and female employment opportunities would be severely restricted in a number of fishing ports, especially along the NSW and Victorian east coasts.

A large reduction of shark, a non seasonal catch, and gemfish, both basic fish in the processing and convenience fast food sectors, would add a considerable degree of price and product instability into the fresh fish market.

The two situations in which restrictions on the landing or sale of certain sizes of shark have been made in Australia, one in Victoria since 1972 (school shark) and the other in Western Australia since 1975 (all shark species) have provided the only real data on such economic consequences. However, the quantification of the effects of these measures is complicated by data inadequacies, by the large part-time component of the fishery and by underlying market trends.

Nevertheless, the data available suggest that a considerable fall in shark production resulted, together with a rise in the price paid for shark in both States and an increase in imports of possible substitute fish.

Although some fishermen left the industry, the impact on shark fishermen in general appears to have been minor. The most important reasons for this were the increase in price of shark which partly compensated for lower production and the existence of close alternative fisheries notably the rock lobster and tuna fishery in Western Australia and the gummy shark fishery in Victoria. In the latter fishery however, there has been increased and considerable pressure on the available stocks.

(d) Changes in average mercury concentration

Using Tables 63 and 69 it is possible to calculate the average mercury concentration in the catch remaining of the top ten Australian species after exercising the various alternatives for control, as follows:

| Standard | Alternative | Average mercury remaining mg/kg | % Loss Weight | % Loss Value |
|---|---|---|---|---|
| No control | | 0.31 | 0 | 0 |
| 0.5 | $L_3$ | 0.15 | 36 | 44 |
| | $L_4$ | 0.22 | 8 | 10 |
| 1.0 | $L_3$ | 0.18 | 16 | 20 |
| | $L_4$ | 0.28 | 2 | 3 |
| 1.5 | $L_3$ | 0.21 | 9 | 11 |
| | $L_4$ | 0.31 | 0 | 0 |

These results can be compared with the figure obtained (Table 68) for the weighted mean mercury concentration in the most important Australian species, i.e. 0.31 mg/kg in the top ten, which represent 66% of the total Australian catch (Table 64), and 0.28 mg/kg in the top twenty-five, which excludes pilchard, a species for which only a small proportion is used for human consumption.

(The use of 0.31 (or 0.28) mg/kg provides an extreme basis for assessment since the average concentration in the top twenty species consumed in Australia has been shown to be 0.17 mg/kg, and the average mercury in fish and shellfish eaten by both the average and the extreme consumer 0.15 mg/kg (para (a) above)).

It can be seen that after exercising alternative $L_3$ for a standard of 0.5 mg/kg, the mean mercury concentration in the top ten Australian species could be reduced from 0.31 to 0.15 mg/kg - this could involve not only an overall loss of 36% by weight and 44% by value of the catch of the top ten species, but could eliminate 99% of gemfish, 94% of sharks, 67% of snapper, 45% of flathead and 34% of Australian salmon. Table 69 also shows how, for example, in Victorian school shark, alternative $L_3$ could, in order to restrict the maximum mercury in any individual shark offered for sale to 0.5 mg/kg, result in the rejection of 94% of fish (Table 69) of which 25% (24% of the total catch) would not have exceeded 0.5 mg/kg.

At alternative $L_4$, which ensures that the average remaining in any individual species would not exceed 0.5 mg/kg, only shark and gemfish would be likely to be affected, and the average mercury level in the catch remaining of the top ten species would be 0.22 mg/kg. This would be expected to involve an overall loss of 8% by weight and 10% by value, and to include a 17% weight loss of sharks and 14% of gemfish.

Alternatives $L_1$ and $L_2$ would give values for the average mercury remaining between those of $L_3$ and $L_4$.

It should be noted that even with a standard of 1.5 mg/kg the exercise of alternative $L_3$ should result in a mean mercury concentration in the catch remaining which exceeds 0.5 mg/kg only in WA whiskery shark (0.53), WA bronze whaler (0.51), WA gemfish (0.67) and hapuku (0.51).

Clearly the exercise of control based on eliminating individuals from the catch, using alternative $L_3$ with a tandard of 0.5 mg/kg, would, while reducing the average mercury concentration from 0.31 to 0.15, be very costly to the industry as a whole and to fishermen of certain species of fish. The problem of sorting trawled gemfish would be different from that of netted sharks for which size at capture can be administered to some extent by control of mesh size. Control based on the average concentration in the catch remaining ($L_4$) should reduce the average mercury from 0.31 to 0.22, while having much less effect on the industry. Alternative $L_4$ with a standard of 1.0 mg/kg should reduce the average mercury concentration to 0.28. Fish with the highest mercury levels would be eliminated from the catch, except with alternative $L_4$ for 1.5 mg/kg for which there would be no losses.

It has been noted above that in the current situation where a measure of control of sharks already exists, the abolition of controls should be expected to result in an increase in the quantity of large shark landed. Since these contain higher mercury concentrations than smaller sharks they would contribute to a marginally higher overall average mercury concentration in sharks offered for sale, but this should not exceed the average figure of 0.82 mg/kg used for sharks when computing the average in all species (Table 68). By the same token, heavy exploitation of any species including shark, would reduce the average size and therefore the average mercury concentrations.

It has been suggested to the Working Group that while the choice of the 95% confidence interval is a useful statistical yardstick, it may not be identical with the degree of tolerance expected or permitted by Health Inspectors. However, the latter is likely to be difficult to quantify; instead the 95% interval will need to be used as a reference point on which to base alternative levels of acceptability.

(e) Changes in maximum mercury concentration

Maximum mercury concentrations in the catch remaining after exercising the various alternatives for control are shown in Table 69 for the individual species for which adequate data were available. It will be noted that using alternative $L_3$ the maximum would be equal to the limiting standard, i.e. 0.25, 0.5, etc. (except where the whole catch would have been eliminated, noted by - in Table 69). This was also true even where the maximum mercury concentration recorded for the species (column 2 of Table 69) was less than the selected standard, the reason for this being that in the method chosen for the purpose of computation, the standard was referred to the 95% confidence intervals for the average and individual mercury data (see Figures 6 and 7 and Appendix 7).

The degree of importance attached to the maximum mercury concentration in the catch before or after the application of controls will reflect the attitude taken by the regulatory authority after due consideration of the information provided by the Working Group on average mercury levels in the catch, and on the probability of sustained consumption of the larger sizes of species with the higher mercury concentrations.

(f) The "no correlation" situation

The foregoing represents the Working Group's analysis of species for which data, defined as adequate, were available for regression analysis, from which significant (according to selected criteria) correlations between mercury concentration and size of fish were obtained. For species with inadequate data or a non-significant correlation, for example tuna and Australian salmon (Table 61 et seq.), a "no correlation" analysis was applied.

Reference to mercury/size regressions provides the opportunity for sorting a catch on the basis of size of fish, i.e. by the administration of a legal maximum size. As stated above, this may in some circumstances result in a considerable loss of the catch, a proportion of which is composed of individual fish in which the mercury concentration does not exceed the standard, coupled with administrative costs incurred by the fishing industry and the inspecting authority.

The "no correlation" approach does not allow sorting of the catch and therefore represents an "all-or- nothing" situation in which the whole catch must be either accepted or rejected or in which warnings to the public should be considered as an alternative.

The choice of approach will be the prerogative of the regulatory authority, whose attitude could be influenced by their acceptance or otherwise of the statistical yardsticks employed to establish whether mercury/size correlations have a practical role for administrative purposes.

In the "no correlation" approach the selected mercury standard can be referred to the average mercury concentration in the catch, to the 95% confidence intervals of the average and of the individual data, or to some other confidence interval equivalent to the degree of tolerance accepted by the regulatory authority.

The legal maximum size approach allows the possibility of reducing an average mercury concentration in individual species or in the total catch. The losses to the fishery should therefore always be less than those from the "no correlation" approach, which determines whether the entire catch of a species is acceptable or not.

4.3(ii) Emerging fisheries

Section 4.2 (iv) has reviewed the available information on mercury concentrations in species likely to be of importance in emerging fisheries. It is not possible to uantify the effects of various alternatives for control, but in the south-east of Australia the strict application of alternative ($L_3$) and a 0.5 mg/kg standard would clearly affect the sales of gemfish, sharks, deep sea trevalla, deep sea flathead, blue grenadier and perhaps king dory.

In the Great Australian Bight, gemfish and shark would be most affected, followed by Bight redfish and latchet, and, to a more limited extent, other species.

Mercury data from the North West Shelf were too limited for detailed assessment but it must be expected that sharks and rays, and perhaps a few other species would be affected. The main species in pelagic fisheries all appear to contain low concentrations of mercury, noting that if they are reduced to fish meal a different standard is likely to apply.

There is insufficient information on mercury oncentrations in tuna species likely to be caught in ustralian waters for an assessment, but generally some individuals are likely to exceed a 0.5 mg/kg standard.

Developing fisheries may offer opportunities to existing fishermen, such as shark and trawl fishermen, displaced by mercury restrictions, but this potential is small. There is considerable risk attached to the development of any fishery and with the imposition of stringent mercury limits (noting that some emerging fish species have high average mercury levels) the uncertainty and risk could place such fisheries beyond the reach of Australian fishermen. The need for large specialised vessels and associated training, the distance and at times relocation involved and the existence of other boats exploiting or in a position to exploit such resources far more economically than displaced shark or trawl fishermen, are further limitations on such opportunities.

4.3(iii) Fish imports

Again it is not possible to quantify the effects of various alternatives for control on the quantities and types of fish that might be imported into Australia, and the consequences of this in the context of the mercury 'problem'. Conceptually, as the alternatives become less restrictive from $L_3$ to no-control, there exists a likelihood of foreign nations increasing the proportion or quantity of high mercury level fish supplied to Australia. The extent of any increase will be influenced by the extent to which countries are already holding back high mercury level fish, as well as by other factors, unrelated to mercury in fish, such as the extent of consumer demand for the imported product. Clearly whatever the mercury level in the product, no sales will be made if no market exists.

In practice the likelihood of an increase in imports of high mercury fish is likely to be confined to products from New Zealand. Australia is an important market for New Zealand fish, and the equivalent Australian fish (gemfish, snapper, ling) can have high mercury levels. Other exporters such as Japan, South Africa and certain European countries enforce less stringent mercury requirements than Australia, and their fish available for export is generally low in mercury content.

If it is recognized that a particular control alternative is likely to have an undesirable consequence, in respect to 'encouraging' high mercury level fish imports, the use of an import standard which is more stringent than the domestic standard must be considered; for example precedents already exist in Sweden and Denmark. However, such an arrangement would, prima facie be in breach of Australia's obligations under Article 3 of the General Agreement on Tariffs and Trade.

In the current situation mercury concentrations in imported fish are generally lower on average than the major species caught in Australia, a fact which has contributed to the difference between 0.28 mg/kg in the top 25 Australian species (Table 68) and the lower values of 0.15-0.17 mg/kg (paragraph (1)(a) above) in fish actually consumed. In predicting the likely consequences of controls to average mercury concentrations in imported fish, the present trend towards replacing imported fish on the Australian market by an increasing quantity of fish from emerging fisheries will need to be taken into consideration.

## 5. SUMMARY AND CONCLUSIONS

### 5.1 Technical problems of data gathering

During the course of its exercise in data gathering the Working Group has identified, and where possible, attempted to rectify, potential sources of error and bias, e.g.

(1) in the design of consumer surveys (Section 3.2);

(2) in the identity of fish offered for sale;

(3) in the selection and preparation of material for chemical analysis (Section 3.1(i));

(4) in analytical techniques for total, inorganic, organic and methylmercury and selenium (Section 3.1(ii));

(5) in the statistical analysis and evaluation of experimental results.

### 5.2 Quantities of fish eaten

(1) Fish makes a minor contribution (less than 1%) to total foods in the Australian diet (Section 2.6(iv)).

(2) From official statistics it has been estimated that average annual fish consumption in Australia is about 7 kg. At about 19g per day this is similar to fish consumption in the US and Canada (17g) and the UK (20g), but less than that in France (39g), Sweden (56g) and Japan (84g) (Section 2.3).

(3) More detailed information on fish consumption in Australian capital cities was obtained from a special consumer survey undertaken by PA Consulting Services for the Working Group. This showed that average fish consumption in Australian capital cities in 1976/77 was 10 kg, giving an Australia-wide estimate of 8-9 kg (about 25g per day).

(4) The survey showed that fish consumption was highest amongst individuals on a diet, those with high incomes and in households consisting of males only.

(5) 6.4% of the persons sampled from capital cities consumed in excess of 500g weekly, with 0.9% in excess of 1000g.

(6) The average consumer ate a variety of fish and seafoods. Of the total weight eaten, 77% was finfish and 23% seafoods (shellfish). Freshwater species were rarely eaten nor were they represented in the most important species caught or consumed in Australia.

(7) As an extension of the survey, and in a parallel survey by the Commonwealth Department of Health, a deliberate search was made amongst groups expected to have high fish consumption. The group observed to be exhibiting the highest average consumption of fish and seafood (1680g in the survey week) was the Aboriginal community at One Arm Point, WA. This is consistent with reports of heavy fish eating by other remote indigenous communities, e.g. the Anbara Aborigines of Arnhem Land. For comparison, the average consumption in the survey week by selected persons connected with the fishing community was 1034g and by persons on a diet 607g, these two samples having been selected on the basis of highest frequency of consumption in a screening survey.

(8) Most respondents in both Surveys of extreme consumers ate a variety of fish and seafoods. Few ate one species selectively frequently in the week - less than 4% of consumers selectively ate one species three or more times in the survey week.

(9) The highest individual consumption of seafood claimed in Australian studies (PA survey) was 3580g during the survey week and included eight kinds of fish or fish products. The extreme consumer in the Health survey was an Aboriginal man who ate 2680 grams and the highest non-Aboriginal respondent ate 2000 grams during the survey week.

For comparison, one US study (Marsh et al 1975) concluded that it was unlikely that any US consumers consistently eat more than 200 oz per month (ca 1300g per week), while a Swedish study (Jonsson et al 1972) recorded 6% of a sample of salt-water fishermen as eating more than 200g per day (1400g per week). 1% of individuals from an English fishing community ate more than 750g per day (greater than 5250g per week) (Lindsay in press).

(10) There was a tendency for heavy fish eaters to be consuming less fish when re-interviewed. This was also a feature of surveys in the United States and United Kingdom and must be taken into consideration in the assessment of sustained consumption by extreme consumers.

(11) The Working Group has agreed that the choice of definition of the extreme consumer for the purpose of setting a standard is a matter for toxicological assessment. It has therefore limited any speculation on the significance of Australian extreme consumers to analysing the results in such a way that they can be compared with accepted yardsticks, for example the 9th decile approach used by FAO/WHO and the reference level approach of Shepherd (1975) adopted in the United Kingdom.

(12) In assessing the significance of the extreme intakes noted above, it is important to remember that in the more broadly based random survey only 0.9% of individuals ate in excess of 1000 grams. Since this survey covered four quarters of a year the results should be more representative of annual consumption by the population as a whole than those taken at one point of time.

(13) Maximum fish consumption referred to the 9th decile of FAO/WHO (Section 3.3 (iii)) was 679g (3½ times the average) and 379g observed from the data in the survey week compared with 406, 417 and 490g for the US, Canada and UK, and 735, 1372 and 2085g for Finland, Sweden and Japan respectively (Margolin unpublished report).

(14) The calculation of reference levels (the time weighted average consumption level of the most extreme consumer (Shepherd 1975) - (Section 3.3 (iii)) based on extreme consumers from the PA and Health Department surveys during the survey week gave a range of values corresponding to the number of consumers chosen.

## 5.3 Mercury in the diet

(1) Mercury concentrations in Australian foods other than fish are relatively very low, generally averaging little more than 0.002 mg/kg.

(2) The highest total mercury concentrations in Australian fish were recorded in various species of shark (flake) (Section 3.1). Of non-shark species gemfish, ling, snapper, flathead and blue grenadier contained highest average and maximum concentrations. Elevated levels in shark, gemfish, ling and snapper are consistent with overseas observations from which the highest concentrations of mercury have been recorded in the larger, longer-lived species at the top of the food chain, e.g. swordfish, shark, halibut, dogfish, some tuna, etc. Freshwater fish may contain elevated concentrations of mercury, but they appear not to figure largely in the Australian diet.

(3) Imported fish and fish products generally contained relatively low concentrations, the exceptions being snapper, barramundi, hake and some canned tuna.

(4) Invertebrate species generally contain very low levels of mercury.

(5) With few exceptions the percentage of organic in total mercury is in excess of 90%.

(6) The concentration of total mercury in fish shows considerable variation (i) between fish of the same size, (ii) between different sizes of fish and (iii) between different species.

(7) A number of species, e.g. shark, gemfish, snapper, exhibit a well correlated relationship between total mercury and size. In some species, e.g. Australian salmon, deepwater flathead, this relationship was weak or absent.

(8) On a national basis the most frequently eaten fish consumed at home by the average consumer (Table 35 of Section 3.2) - tuna, salmon, fish fingers, sardines, cod and whiting, which were consumed on two thirds of occasions - are in the moderate/low mercury category. Other species, some with higher mercury concentrations, e.g. shark, may be locally more important. One quarter of average fish consumption is from take away outlets and dining out where there is less emphasis on canned fish species (tuna and salmon) and more on fresh and frozen fish. Some species with higher mercury concentrations, e.g. shark, gemfish, are more important at these outlets, especially take away fish shops.

(9) Of species eaten on average by the extreme (non-Aboriginal) consumer sample (Table 42 in Section 3.2) tuna, snapper, whiting, flounder, canned salmon and bream together constituted 43% of fish consumed. Flake, which is in the higher category of mercury content, composed only 3% of fish eaten by extreme consumers, but like certain other species is locally much more important. Aboriginals ate a variety of less widely eaten species, including a high proportion of turtle meat and turtle eggs.

(10) The species weighted average mercury concentration in the ten most important fish species in the Australian catch was calculated to be 0.31 mg/kg. This compares with a weighted average of 0.17 mg/kg for the top twenty fish eaten by Australian consumers, and the value (0.15 mg/kg) obtained from the wide array of fish and seafoods eaten by both the average and extreme Australian consumers in the PA Survey.

(11) It has been noted that misnaming of species, either deliberately by fish retailers or through lack of information by consumers, may cause errors in interpretation of the data and has had to be considered carefully in further computations.

(12) Additional species, particularly those appearing on the market from recently developing trawl fisheries, may either not have been represented in the 1976/77 consumer survey, or may have appeared under a different name.

(13) Fish were analysed for selenium and other elements, and results presented in Section 3.1(v). Their precise role in the toxicology of mercury has yet to be fully evaluated.

## 5.4 Sources of mercury in fish

(1) Australian waters, at least along the eastern and northern coasts, appear to be under the influence of naturally occurring mercuriferous deposits (Section 2.4(i)).

(2) A few areas of mercury pollution from industry exist in Australia (Section 2.6(i)(c)), for example in Port Phillip Bay, Botany Bay and the Derwent estuary, where elevated mercury concentrations have been recorded, particularly in localised species such as flathead and shellfish.

(3) Controls of mercury emissions have already proved successful in reducing mercury concentrations in fish in other countries, e.g. Sweden and Canada. Some reductions in mercury emissions have already been recorded in Australia (Section 2.6(i)(c)); others are expected as a result of Australian Environment Council initiatives (Section 2.6(vii)). The application of emission controls is of importance not only to the accumulation of metals in fish tissues but also to the survival and behaviour of fish and shellfish and their young (Section 2.4 (vi)).

(4) However, for the most part it must be assumed that the major contribution to mercury accumulation in Australian fish is through the food chain, or by direct uptake, from naturally occurring background concentrations.

## 5.5 Quantities of mercury ingested

(1) From calculations based on the 1976 Market Basket survey and on consumer surveys undertaken for the Working Group, it appears that the ingestion of mercury in foods other than fish, although it might constitute in excess of 70% of total mercury ingested by the average fish consumer contributes a much smaller proportion of the total mercury ingested by the extreme fish consumer. Mercury in fish is predominantly methylmercury. A figure of 90% has been used in calculations of methylmercury ingestion. The proportion of methylmercury in other foods, although apparently less than in fish, can be very high (Swedish Expert Group 1971).

(2) From the results of the 'broad-brush' consumer survey it was calculated that the 194 grams of fish eaten weekly by the average capital city consumer would have contained 0.03 mg total mercury, which is equivalent to 0.08 mcg/kg body weight/day for the 56 kg average body weight of consumers in the survey.

(3) The 6.4% of consumers in capital cities eating in excess of 500g weekly would have ingested more than 0.08 mg in the week, or assuming 56 kg body weight 0.2 mcg/kg body wt/day total mercury, and the 0.9% in excess of 1000g weekly would have ingested more than 0.16 mg or 0.38 mcg/kg body weight per day.

(4) The fish eaten by the most extreme consumer in the PA survey, i.e. 3580g during the survey week, would have contained 0.24 mg of total mercury, compared with maximum mercury intake by a PA consumer of 0.63 mg (1.2 mcg/kg/day) by the next highest consumer (2840g) of fish. Maximum mercury intake in the Health survey was 1.49 mcg/kg/day. Mercury data from fish species eaten by Aboriginals was inadequate for calculation of their mercury intakes.

(5) Maximal mercury ingestion based on the FAO/WHO 9th decile would be 0.26 mcg/kg/day (3½ times the average) or 0.15 mcg/kg/day (observed).

(6)) Reference levels based on the highest consumers (the critical group of Shepherd 1975) gave results between the 9th decile (para (5) above) and extreme consumer (para (4) above) estimates.

(7) Relative to the provisional tolerable intake proposed by FAO/WHO of 0.61 (0.41 Me Hg) mcg/kg/day clearly the average Australian consumer at 0.08 mcg ingests a very much smaller amount. Ninth decile estimates are less than the provisional tolerable intake, while some extreme individuals during the survey week (remembering that this seems likely to overestimate sustained consumption) exceeded it but at levels well under the symptom level of 10 x the provisional tolerable intake. Shepherd's estimates were more or less than provisional tolerable intake depending upon the number of extreme consumers used in calculation.

## 5.6 Mercury in hair and blood

(1) The Working Group has concluded that hair and blood mercury concentrations should be used as indicators of mercury intake and body burden only with great caution, and considerable care should be exercised in sampling, collection, handling, analysis and interpretation. While mercury concentrations in hair and blood provide useful indices of mercury ingestion on a group basis, they should not be used in isolation for individual diagnoses because of their wide variability.

(2) Most of the results obtained by the Working Group represent deliberate attempts to seek out extreme fish consumers expected to provide extremes of mercury ingestion evidenced in hair and blood indicators, and should be viewed in that way.

(3) In almost all cases, and particularly where levels were high, resampling of the hair of individuals gave markedly lower readings (Section 3.4, Table 59). While changed dietary habits is a possible cause, the results have focussed attention on the accuracy of analytical methods for mercury in hair and on the problem of contamination of hair by mercury.

(4) Table 70 summarises the records of total mercury in hair from the various surveys. The maximum identified in the PA survey was 27 mg/kg from Melbourne, a male shop assistant of Greek origin, who, although he consumed a moderate 780g during the survey week, claimed he ate more as a general rule. When revisited his hair level was 6 mg/kg and his blood 0.018. The maximum hair level identified in the Health survey was 7 mg/kg and by Penington 37 mg/kg, both also from Melbourne. The maximum recorded from all other States in the PA survey was 7.8 (0.1 when revisited) in Sydney by PA, and 6.8 (4.6) in Queensland by the Health survey (Table 70). Average State levels, noting these were from identified extreme consumers,

# TABLE 70
## HAIR MERCURY BY STATE
(mg/kg)

Results from PA Survey: Department of Health results in parenthesis. Data obtained in Victoria by Penington and by the Victorian Department of Health also shown.

| Capital (State) | Source | Sample Size | Mean | | Range |
|---|---|---|---|---|---|
| Hobart | PA | 2 | 3.4 | | .45 - 6.4 |
| (Tasmania | | no samples) | | | |
| Canberra | PA | 7 | 1.3) | ) 0.8 | .61 - 1.9 |
| (ACT controls only | Health | 14 | 0.5) | | 0.2 - 1.5) |
| Adelaide | PA | 14 | 2.1) | ) 1.8 | .46 - 4.3 |
| (South Australia | Health | 19 | 1.6) | | .5 - 4.6) |
| Brisbane | PA | 21 | 1.4) | ) 1.7 | .28 - 4.1 |
| (Queensland | Health | 22 | 1.9) | | .4 - 6.8) |
| Sydney | PA | 29 | 2.1) | ) 1.7 | .42 - 7.8 |
| (New South Wales | Health | 31 | 1.4) | | .5 - 6.6) |
| Perth | PA | 18 | 1.9) | ) 1.7 | .35 - 7.4 |
| (Western Australia | Health | 26 | 1.6) | | .25 - 3.0) |
| Melbourne | PA | 60 | 4.1) | ) 3.1 | .37 - 27 |
| (Victoria | Health | 33 | 1.6) | | .27 - 7) |
| | Penington | 301 | 2.0 | | .18 - 37 |
| | Vic. Health Dept. | 800 | 2.0 (est) | | G.T. 50 - 360 |

were usually less than 2 mg/kg, the highest being 3.9 in Melbourne. Of 800 hair samples analysed for the Victorian Health Department only 14 exceeded 9 mg/kg but since these ranged up to 360 mg/kg and since all associated blood levels were low (see para. 5) it was presumed that external contamination had been a contributory factor.

(5) The maximum blood level (0.038 mg/litre) was recorded in the Health survey from a male in Carnarvon, WA who ate 2000g of fish and seafood during the survey week (hair level 2.8/1.5). The maximum blood level from the P.A. survey was 0.022 from a fish wholesaler in Melbourne, who consumed 2100g of fish and seafood during the survey week and as a normal rule. His hair level was 8 (7 on revisit) mg/kg. The maximum blood level recorded by Penington was 0.021, and by the Victorian Health Department survey 0.011*. The maximum blood level recorded in the recent UK study (Lindsay in press) was 0.024 mg/litre.

(6) Table 71 gives the equivalent blood and hair mercury levels, fish consumption and estimated mercury intakes for selected average and extreme consumers. It will be recalled from Section 3.4, (Appendix 5B) that whereas other workers had found a significant relationship between mercury levels in hair and blood, this was not the case from the present study.

## 5.7 Alternatives for control and their consequences

(1) In the current situation of a mercury standard of 0.5 mg/kg, the quantities of the larger sizes of school shark caught in Victoria and of several species of shark in Western Australia have been controlled by maximum size regulations. If controls were discontinued the average mercury concentration in the Australian shark catch could be expected to increase but this would have only a marginal effect on the quantity of mercury consumed by the public.

(2) In the event that a mercury standard involving controls is considered to be necessary, various alternatives for control exist, including prohibition of capture of fish of certain sizes or species, or from certain areas, warnings to the public about areas, species or quantities to be consumed, and so on.

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* (This does not include the two special cases from Victoria referred to in 2.6(iv) para. 7.)

TABLE 71

SUMMARY OF FISH CONSUMPTION, ESTIMATED MERCURY INTAKE AND HAIR AND BLOOD MERCURY LEVELS FROM DIFFERENT SURVEYS

| Group | Fish consumption g/day | Body weight kg | Estimated Mercury intake (mcg/kg/day) Total | Organic (= 90%) | Hair Mercury First/Revisit (mg/kg) | Blood Mercury (mg/litre) |
|---|---|---|---|---|---|---|
| WHO "earliest effects" | - | 70 | - | 3.0-7.0 | 50-125 | 0.2-0.5 (20-50mcg/100ml) |
| FAO/WHO provisional "tolerable" intake | | | | | | |
| (i) FAO/WHO (1972) | - | 70 | 0.61 | 0.41 | 6.0 | 0.02 |
| (ii) WHO (1976) | - | 70 | - | 0.3-0.7 | 5.0-12.5 | 0.02-0.05 |
| Market Basket Survey (1976) | | | | | | |
| - from fish | 18 | 70 | 0.03 | 0.025 | - | - |
| - from all foods | - | 70 | 0.11 | - | - | - |
| PA Broadbrush Survey | | | | | | |
| Average consumer | 28 | 56 | 0.08 | 0.07 | - | - |
| Respondents consuming: | | | | | | |
| - G.T. 1000 g/week (0.9% all respondents) | G.T. 143 | 56 | G.T. 0.39 | G.T. 0.35 | - | - |
| - G.T. 500 g/week (6.4% all respondents) | G.T. 71 | 56 | G.T. 0.20 | G.T. 0.18 | - | - |
| Average consumer on a diet | 47 | 56 | 0.13 | 0.12 | - | - |
| FAO/WHO 9th decile | | | | | | |
| - 3.5 x average consumption | 97 | 56 | 0.26 | 0.23 | - | - |
| - observed from data | 57 | 56 | 0.15 | 0.14 | - | - |
| PA Purposive Survey | | | | | | |
| (i) Respondents with highest fish consumption: | | | | | | |
| - of all consumers | 511 | 73 | 0.47 | 0.42 | 1.1/- | - |
| - of consumers on a diet | 511 | 73 | 0.47 | 0.42 | 1.1/- | - |
| - of consumers connected with fishing industry | 406 | 75 | 1.21 | 1.09 | 10.0/- | - |
| (ii) Average consumer connected with fishing industry | 148 | 63 | 0.37 | 0.33 | - | - |
| (iii) Respondents with highest: | | | | | | |
| - hair mercury | 111 | 73 | 0.40 | 0.36 | 27.0/6.0 | 0.018 |
| - blood mercury | 300 | 60 | 0.48 | 0.43 | 8.0/7.0 | 0.022 |
| - mercury ingestion | 406 | 75 | 1.21 | 1.09 | 10.0/- | - |

TABLE 71 (Cont.

| Group | Fish consumption g/day | Body weight kg | Estimated Mercury intake (mcg/kg/day) Total | Organic (= 90%) | Hair Mercury First/Revisit (mg/kg) | Blood Mercury (mg/litre) |
|---|---|---|---|---|---|---|
| Health Purposive Survey | | | | | | |
| (i) Non-Aboriginal respondents with highest: | | | | | | |
| - fish consumption | 286 | 95 | 0.72 | 0.65 | 2.8/1.5 | 0.038 |
| - hair mercury | 111 | 95 | 0.13 | 0.12 | 7.0/5.0 | - |
| - blood level | 286 | 95 | 0.72 | 0.65 | 2.8/1.5 | 0.038 |
| - mercury ingestion | 206 | 55 | 1.49 | 1.34 | 6.6/8.3 | - |
| (ii) Aboriginal respondents with highest: | | | | | | |
| - fish consumption | 383 | 41 | - | - | 1.3/- | 0.002 |
| - hair mercury | 239 | 52 | - | - | 3.0/- | 0.005 |
| - blood mercury | 310 | 74 | - | - | 2.5/- | 0.008 |
| (iii) Average aboriginal consumer | 240 | - | - | - | 1.6/- | - |

* WHO (1976)

(3) One way of using fish containing mercury concentration above permissible levels could be to blend it with other foods or other fish species with low mercury levels.

Under the draft standard for metals in food the fish content of fish products may not contain mercury exceeding 0.5 mg/kg.

The draft standard does not appear to preclude the blending of two or more fish species provided the resultant blend is less than 0.5 mg/kg. However such blending would not appear to be possible for canned fish, such fish must be prepared from fish 'fit for human consumption' and there is doubt as to whether fish with a mercury content exceeding 0.5 mg/kg would be classed as fit for human consumption.

(4) Depending on the degree of acceptance, on statistical or practical grounds, of a relationship between mercury concentration and size of fish, the application of a legal maximum size has been considered. The disadvantages of such a system are the difficulty of obtaining data on mercury/size composition representative of a species and the area being considered for control, the variability of the data which precludes precision in the choice of a legal maximum size, the costs to industry of sorting and rejecting fish, and the administrative costs of inspection. One alternative is the rejection of whole catches of particular species in which a selected parameter of mercury concentration (e.g. the mean, maximum or some other specified level) in the catch exceeds the standard. Other alternatives would be as in paragraph (2) above.

(5) Predictions of the likely consequences of rigidly enforcing the present standard (excepting SA) of 0.5 mg/kg have demonstrated that of the order of 36% by weight and 44% by value of finfish in the top ten species in existing Australian fisheries could be eliminated from sale. In terms of percentage losses the greatest effect would be experienced by Tasmania (91% weight, 92% value). However the losses which would be experienced by Victoria (55% weight, 69% value) and New South Wales (49% weight, 44% value) would be more serious in terms of actual quantities.

(6) Relative losses at mercury standards 0.25, 0.5, 0.75, 1.0, 1.25 and 1.5 mg/kg for various interpretations of each standard have been computed. Weight and value losses at 1.0 mg/kg would be less than half those at 0.5, and at 1.5 mg/kg they would be reduced to about one quarter.

(7) The effects of enforcement by control of maximum size of fish, where appropriate, have been considered. Control to ensure that the average mercury remaining in fish offered for sale did not exceed 0.5 mg/kg could, in the top 10 species, result in a loss of 8% in weight and 10% in value (compared with para (iv) above). Losses from enforcing maximum sizes at (a) where the mean mercury concentration equals 0.5 mg/kg and (b) where its 95% confidence interval is likely to equal 0.5 mg/kg, would result in greater losses.

(8) The weighted average concentration of total mercury in the top ten species of finfish caught in Australia is 0.31 mg/kg. (It should be noted, however, that the weighted average concentration in all species consumed in Australia does not exceed 0.15 mg/kg.)

(9) Rigid application of standards of 0.5, 1.0 and 1.5 mg/kg should result in an average concentration of mercury in the catch remaining from the top ten species of 0.15, 0.18 and 0.21 mg/kg respectively (Section 4.3(i)(d)). These small differences in average mercury concentration in the catch remaining should be compared with the losses of 44, 20 and 11% in value necessary to achieve them. The comparable result from attempting to achieve an average of no more than 0.5, 1.0 and 1.5 mg/kg respectively in any individual species would be an average of 0.22, 0.28 and 0.31 (= no change) mg/kg in the catch remaining of the top ten species and could involve losses of only 10, 3 and 0% in value respectively.

(10) The social and economic consequences to the fishing industry of applying such controls has been discussed. These include an expected price rise of fish in the short term, quantification of which is complicated by a number of other factors. In the longer term, imports could increase and consumers may switch to other fish species and to non-fish items, with a dampening effect on the price rise. The impact on some sections of the fishing industry - particularly those associated with gemfish, shark and snapper - could be severe, because there are few alternative fishing activities to absorb displaced fishermen and associated labour and capital investment in areas where these species are caught.

(11) A number of species in emerging fisheries could be affected by mercury controls. These include demersal species on the south-east and north-west coasts and in the Great Australian Bight, for example, gemfish, sharks, deep sea trevalla, deep sea flathead, blue grenadier, etc. Pelagic species, mackerel, jack mackerel, etc. generally contain low concentrations of mercury. Some individuals of tuna would be affected by an 0.5 mg/kg standard.

(12) Imported species, with some exceptions, are generally relatively low in mercury and their inclusion in the diet has the effect of reducing the average mercury concentration in fish consumed to 0.15 mg/kg compared with that of fish caught in Australia (0.28 mg/kg in the top 25 species). It has been speculated that a less stringent standard would encourage imports containing higher mercury concentrations than at present. However, whether this would in fact eventuate would depend on a number of factors which have been discussed.

(13) The exercise of control of fish consumed has implications over and above consideration of the commercial fishery. The PA consumer survey (1978) revealed that a substantial proportion (27% on average, but reaching around 50% in Hobart and Perth) of all fresh and frozen fish consumed was in the category "caught or a gift". (This is equivalent to 8% of all fish, including canned, smoked, etc.) Although there is no quantitative information on species caught by amateurs, the average mercury concentration in fish eaten in households which included an amateur fisherman was very similar to that of the average household. Amateur catches would not be subject to regulations covering landings and markets, and effective inspection of amateur catches would not be practicable. Their control would therefore need to rely on warnings and prohibition of species, size and areas, but with some reservations as to their likely success.

(14) In summary, the rigid application, i.e. to attempt to exclude from sale most individual fish containing in excess of 0.5 mg/kg, would have a crippling effect on the fishing industry. The effect could be modified using less stringent alternatives for applying the standard, but their application would still create considerable administrative difficulties and costs to the fishing industry and regulatory authorities.

## 6. FACTORS REQUIRING SPECIAL CONSIDERATION DURING RE-ASSESSMENT OF THE SITUATION REGARDING MERCURY IN FISH

The Working Group on Mercury in Fish recognises that toxicological assessment of the Australian situation is properly the function of the National Health and Medical Research Council (NH & MRC) and its Committees, which are responsible for any recommendations for the control of mercury in fish reaching the consumer. This notwithstanding, the Working Group has the responsibility for drawing the attention of the Australian Fisheries Council to features which will be of special significance to the NH & MRC's deliberations, some of which will require further research.

(1) On no occasion has an Australian resident been identified with a methylmercury intake from fish which exceeds the threshold (first symptom) level referred to by FAO/WHO. Identified intakes seldom exceeded, and were generally much lower than FAO/WHO provisional tolerable weekly intake levels.

(2) Hair and blood concentrations from the Working Group's surveys never exceeded the equivalent of the FAO/WHO threshold level, rarely exceeded, and were generally much lower than, the equivalent of the FAO/WHO provisional tolerable weekly intake. Where unusually high hair mercury levels were identified in other studies, e.g. up to 360 mg/kg by the Victorian Department of Health, these were judged, on the basis of low levels in corresponding blood samples and inadequate fish consumption, to be due to external contamination.

(3) No known clinical symptoms of methylmercury poisoning have been confirmed in Australian residents, even where fish consumption had been relatively high. Although Health authorities will be on the alert for clinical effects to the foetus and subclinical effects generally, there has been no positive identification of these in Australian residents.

(4) When considering the relevance of such yardsticks for assessment as the FAO/WHO calculations, the following need to be noted:

(a) Mercury levels in hair have proved to be an unreliable single indicator of body burden.

(b) Re-examination of Iraqi and Japanese data on methylmercury poisoning (Marsh et al, 1975) indicated that the minimal blood level at the onset of symptoms was substantially higher than that suggested by FAO/WHO.

(c). Recent UK studies (Lindsay, in press) concluded that the consumption of methylmercury at the level of the FAO/WHO provisional tolerable intake resulted in blood and hair levels nearly an order of magnitude lower than those indicated by FAO/WHO.

(d) In 1978 a safety factor of X5 was considered acceptable by a US Court, compared with X7 suggested by the US FDA and X10 by FAO/WHO.

(e) The view that other chemicals, particularly selenium, may modify the toxicity of methylmercury has popular support, but more research is required. Ganther (pers. comm.) believes that the best approach is to identify the form of selenium in fish so that direct studies of its intrinsic nutritional potency and activity in detoxifying methylmercury can be carried out. Research on the chemical structure of methylmercury in fish and human tissues would similarly be important. It is significant that the possible activity of selenium was deliberately not cited in the US Court case.

(f) In May 1978, in the United States, where fish consumption and mercury concentrations in fish are not dissimilar to those of Australia, the guideline was revised from 0.5 mg/kg to 1.0 mg/kg "because of new information before us supplied by the National Marine Fisheries Service and others as well as an adverse court decision ...".

(g) In the UK, where fish consumption and mercury concentrations in fish are not dissimilar to those of Australia, it was concluded that regulations were not required.

(h) In Sweden, despite serious mercury pollution and higher fish consumption, a standard of 1.0 mg/kg with supplementary controls was considered to provide adequate protection.

(i) In Australia mercury in fish is, for the most part, not of anthropogenic origin. In localised areas of mercury emission, controls may be expected to improve the situation. In developing fisheries the reduction of average size through increased exploitation may be expected to lead to lower average mercury levels where mercury is correlated with size. The possibilities for reducing the mercury concentration in whole or unprocessed fish offered for sale, by depuration or other means, do not seem very hopeful at the present time.

(j) Consideration needs to be given to the view that, since a mercury standard is based on calculations of average mercury ingestion, the Australian system of rejecting consignments of imported or domestic fish containing individuals with mercury exceeding the standard is unnecessarily stringent. Other countries, e.g. the US, Canada and New Zealand, regulate on the basis of average mercury concentration in a consignment. (See Appendix 6)

(k) The administration of different standards, with differing levels of enforcement, between Australia and other countries, and within Australia, has led to problems of discrimination and of evasion of controls.

(l) Attention is drawn to various recent reports which have reviewed and added to the understanding of the mercury problem. These include the report of Margolin (1977), which was used in the US Court case, the USA National Marine Fisheries Service report (1978), which evaluated the chance of US seafood consumers exceeding the current acceptable daily intake for mercury, the unpublished report of Spitzer which includes the identification of certain sub-clinical effects in Canadian Indians, Lindsay's (in press) report on UK extreme fish consumers, Kjellstrom's (pers. comm.) studies in New Zealand, etc.

(m) The Working Group has corresponded with many overseas researchers working on mechanisms of intoxication and detoxification (see Section 9), however most research is still in progress. The bulk of opinion of these workers suggests that, while an understanding of the processes involved is still a long way off, there is ample evidence of detoxifying processes. The role of selenium and other trace elements should be examined.

Almost all these researchers believe the mercury "problem" is overstated. Few of these researchers would identify themselves as toxicologists but their understanding is clearly derived from research experience in this field.

## 7. RECOMMENDATIONS OF THE WORKING GROUP

The Working Group on Mercury in Fish presents its report to the Co-ordinating Committee on Metals in Fish and Fish Products. The Working Group while recognising that further research is needed in some areas, believes the report provides an adequate basis for a review of the standard for mercury in fish. The Working Group therefore recommends:

(1) The National Health and Medical Research Council should be requested to re-examine the standard on mercury in fish in the light of information and conclusions provided in the Working Group's report.

(2) The National Health and Medical Research Council should be asked to provide the Australian Fisheries Council with a fully documented account of the basis for its conclusions.

(3) There should be publication of the reports of the Working Group and of the considerations of the National Health and Medical Research Council referred to in (2) above in view of the considerable expenditure of time and money and the support and interest given throughout Australia and overseas to the activities of the Working Group.

(4) The National Health and Medical Research Council should be requested to clarify the situation with respect to the blending of fish species which exceed the permissible mercury concentration with the same or different species containing lower concentration, with special reference to the apparent anomaly between canned and other fish, and to review the need for applying the same standard to the fish content of fish products.

(5) In the event that the National Health and Medical Research Council maintains that a standard for mercury is warranted, control by maximum size may provide a useful measure for controlling the intake of mercury from some species, but should never be attempted without detailed data representative of the mercury concentration, size and weight composition of fish from defined localities.

(6) The source and accuracy of analytical data on mercury in fish needs to be known before attempting to compare them with, and predict the consequences of, mercury standards. Where possible a reference technique, such as that proposed by the Joint Technical Working Group on Marine Pollution, should be adopted.

(7) Attention should be drawn to the fact that metal standards which prescribe maximum permissible levels are based on calculations of average consumption. This, in association with arbitrary safety factors, variously argued for mercury as X7 and X5 in the US courts, compared with X10 used in Australia and elsewhere, may result in an unnecessarily wide margin of safety which should be re-examined.

(8) Inspection by Commonwealth and State authorities requires the rejection of individual fish containing in excess of the mercury standard. The proposal to enforce this under the Trade Practices Act would have had the most serious consequences for the fishing industry. Instead, and in view of recommendation 7 above, consideration should be given to inspection measures which take note of average, rather than maximum, levels of a metal in consignments of fish offered for sale as is the case in some of the major fish importing nations which inspect for mercury. There are precedents within the NH & MRC's recommendations for controls based on multiple sampling procedure, for example with microbiological standards.

(9) The problems experienced in Victoria resulting from the lack of uniform administration of the mercury standard between regulatory authorities throughout Australia, require careful examination when considering the application of any future recommendations for the control of metals in fish and fish products.

(10) Analyses should be undertaken of mercury concentrations in fish species expected to be of importance to developing fisheries in order that management and marketing policies can be framed ahead of intensive capitalisation. (This recommendation was adopted by the Australian Fisheries Council at its meeting in 1978.)

(11) While the problems of analysis of total mercury in fish now seem to be well understood, there is a need for further evaluation of analytical techniques for methylmercury.

(12) Because the results of Australian and UK studies showed less mercury in blood for a given mercury intake than predicted by FAO/WHO for its provisional tolerable intake, more detailed information on the relationship between mercury ingestion and mercury in blood and hair would be desirable - this could be obtained from extended duplicate diet studies such as those recently undertaken in the UK.

(13) Australian research on the detoxifying role of selenium and other substances should be encouraged and supported. CSIRO Division of Food Research has already prepared material for feeding trials with experimental animals and research has commenced in Western Australia on the chemical structure and association between mercury and selenium in fish.

(14) The problem of incorrect naming of fish offered for sale, while creating difficulties in the assessment of quantities of mercury consumed with fish, has wider implications for the fishing industry which should be examined with a view to improved regulation of fish names. The possibility for identification of fish flesh has been improved by recent work at the CSIRO Food Research Laboratory in Hobart.

(15) Every opportunity should be taken to encourage the minimisation of mercury discharges into the environment.

## 8. ACTIVITIES OF THE WORKING GROUP ON MERCURY IN FISH

During the period from November 1975 members of the Working Group have participated in the following activities:-

(1) Seventeen formal meetings of the Working Group.

(2) Nine meetings of the committee steering the Fish Consumption survey.

(3) Meeting with the Co-ordinating Committee on Metals in Fish and Fish Products.

(4) Regular reporting to Co-ordinating and Standing Committees.

(5) A meeting with the Food Science and Technology Committee of the NH & MRC.

(6) Advice on relevant projects submitted for funding by the Fishing Industry Research Trust Account.

(7) Sponsoring the organisation, by the Joint Technical Working Group on Marine Pollution, of Analytical Workshops on total mercury and methylmercury, funded from the Fishing Industry Research Trust Account.

(8) Correspondence and data gathering from interested groups in Australia and throughout the world.

(9) Meeting and discussion, both in Australia and overseas, with other workers in the field of heavy metals.

(10) Selection of consultants to undertake an Australia-wide consumer survey and guiding its progress through to publication.

(11) Planning of screening surveys to identify extreme consumers of fish for diet history studies by consultants.

(12) Assistance with the planning and evaluation of the Department of Health study, assisted by FIRTA funds.

(13) Reviewing relevant Australian and world literature in the preparation of its Final Report.

(14) Analysing and evaluating data collected on behalf of Co-ordinating Committee, and examining the economic consequences of alternatives for controlling the amount of mercury consumed with fish.

## 9. ACKNOWLEDGEMENTS

The Working Group wishes to acknowledge the provision of data by the various State and Commonwealth organisations; the support of the Department of Primary Industry, in particular Mr Con Keating, who attended all Working Group meetings and convened the Sub-Committee steering the consumer surveys, Mr Stephen Hillman, Mrs Jane Best and Mr Stan Jarzynski who contributed significantly to the Report; the willing assistance of Mrs Ruth English, Department of Health, at Working Group and Steering Committee meetings; statistical advice from the Australian Bureau of Statistics, the Bureau of Agricultural Economics and CSIRO, and in particular Mr Nick Caputi and Mr Ian Lethbridge of WA Department of Fisheries and Wildlife; Mr John Thomson (Tasmania), Mr John Edmonds (WA), Dr Roger Bradbury (ACT) and Mr Terry Walker (Victoria) for special assistance and manuscript reading; Mr Terry McKay, Department of Science, for organising analytical workshops; and the ready co-operation and assistance of Australian and overseas experts on mercury in fish. The Working Group also acknowledges the allocation of special funds from the Fishing Industry Research Trust Account for the Consumer Survey undertaken by PA Consulting Services, for funds to the Department of Health for its Dietary Study of Australians consuming significant amounts of fish products, and for funds to the Joint Working Group on Marine Pollution for the Analytical Workshops on Mercury. The important contribution made by past members of the Working Group and its Secretariat - Dr Olivia Woodward, Dr R.H.C. Fleming, Mr Stephen Medza and Mr Ray Pattison - is also gratefully acknowledged.

We have also received helpful advice from a number of specialists around Australia, including Dr N. Agar and Mrs P. de Silva (Victoria), Professor H. Bloom, Dr J. Olley and Mr S. Thrower (Tasmania) Dr D. Brown and Dr E. Underwood (WA), Dr R.W. Olafson (Qld) and Ms B. Meehan (ACT).

Many overseas researchers were contacted either personally, by the Working Group's Chairman, or in correspondence. Amongst those who provided valuable information we would like to thank the following: Drs R. Brooks, T. Kjellstrom and M. Robinson, New Zealand; Professor J. Cavanagh and Dr G. Topping, United Kingdom; Drs H. Freeman, A. Gervais, J. Uthe, R. Willes and Professor W. Spitzer, Canada; Dr T. Suzuki, Japan; Drs Fagerstrom and A. Svenson, Sweden; Drs C. Carry, R.A. Finch, L. Goldwater, L. Hecker, S. Margolin, J. Martin, R. Martin, J. Spinelli, G. Stoewsand and Professor H. Ganther, USA; Dr A. Pongase, Mexico; Dr L. Kosta, Yugoslavia; and Dr F. Lu, FAO.

## Personal Communications

The as yet unpublished views of a number of scientists have been detailed in this Report. Their addresses are set out below:

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## SECTION 10

## APPENDICES AND REFERENCE

## PAPERS

# APPENDIX 1

## GUIDELINES FROM THE NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL

**National Health and Medical Research Council**

COMMONWEALTH OF AUSTRALIA

TELEPHONE: 81 8411
TELEGRAMS: 'HEALTH, CANBERRA'

IN REPLY PLEASE QUOTE: 75/2888

P.O. BOX 100
CURTIN, A.C.T. 2605

Mr A.G. Bollen,
Chairman,
Co-ordinating Committee on Heavy Metals in Fish and Fish Products,
Australian Department of Agriculture,
CANBERRA. A.C.T. 2600.

Dear Mr Bollen,

I refer to Annex C. of the report of the meeting of the Co-ordinating Committee on Heavy Metals in Fish and Fish Products of 4 March 1975, which has been brought to my attention by the Department of Health representative on the Committee.

I have noted the points raised in the paper "Proposal for the Control of Mercury Levels in Seafoods Under the Trade Practices Act".

The Food Committees of the NH & MRC are prepared to examine all the recent evidence referred to in your submission, as well as any other evidence that is placed before your Committee.

The procedure laid down for the consideration of food additives and contaminants may be deduced from the format for application for use of a food additive. This may be used as a guide to the requirements of the Food Additives Sub-committee. (Copy of proforma attached.)

In its original examination in the years 1971-2, the Committee had before it the results of surveys undertaken in certain States of Australia into the levels of mercury found at that time in various species of fish on the Australian market. In addition, it had the toxicological data from the various parts of the world, in which the problem had become evident or manifested, as well as surveys into fish intake patterns. These surveys particularly related to certain identified groups in the population considered to be at special risk. The recommendations of FAO/WHO, together with an accumulation of data from other world authorities, were also considered.

To enable the FAD to re-examine the matter in depth in a comparable manner, it is suggested that it will be necessary to place before the Committee the following basic data:

(i) Levels of mercury found in various types of fish on the market at present, as well as those found over the last 4 years, to enable trends in levels to be identified.

(ii) Toxicological data with detailed reports on all investigations carried out. It is important to note that reports of adverse results are also required.

(iii) Patterns of fish consumption by the Australian population, especially in relation to groups considered most at risk, for example, pregnant women.

(iv) Detailed analysis of levels set in other countries, including concomitant legislation relating, for instance, to prohibited areas of fishing and warnings on consuming more than a specified amount of fish per day or per week. These should include levels and recommendations regarding proposed new levels, with supporting evidence to show that high risk groups are statistically unlikely to exhibit any signs of any form of mercury intoxication from continued consumption at the highest levels found in the patterns of consumption, including recommendations relating to any safety factor, to cover all groups and all intakes in the community.

(vi) If there were any evidence that concomitant legislation may be required regarding information for the consumer of limitations of consumption, labelling requirements regarding canned fish and fish products, and in particular, the problem of informing the consumer purchasing fish at such retail outlets as fish and chip shops, recommendations to cover these points would be required by the Food Committees of Council.

(vii) If there is evidence placed before the Committees regarding the mercury/selenium ratios and possible protective effects, either in relation to selenium, or other substances, it would be necessary to include data on surveys of levels of such substances in fish on the market, the types of fish concerned, and where the catches originated, and to include reference to possible action regarding those fishing areas in which uptake of these other substances may be deficient.

(viii) It is suggested that it may be of advantage to consult with Dr R.H.C. Fleming, Chairman of the Food Additives Sub-committee of the NH & MRC., P.O.Box 100, Woden, A.C.T., in the first place, and for a delegation to attend a meeting of the Food Additives Sub-committee to discuss in detail the types of information required.

It would be appreciated if you would forward the above information to the Standing Committee on Fisheries for its guidance.

Yours sincerely,

(K.W. Edmondson)
Secretary of the Council

27/6/75

NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL

# FORMAT FOR THE APPLICATION FOR THE USE OF A FOOD ADDITIVE

## APPROVED BY COUNCIL AT THE SEVENTY-FIFTH SESSION IN NOVEMBER 1972

Applications should be addressed to:

The Secretary,
National Health and Medical Research Council,
P.O. Box 100,
WODEN. A.C.T. 2606

Attention: The Chairman,
Food Additives Subcommittee.

Fifteen copies of the information requested, in the order listed below, should be supplied by the applicant.

PART A

1. Name of Applicant (in Full and in BLOCK letters).

2. Address.

3. Type of Business.

State: (a) whether manufacturer of proposed additive, manufacturer's agent or food processor;

(b) whether this application is on behalf of a single firm or organisation;

(c) whether this application is on behalf of the food processing industry or other firms or organisations;

(d) if on behalf of the food processing or other industries or organisations, names and addresses of these.

4. State: (a) chemical and/or common name of proposed additive (N.B. - Trade names are not acceptable);

(b) specific type of food for which requested;

(c) proposed minimum and maximum levels of use in each item shown in 4(b).

5. State the purpose of the additive in respect of each food listed in 4(b). Show evidence that the additive will have the intended physical or other technical results when added to the particular food(s) listed in item 4(b).

6. Show evidence as to whether or not the same objectives can be obtained by good manufacturing practices or by additives currently approved in Australia.

7. State the limits of the probable daily intake of the additive in the diet.

8. Give evidence of approval and state to your knowledge if approval has been rejected by any statutory body or authority.

9. State the chemical structure and formula of the additive and describe it in precise chemical terms and state all physical details.

10. State the nature and amounts of impurities present in the additive.

11. State a recognised standard of purity for the additive, e.g. Food Chemicals Codex, British Pharmacopoeia, British Pharmaceutical Codex, British Standards Institute, FAO/WHO Report No. 38B, etc.

12. Show information regarding the stability and persistence of the additive in the food(s) in which it is to be used.

13. State the advantages which will accrue to the consumer from the use of this additive.

14. If it is intended to use the additive in packaging materials, state the maximum amount(s) (supported by evidence) that may be incidentally absorbed by the food(s) from the food packaging material.

15. Show evidence in the form of a request or requests from manufacturers of a specific type of food or foods setting out the purpose to be served by the additive and establishing the need for it.

16. (a) State the analytical method to determine the amount of additive in the raw, processed and/or finished food.

(b) State the analytical method to determine any substance formed in or on such food because of the use of the additive.

The applicant is requested to supply with his application a sample of approximately 100 gram (or sufficient for 20 analyses) of the proposed additive. This sample may be used for collaborative studies by control laboratories and/or the applicants laboratory.

NOTE: These methods must be such that they can be applied with consistent results by a suitably equipped laboratory and trained personnel and should, where possible, be such that they can be used for food control purposes.

17. Supply a summary of the pharmacological and toxicological information given in Clause 20 including a summary and bibliography of pertinent literature.

**PART B**

Information regarding Clauses 18 and 19 of Part B will be treated in confidence by the Food Additives (Reference) Subcommittee and no disclosure will be made. Information regarding Clause 20 may be made available to State Health Departments on a confidential basis.

18. Give an outline of the method of manufacture of the additive.

19. Give full details of the analytical controls used during the various stages of manufacturing, processing and packing of the additive.

20. Show full details of pharmacological and toxicological investigations carried out according to the general terms of reference given in World Health Organisation Technical Report, Series 144, 'Procedures for the testing of intentional food additives to establish their safety for use'. Briefly these require:

(a) acute, short-term and long-term (chronic) toxicity studies. Chronic toxicity data should be given for at least two species, one of which should be the dog and carried out over the major portion of the life span of the experimental animal. Chronic toxicity experiments should aim to give the data needed to establish a 'no-effect' level;

(b) reporting of any physiological effects and any abnormal reactions, including carcinogenesis, teratogenesis in pregnant species, sensitivity, tolerance or idiosyncrasy in response to the additive;

(c) biochemical information on the possible mode of action if available; metabolic studies to show rate, extent and mode of elimination;

(d) evidence of non-interference with essential dietary constituents.

(e) summary and bibliography of pertinent literature.

NOTE: Full reports are required of adequate tests which will show that the additive will be safe when used as proposed. The reports shall include detailed data derived from appropriate animal and other biological experiments in which the methods used and the results obtained are clearly set out. Details of any reports which could bias an evaluation of the safety of the additive shall NOT be omitted.

21. The information supplied in response to items 1 to 20 in the application should be attested to by a statutory declaration in some suitable form along the following suggested lines:

'I .................................... declare that the information set out in this application fully sets out the matters required and that the same are true to the best of my knowledge and belief and that no information has been withheld which might prejudice this application.

Signature ............ ..........

Declared before me ..................... this ....................

day of ........................... 19.....

Justice of the Peace of
Commissioner for Affidavit'

## APPENDIX 2

## DATA COLLECTION FOR THE WORKING GROUP DATABASE

| DATE OF CAPTURE | DATE OF ANALYSIS | FISH IDENTIFICATION | ORGANISATION RESPONSIBLE | | | FISH SPECIES 7 | | | | | | LENGTH (CM) 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | i.e. Analyst's identification code | Submitting Organisation | Collecting Organisation | Analysing Organisation | Scientific Name (1) | Common Name (2) | Identification taken from (3): Whole fish | Carcass | Fillet | If doubt in identification please commemt (4) | Length of Caudal Fork (L.C.F.) | Length if L.C.F. CANNOT be used (State method) |
| 1 | 2 | 3 | 4 | 4 | 4 | | | | | | | | |
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| WEIGHT (KG) 9 | | SEX 10 | | AGE OF FISH 11 | | DEVELOPMENT STAGE OF FISH 12 |
|---|---|---|---|---|---|---|
| TOTAL | WEIGHT IF TOTAL WEIGHT NOT MEASURED (state method) | MALE | FEMALE | AGE | METHOD OF AGEING | GIVE DETAILS, E.G. JUVENILE BREEDING FEMALE ETC |
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| LOCATION OF CAPTURE 13 | | | | WATER BODY 14 | | | | | HUMAN CONSUMPTION 15 | | GROUPED SAMPLE 16 | | ORIGIN OF SAMPLE 17 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IF AUSTRALIAN | | | IF IMPORTED | | | | | | | | | | | | | | |
| State (1) | Grid (2) | Name of location (3) (Be as specific as possible) | Country of origin or unknown (4) (Insert product type in 19) | Lake | River | Estuary | Inlet | Oceanic | YES | NO | YES (State no. in sample) | NO | Research sample | Commercial catch (ex vessel) | Amateur catch | Markets, Co-ops & Processors | Retail or fish shop |
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| POSSIBILITY OF SAMPLING BIAS IN TERMS OF SIZE 18 | | | | | | CONDITION OF SAMPLE WHEN ANALYSED 19 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From selection of landed catch | | | From method of capture | | | | | | | | | | | | | | |
| Random sample | | Other sampling method (Please specify) | Avoiding small fish | Relatively unbiased | Avoiding large fish | Raw fresh | Raw frozen | Raw iced | Salted | Dried | Smoked | Cooked | Canned | Fish fingers | Alcohol | Formaldehyde | OTHER (PLEASE SPECIFY) |
| Yes | No | | | | | | | | | | | | | | | | |
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| METHOD OF MERCURY ANALYSIS 20 | | | | | | | | | | MERCURY LEVEL OF MUSCLE 21 | | MERCURY LEVEL OF FISH OTHER THAN MUSCLE 22 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DIGESTION METHOD (1) | | | ANALYSIS METHOD (2) | | | | ACCURACY OF (3) MEASUREMENT | CALCULATION (4) OF RESULT | | | | | | | | | |
| Hot Acid | Cold Acid/ Permang. | OTHER (Give details) | Cold vapour A.A.S | Colormetric | Neutron Activation | Other (state in 25) | EXPRESSED AS A PERCENTAGE | WET WEIGHT | DRY WEIGHT | TOTAL MERCURY (mg/kg) | METHYL MERCURY (mg/kg) | PORTION OF FISH SAMPLED | Total mercury (mg/kg) | Methyl mercury (mg/kg) | PORTION OF FISH SAMPLED | Total mercury (mg/kg) | Methyl mercury (mg/kg) |
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| OTHER CHEMICALS ANALYSED FROM SAME SAMPLE 23 | | | | | | | |
|---|---|---|---|---|---|---|---|
| A LEVEL[1] (mg/kg) | CHEMICAL[2] | B LEVEL[1] (mg/kg) | CHEMICAL[2] | C LEVEL[1] (mg/kg) | CHEMICAL[2] | D LEVEL[1] (mg/kg) | CHEMICAL[2] |
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| SIMULTANEOUS WATER SAMPLE 24 | | | | | | | SIMULTANEOUS SEDIMENT SAMPLE 25 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tick if sample available | Total mercury (mg/kg) | Methyl mercury (mg/kg) | OTHER CHEMICALS | | | | Tick if sample available | Total mercury (mg/kg) | Methyl mercury (mg/kg) | OTHER CHEMCIALS | | | |
| | | | Level (mg/kg) | Chemical | Level (mg/kg) | Chemical | | | | Level (mg/kg) | Chemical | Level (mg/kg) | Chemical |
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COMMENTS

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# APPENDIX 3

# FISH CONSUMPTION BY HEAVY FISH EATERS AT TWO POINTS IN TIME

APPENDIX 3

Section 3.2

## FISH CONSUMPTION BY 'HEAVY' FISH EATERS AT TWO POINTS IN TIME

### Introduction

The broad-brush survey of fish consumption disclosed that some 6% of Australians living in capital cities ate more than 500 grams of fish and seafood in the survey week during 1976-77 and 2% consumed more than 750 grams. Such statistics are of limited value when examining the potential exposure of consumers to high levels of mercury ingestion as heavy fish consumption in the survey week may not have been typical. This aspect has been examined in a study of heavy fish eaters in the United States where it was found that 1.4% of persons ate more than 3,000 grams of fish and seafood in a survey month (Marsh et al 1975). A repeat survey some months later suggested that few if any of these persons maintained a steady total fish diet greater than 3,000 grams monthly.

Some information on fish consumption at two points in time was collected when surveying heavy fish eaters. This appendix presents these data.

Sources of Data: In order to obtain a sample of heavy fish eaters for more detailed study a screening survey was conducted. In the PA study information was collected on frequency of fish and seafood consumption the week preceding this interview. Similar information was collected some three months later for those persons selected for detailed study. Thus, comparable information on weekly fish consumption was collected some months apart for 150 respondents. Data collected in the Health screening survey concerned respondents' usual fish consumption.

Results: The numbers of respondents who ate certain numbers of fish meals in the two weeks, three months apart, are presented in Table 1. The table shows that 19 persons ate fish at two meals or less in both survey periods and three ate nine or more.

Table 2 summarises the information in the previous table, setting out the number of respondents who ate fish at various frequencies in the screening and diary interviews and in both interviews. The Table shows that 118 respondents said they ate five or more fish meals in the week before the screening interview and 52 ate more than five fish meals in the diary week. A total of 48 people ate five or more fish meals in both weeks.

Generally, the frequency of fish consumption reported in the diary interview was lower than that of the screening interview. This could result from a more accurate reporting of consumption when a diary was used as distinct from the recall method employed in the screening interview. When recall is used there is often a bias towards over-reporting of consumption as items eaten or purchased in earlier periods are telescoped into the survey period. It will be recalled that the broadbrush survey was conducted using a recall method and although considerable care was taken to avoid telescoping it is likely to have occurred, although to a lesser extent than indicated in Table 2.

Besides this difference in the overall frequency of consumption between the two periods, there was also a change in the level of consumption by individual fish eaters. Five persons were eating fish five or more times in the diary interview who ate less than five fish meals in the screening week. These represented about one third of persons eating fish five or more times in the diary interview week. This proportion would of course have been higher if there was over-reporting of consumption in the screening survey.

In addition it will be observed from Table 2 that the higher the frequency of fish consumption, the greater the percentage fall in fish consumption between the screening and diary interview. This would seem to suggest that at higher levels of fish consumption, individuals are less likely to sustain consumption levels or to over-report consumption in recall studies.

Generally the results of this analysis would seem to confirm the hypothesis that the broadbrush survey results tend to overstate the proportion of heavy fish eaters. This may be because of over-reporting in a recall interview or changes in consumption levels from week to week resulting in fewer individuals consistently consuming high quantities of fish. The higher the reported level of fish consumption the less likely it is to be sustained.

APPENDIX 3

Section 3.2

TABLE 1

NUMBER OF RESPONDENTS
BY NUMBER OF FISH MEALS
Screening and Diary Week Interviews

| Diary Interview | Screening Interview | | | | | | |
|---|---|---|---|---|---|---|---|
| No of meals | 1-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-32 | TOTAL |
| 0 | 1 | 1 | 5 | 5 | 1 | 0 | 13 |
| 1- 2 | 2 | 9 | 12 | 8 | 7 | 5 | 43 |
| 3- 4 | 2 | 13 | 11 | 9 | 4 | 3 | 42 |
| 5- 6 | 1 | 3 | 17 | 9 | 0 | 4 | 34 |
| 7- 8 | 0 | 0 | 6 | 4 | 4 | 1 | 15 |
| 9-19 | 0 | 0 | 0 | 2 | 0 | 1 | 3 |
| TOTAL | 6 | 26 | 51 | 37 | 16 | 14 | 150 |

## APPENDIX 3

Section 3.2

### TABLE 2

**NUMBER OF RESPONDENTS AT SELECTED LEVELS OF CONSUMPTION FREQUENCY**
Screening and Diary Interviews

| Fish Consumption (Times per week) | SCREENING Interview | DIARY Interview | Both Interviews |
|---|---|---|---|
| 3 and over | 144 | 94 | 91 |
| 5 and over | 118 | 52 | 48 |
| 7 and over | 67 | 17 | 12 |
| 9 and over | 30 | 3 | 1 |

# APPENDIX 4

A. CALCULATION OF AVERAGE BODYWEIGHT OF RESPONDENTS

B. APPLICATION OF THE CRITICAL GROUP CONCEPT

# APPENDIX 4

Section 3.3

## A. CALCULATION OF AVERAGE BODYWEIGHT OF RESPONDENTS

The Group calculated the average weight of persons covered in the broadbrush survey to have been about 56 kg per person. This was calculated using the age groups of persons covered by the survey and applying to all groups less than 20 years, their average weight based on a NH & MRC booklet presenting data on the height, masses and head circumferences of infants and children (NH & MRC 1975b). Information in the booklet was based on surveys of NSW children between 1970 and 1972. The average weight of adults aged 20 and over was obtained from information collected in the PA and Health purposive surveys.

A comparison of weights from the purposive surveys and the NH&MRC booklet can be made for two groups, namely 10-14 and 15-19 years old and this is presented below.

| Age | Purposive Survey | NH & MRC Booklet (mean) |
|---|---|---|
| 10-14 | kg | kg |
| Males | 43 | 39 |
| Females | 43 | 41 |
| 15-19 | | |
| Males | 59 | 63 |
| Females | 55 | 55 |

The data used to calculate the average weight of respondents in the PA broadbrush survey are presented below.

The average weight of purposive survey respondents was 63 kg. This was higher because data on consumption was collected for individual respondents and not the whole household. These respondents were mainly adults with the exception of some teenage school children interviewed. The following table sets out the calculation of average weights based on survey observations.

## TABLE 1

## CALCULATION OF AVERAGE WEIGHT OF PA BROADBRUSH SURVEY RESPONDENTS

| Age Group (years) | % of Respondents in Age Group | Average Weight (kg) |
|---|---|---|
| **Male** | | |
| 0-2 | 5.2 | 12 |
| 3-9 | 13.5 | 22 |
| 10-14 | 10.5 | 39 |
| 15-19 | 8.9 | 63 |
| 20 and over | 61.9 | 72 |
| **Female** | | |
| 0-2 | 4.7 | 11 |
| 3-9 | 11.7 | 21 |
| 10-14 | 10.2 | 41 |
| 15-19 | 8.8 | 55 |
| 20 and over | 64.7 | 64 |

| | | kg |
|---|---|---|
| Average Weight | Male : | 57.9 |
| | Female : | 53.4 |
| | weighted average : | 55.7 |

TABLE 2

CALCULATION OF AVERAGE WEIGHTS OF PURPOSIVE SURVEY RESPONDENTS

| Age Group | Sex | No. of Respondents | Total Weight kg | Average Weight kg |
|---|---|---|---|---|
| 10-14 | Males | 24 | 1 030 | 42.9 |
| | Females | 14 | 603 | 43.1 |
| 15-19 | Males | 13 | 769 | 59.2 |
| | Females | 17 | 930 | 54.7 |
| Over 19 | Males | 78 | 5 617 | 72.0 |
| | Females | 165 | 10 553 | 63.9 |
| All persons | | | | |
| | Males | 115 | 7 416 | 64.5 |
| | Females | 196 | 12 086 | 61.7 |
| | Total | 311 | 19 502 | 62.7 |

Section 3.3

## B. THE APPLICATION OF THE CRITICAL GROUP CONCEPT TO OBTAIN A REFERENCE LEVEL FOR EXTREME CONSUMERS - Method of Shepherd (1975)

Shepherd (1975) found that a lognormal function provided an acceptable fit to the tail of the distribution of consumption of fish and seaweed (laverbread) in the United Kingdom. He used this observation to define a reference level for extreme consumers as a basis for determining the dimensions of the "critical group", i.e. the population group to which the International Commission on Radiological Protection recommended its dose limits should be applied.

Shepherd defined a "reference group" as all the people exposed in a critical pathway, and a "limiting group" as the relatively small subgroup (about 30) of the most extreme individuals on whom control will be based. He used the term "reference level" for the level of consumption derived from the habits of the limiting group which can be used together with the relevant dose limit to calculate derived working limits. The reference level of consumption reflects the time-weighted average consumption levels of the most extreme consumers.

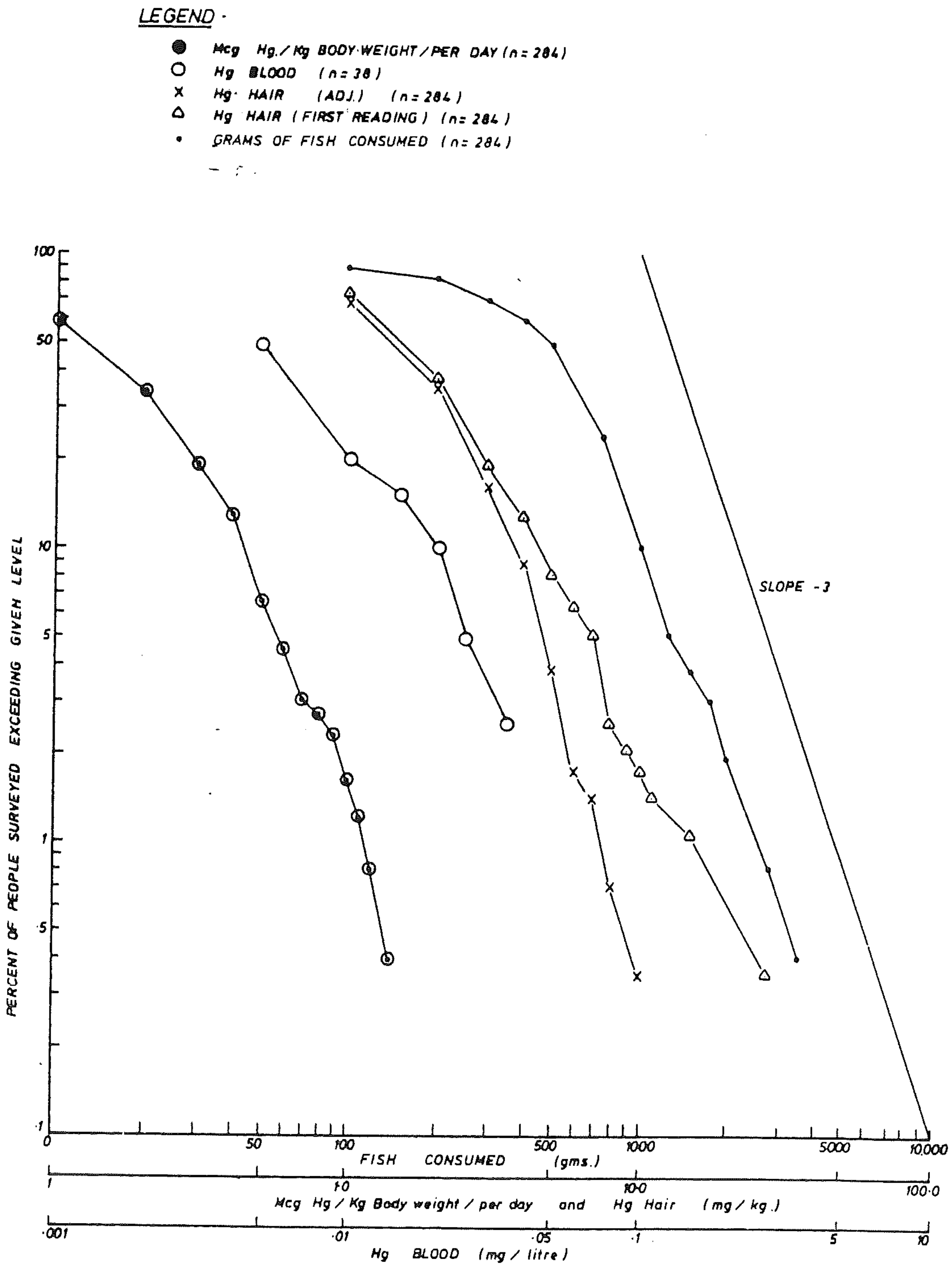
Using the fact that the number of people exceeding any given level falls rapidly as the consumption rate increases, roughly as a power function with a negative slope of about three, Shepherd concluded that, if the size of the limiting group is chosen to be about 30, the most extreme individual is unlikely to exceed the consumption of the first of the 30 individuals by more than a factor of three. The arithmetic mean of the limiting group of 30 people lies at about 1.38 times the consumption of the first of the 30 individuals.

Shepherd therefore found it convenient to estimate the level exceeded by about 30 people in the whole reference group and set the reference level at about 1.4 times this. He showed that in practice the most extreme individual is unlikely to exceed the reference level by more than a factor of two or three. Where the tail of the distribution of consumption does not approximate to a lognormal distribution with a slope of -3, the arithmetic mean of the 30 individuals should be calculated directly.

For situations in which not all the reference group were surveyed and the sample is biased towards heavy consumers, it is more appropriate to base the reference level on, say, the top ten consumers.

Data on average fish consumption from the broadbrush survey, and on extreme fish consumption, mercury ingestion, hair and blood levels (PA and Health data combined) shown in Figure 4 of Section 3.3 have been represented in Figure 1 of Appendix 4B. The graphs for each approximate to Shepherd's requirement for a lognormal distribution with a slope of -3 for the tail of the distribution, so that his assumption for calculating a reference level is fulfilled.

Shepherd suggested that the choice of number of people on which to base the reference level is not critical, since the reference level changes only slowly with the number of people. However, the results given in the tables in Section 3.3 suggest that a wide range could result from sample sizes of 5 to 30, and that the number chosen could determine whether the mercury ingested exceeded FAO/WHO provisional tolerable weekly intake or not. This is true also of the rather higher levels of mercury ingestion calculated from individuals in the same table. However, whether or not it is strictly appropriate to apply Shepherd's method to the data collected by the Working Group requires further discussion.




APPENDIX 4B

FIGURE 1

CUMULATIVE FREQUENCY DISTRIBUTIONS
OF DATA GIVEN IN FIGURE 4 COMPARED WITH
A LOG-NORMAL DISTRIBUTION

# APPENDIX 5

A. HAIR ANALYSIS READINGS AND SELECTED CHARACTERISTICS OF SAMPLE

B. RELATIONSHIPS BETWEEN FISH CONSUMPTION, MERCURY INGESTION AND MERCURY IN HUMAN TISSUES

C. THE RELATIONSHIP BETWEEN MERCURY AND SELENIUM IN HAIR

APPENDIX 5A

Section 3.4

## HAIR ANALYSIS READINGS AND SELECTED CHARACTERISTICS OF SAMPLE

### Introduction

Multiple regression analysis was used to test the relationship of a set of independent variables, (fish consumption, occupation, country of origin etc.) to the hair mercury readings of the 311 individuals surveyed in the purposive surveys.

### Specification and Data

A linear regression equation was specified of the type,

$$y = a + B1X1 + B2X2 .... BnXn + E$$

Where y was mercury readings in hair and the independent variables were as follows:-

- "Non-binary" Variables
  - Fresh and frozen fish consumption
  - Other fish consumption
- "Binary" variables
  - occupation
    - .. home duties
    - .. student
    - .. employed in fishing industry
    - .. other
  - country of origin
    - .. Australia/N.Z.
    - .. Mediterranean
    - .. aboriginal
    - .. unknown
    - .. other
  - City of residence
    - .. Melbourne
    - .. other
  - Participating survey
    - .. PA Survey
    - .. Health Department Survey

## Results

Table 1 sets out the B (regression) coefficients and the constant calculated for the four models tested, and their significance as estimated using Student's t. A measure of the extent to which the independent variables 'explain' movements in the dependant variable ($R^2$) is also shown along with a measure of the overall significance of the equations (F).

The B coefficient values for the variable 'fresh and frozen fish consumption' were positive and significant at the 1% level for all the regression equations, implying that there is one chance in a hundred that such a result could have been achieved by chance. The variable 'other fish consumption' did not give significant values of B up to the 10% level.

The variables 'Melbourne resident' and 'PA survey respondent' had a partial correlation coefficient of 0.33. This might be expected since most of the PA survey respondents lived in Melbourne. Both variables showed highly significant positive B coefficients and this was particularly high for 'Melbourne resident'.

The independent variables for occupation were included in two models. Only the variable 'fishing industry' had significant B coefficients and these were positive and significant at the 1% level.

Of the independent variables for origin, that of 'Mediterranean' gave a positive and significant B coefficient in both of the models in which it was included. The B coefficient of the 'origin unknown' variable was significant at the 1% level in one model and at the 5% level in the other.

The $R^2$ values for the models varied between 0.15 and 0.25.

Since all the models included one or more variables having significant B coefficient values, the F statistics in each case are significant at the 1% level.

## Discussion

For cross-sectioned data such as this the $R^2$ values are considered to be reasonably high. Cross-sectional studies usually have a fairly large proportion of unexplained variation, Mainly because of errors in data collection and analysis.

The study has shown that certain strong relationships do exist between mercury in hair and several of the independent variables. It can, for example, be concluded with confidence that, for this sample, there was a positive relationship between the amount of fresh and frozen fish consumed and the mercury levels in the hair of consumers. No such relationship was found for consumption of other fish products.

It is impossible to separate the effects of the variables 'Melbourne resident' and 'PA Survey respondent' on mercury levels. Both have significant B coefficients which may be due in part to residence in Melbourne. However it would appear that for the sample surveyed, persons residing in Melbourne had higher mercury levels in hair than in other cities and areas.

The binary variable for 'occupation in the fishing industry' showed a strong relationship with mercury levels in both the models in which it was included. The positive sign of the B coefficients indicates that those working in the industry, in this sample, tended to have higher mercury levels in their hair than those not connected with fishing. Neither the occupation of 'home duties' nor 'student' showed any strong relationship with the dependent variable.

Of the four 'origin' variables included in the models, that of 'Mediterranean' showed the strongest relationship with hair mercury levels. This variable had a partial correlation coefficient of 0.31 with the variables 'occupation - fishing industry' and this may influence the results a little. The 'origin - unknown' variable also showed a positive relationship with mercury levels but at a lower level of significance.

## Conclusions

Certain relationships between the level of mercury in the hair and various independent variables have been demonstrated in this study. It must be borne in mind that the results relate only to the sample population and not to the population of Australia as a whole or to any other population groups.

The results give some information on relationships between variables but the cause of these is not implied.

Appendix 5A
3.4

TABLE 1

VALUES OF B COEFFICIENTS
(STUDENTS' t AND SIGNIFICANCE)

| Dependent Variable | Independent Variables | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Occupation | | | Origin | | | | | | |
| | Fresh and Frozen Fish consumption | Other Fish consumption | PA survey participant | Melbourne resident | Home Duties | Student | Fishing Industry | Unknown | Mediterranean | Aust-N.Z. | Aborigine | Constant | $R^2$ | F |
| Mercury level in hair | $0.76x10^{-3}$ (2.84**) | $0.36x10^{-3}$ (0.56) | 0.58 (2.09*) | 1.66 (5.35**) | $0.33x10^{-1}$ (0.1) | $0.17x10^{-1}$ (0.05) | 2.21-1 (3.78**) | | | | | 0.91 (3.25) | 0.20 | 12.72 |
| Mercury Level in hair | $0.73x10^{-3}$ (2.62**) | $0.44x10^{-3}$ (0.66) | 1.05 (3.82**) | - | -0.23 (0.29) | $0.99x10^{-1}$ (3.87**) | 2.36 (3.78**) | | | | | 1.13 (3.90) | 0.15 | 9.19 |
| Mercury Level in hair | $0.11x10^{-2}$ (3.67**) | $0.38x10^{-3}$ (0.6) | 0.47 (1.74*) | 1.65 (5.5**) | - | - | | 2.05 (1.78*) | 2.19 (3.77**) | 0.12 (0.35) | -1.02 (-1.34) | 0.72 (1.95) | 0.25 | 12.47 |
| Mercury Level in hair | $0.12x10^{-2}$ (3.75**) | $0.27x10^{-3}$ (0.40) | 0.91 (3.37**) | | | | | 2.84 (2.39**) | 2.20 (3.67**) | 0.21 (0.57) | -1.27 (-1.59) | 0.85 (2.18) | 0.17 | 9.17 |

* Student's t significant at the 5% level
** Student's t significant at the 1% level

## APPENDIX 5B

Section 3.4

### RELATIONSHIPS BETWEEN FISH CONSUMPTION, MERCURY INGESTION AND MERCURY IN HUMAN TISSUES

A series of correlations between mercury in human tissues, hair and blood, and fish and mercury intake were investigated using linear regression models. The equations derived and the level of significance of the regression coefficients are shown in Table 1. It will be noted that, where possible, each correlation was tested on data from the PA and Health surveys both separately and combined. Data on blood mercury corresponding to hair mercury and fish consumption were only collected in the health survey for 43 respondents, 8 of whom were Aboriginals. Hair and blood samples were taken simultaneously from 11 PA respondents at the time of the follow- up study some six months after the original purposive survey.

Mercury intake estimates were based on the average mercury concentration and quantity of each species of fish consumed and the body weight of each individual respondent.

It was considered that the diet of Aboriginal consumers was sufficiently different, both in quantity and species of fish, to warrant their consideration as a somewhat special case. Further, although English (1978 unpublished) recorded mercury concentrations in some of the species consumed by Aboriginals at One Arm Point, WA, the number of observations was considered inadequate to provide a basis for computing individual mercury ingestion levels during the survey week. However, the results from Aboriginals could reasonably be included in hair/blood mercury relationships which do not involve a knowledge of mercury ingested.

There was a good correlation between fish consumption and mercury intake (Table 1), the relationship was positive and highly significant and the equation specified explained a reasonably high proportion of the variation in mercury intake.

Positive and highly significant correlations were also found in all relationships between mercury in hair and fish consumption and in all those of hair mercury and mercury intake although the equation explained a relatively small percentage of the relationship. Similarly, fish and mercury intake were found to be well correlated with mercury levels in the blood. It should be noted, however, that the degree of correlation was increased when the blood mercury/fish consumption relationship was converted to blood mercury/total mercury intake but was reduced when blood mercury was related to mercury ingestion expressed as a function of body weight (Table 1, equations 6, 7 & 8).

There did not appear to be a significant relationship between mercury in the hair and mercury in the blood. Results from Health survey respondents indicated no correlation between the two. Data from the PA survey however gave a regression coefficient significant at the 0.001 level ($R^2$=0.98) but the equation was based on results from only 11 respondents.

Figures 1 to 4 of Appendix 5B illustrate the wide variability of the raw data used in the relationship described and serve to emphasise the fact that although the correlations between the variables are generally significant the equations obtained do not provide a convincing fit to the data.

There were differences in hair mercury level/fish consumption regressions between PA and Health survey data which could have resulted from differences in mercury concentration in the fish consumed, possibly on an area basis. In the PA, but not in the Health survey, a significant difference was found between States with Melbourne hair levels higher than the ther State capitals for a given fish consumption. The hair mercury concentrations of 15 One Arm Point Aboriginals, which averaged 1.6 mg/kg, were low considering their average fish consumption of 1680g in the survey week. This appears to reflect the dominance of low mercury species (including turtles) in their diet.

Such explanations should not apply to differences between PA and Health survey hair mercury/mercury intake regressions which can be seen from the table to be quite large. For example a difference of 3.4 mg/kg in the hair mercury reading (y) is predicted from the equations when mercury ingestion (x) is 1 mcg/kg/day. At this point the hair mercury level of PA respondents would be predicted as 6.4 mg/kg and for Health 3.0 mg/kg.

A number of the variables in the equation in Table 1 could be expected to be fairly closely related to such factors ; occupation, country of origin of the respondent, and residence especially between Victorian and other residents. Table 2 relates mercury in hair to mercury intake, fish consumption and mercury ingestion expressed as mcg/kg body weight/day taking these other factors into consideration. The table is specified in a similar manner to Table 1 of Appendix A.

The equation in the table explains a considerably higher proportion of the variation in the dependent variable than the corresponding equations in Table 1. For example, the percentage of the variation in mercury in hair explained by mercury ingestion rose from 6% in Table 1 to 23% in Table 2. Residence or otherwise in Victoria was the most significant variable in all three equations being significant at the 0.001 level. Also significant at the 0.01 level, in explaining differences in hair mercury levels, were membership of the fishing industry and a Mediterranean country of origin. Both mercury intake and mcg of mercury ingested per kg per day were also significant at the 0.01 level but fish consumption was significant at the 0.05 level.

## APPENDIX 5B

### TABLE 1

### MATHEMATICAL RELATIONSHIPS BETWEEN MERCURY IN HAIR AND BLOOD, FISH CONSUMPTION AND MERCURY INTAKE

| Relationship | Equation | n | $r^2$ | sig |
|---|---|---|---|---|
| 1. Mercury intake (mcg/week)/ fish consumption (g/week) | | | | |
| . PA | y = 5.65 + .1332x | 151 | .64 | *** |
| . Health | y =-20.3 + .2065x | 133 | .45 | *** |
| . PA and Health | y = .829 + .1539x | 284 | .50 | *** |
| 2. Hair mercury (mg/kg)/ fish consumption (g/week) | | | | |
| . PA | y = 2.12 + 0.00119x | 151 | .04 | ** |
| . Health | y = 0.957 + 0.0012x | 133 | .11 | *** |
| . PA and Health | y = 1.57 + 0.0012x | 284 | .04 | *** |
| 3. Hair mercury (mg/kg)/ mercury intake (mcg) | | | | |
| . PA | y = 1.88 + 0.0113x | 151 | .09 | *** |
| . Health | y = 1.29 + 0.00342x | 133 | .09 | *** |
| . PA and Health | y = 1.69 + 0.0063x | 284 | 0.6 | *** |
| 4. Hair mercury (mg/kg)/ mercury ingestion (mcg/kg body weight/day) | | | | |
| . PA | y = 1.99 + 4.42x | 151 | .06 | *** |
| . Health | y = 1.21 + 1.83x | 133 | .12 | *** |
| . PA and Health | y = 1.72 + 2.60x | 284 | .05 | *** |
| 5. Hair mercury (mg/kg)/ blood mercury (mg/litre) | | | | |
| . Health - | | | | |
| including Aborigines | y = 1.29 + 33.5x | 43 | .04 | NS |
| excluding Aborigines | y = 1.24 + 32.2x | 35 | .04 | NS |
| . PA | y = -0.107 + 341.0x | 11 | .98 | *** |
| 6. Blood mercury (mg/litre)/ fish consumption (g/week) | | | | |
| . Health | y = -0.00075+0.00001x | 29 | .32 | *** |
| 7. Blood mercury (mg/litre)/ mercury intake (mcg) | | | | |
| . Health | y = -0.0001+0.00007x | 29 | .49 | *** |
| 8. Blood mercury (mg/litre)/ mercury ingestion (mcg/kg body weight/day) | | | | |
| . Health | y = -0.00235+0.017x | 29 | .15 | ** |

NS - Not significant at 0.05 level.
** - Significant at 0.01 level.
*** - Significant at 0.001 level.

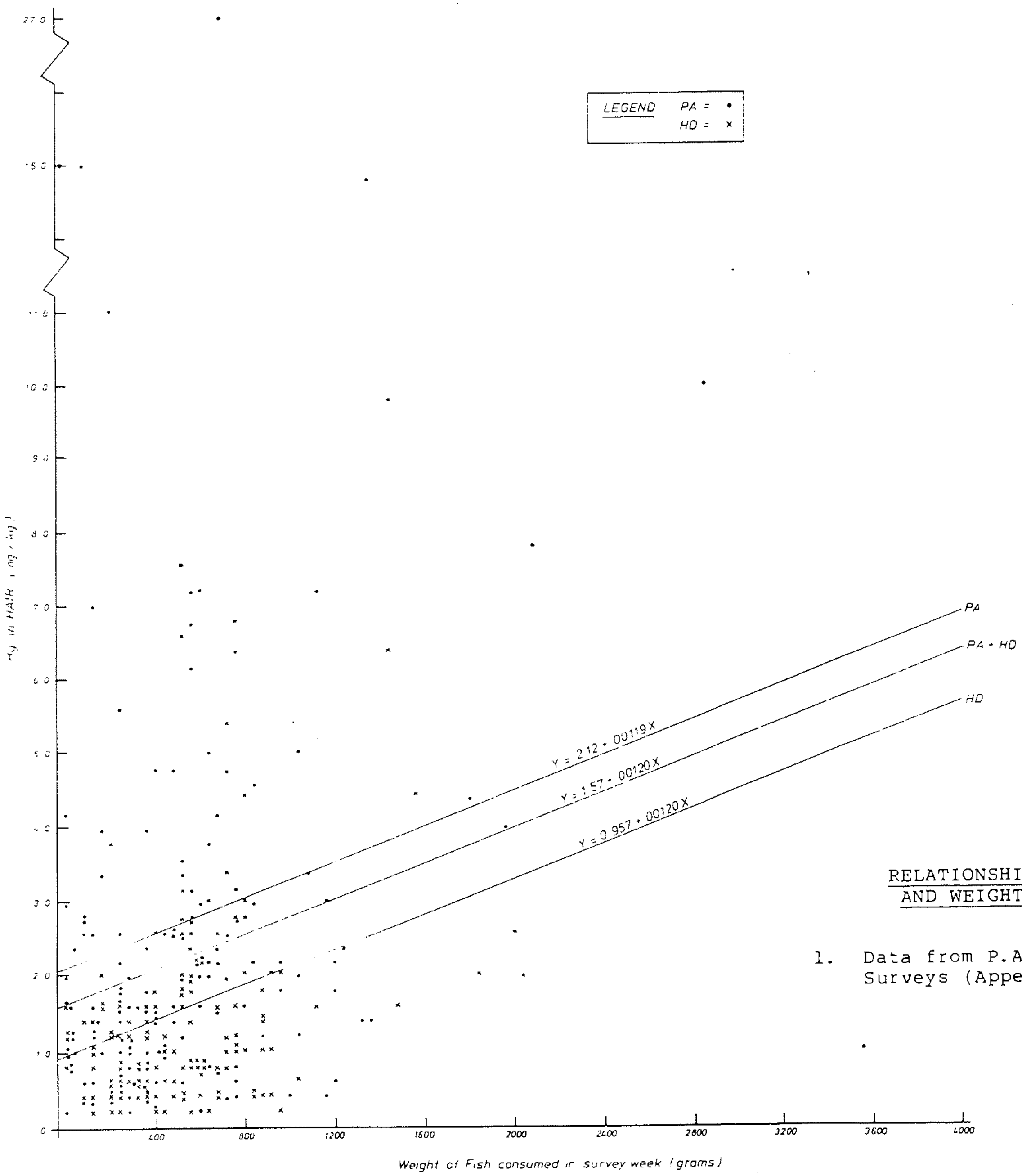
TABLE 2

MATHEMATICAL RELATIONSHIPS BETWEEN MERCURY LEVEL IN HAIR AND FISH CONSUMPTION AND MERCURY INTAKE.
According to Survey Participation, Residence in Victoria, Occupation, Country of Origin and Sex.

| Dependent Variable | Independent Variables: Fish (g per week) | Mercury Intake (mcg) | mcg Hg per kg per day | Health Dept. Participant | Victorian Resident | Occupation: Fishing Industry | Occupation: Home Duties | Occupation: Student | Country of Origin: Aust. N.Z. | Country of Origin: Mediterranean | Male | Constant | $R^2$ | Sign Equations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hg Level in Hair (mg/kg) | .000781 (*) | | | -.49 (NS) | 1.29 (***) | 1.68 (**) | .08 (NS) | -.04 (NS) | .18 (NS) | 1.91 (**) | .20 (NS) | 1.10 | .23 | *** |
| " | | .00445 (**) | | -.59 (*) | 1.19 (***) | 1.74 (**) | -0.05 (NS) | -0.11 (NS) | .28 (NS) | 1.85 (**) | .14 (NS) | 1.23 | .23 | *** |
| " | | | 1.92 (**) | -.59 (*) | 1.21 (***) | 1.75 (**) | -.02 (NS) | -.19 (NS) | .24 (NS) | 1.89 (**) | .17 (NS) | 1.25 | .23 | *** |

NS not significant at the 0.05 level
* significant at the 0.05 level
** significant at the 0.01 level
*** significant at the 0.001 level

Number in sample = 279

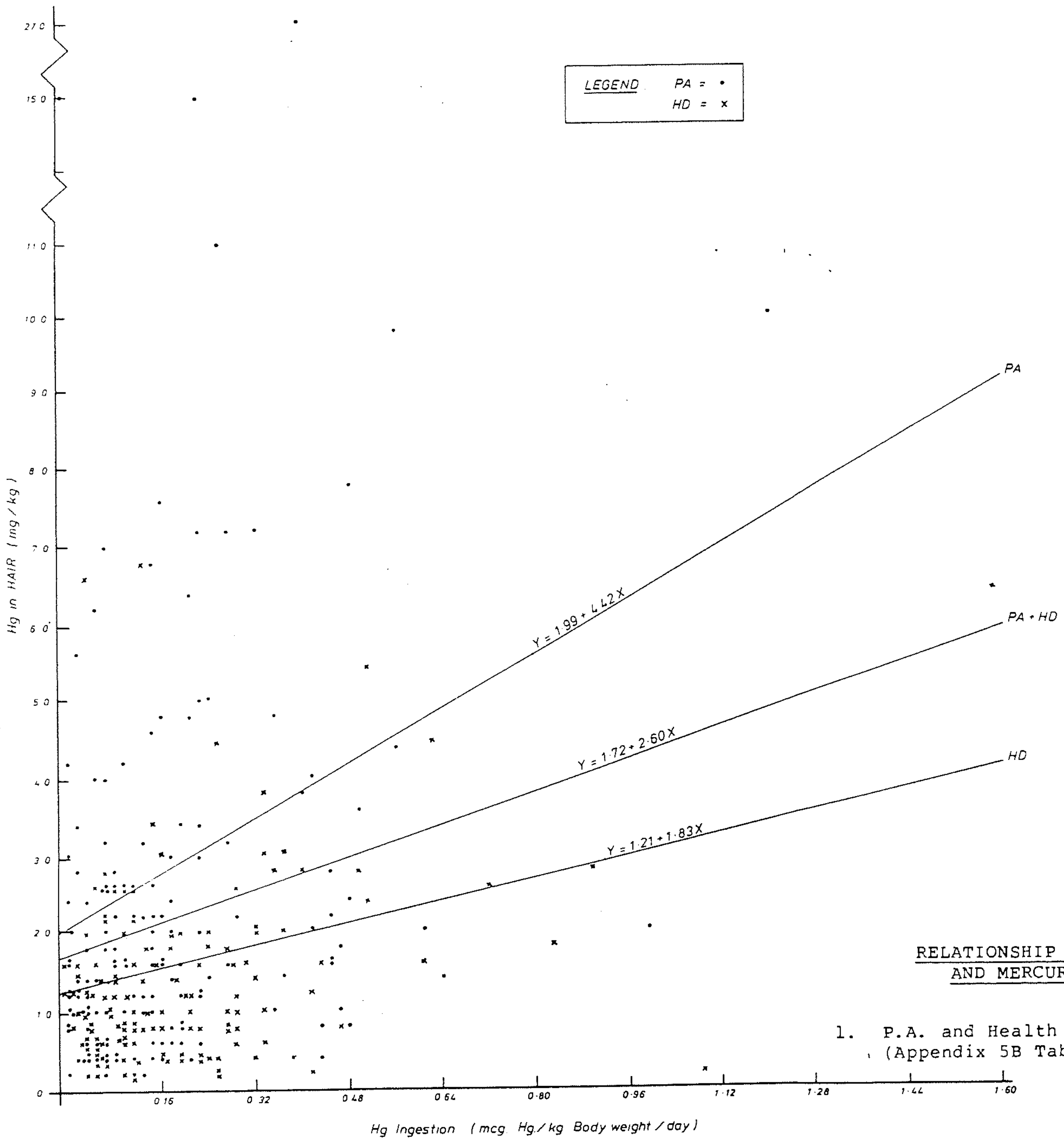



APPENDIX 5B

FIGURE 1

RELATIONSHIPS BETWEEN MERCURY CONCENTRATIONS IN HAIR AND WEIGHT OF FISH CONSUMED DURING THE SURVEY WEEK

1. Data from P.A. and Health Department Surveys (Appendix 5B Table 1 refers).

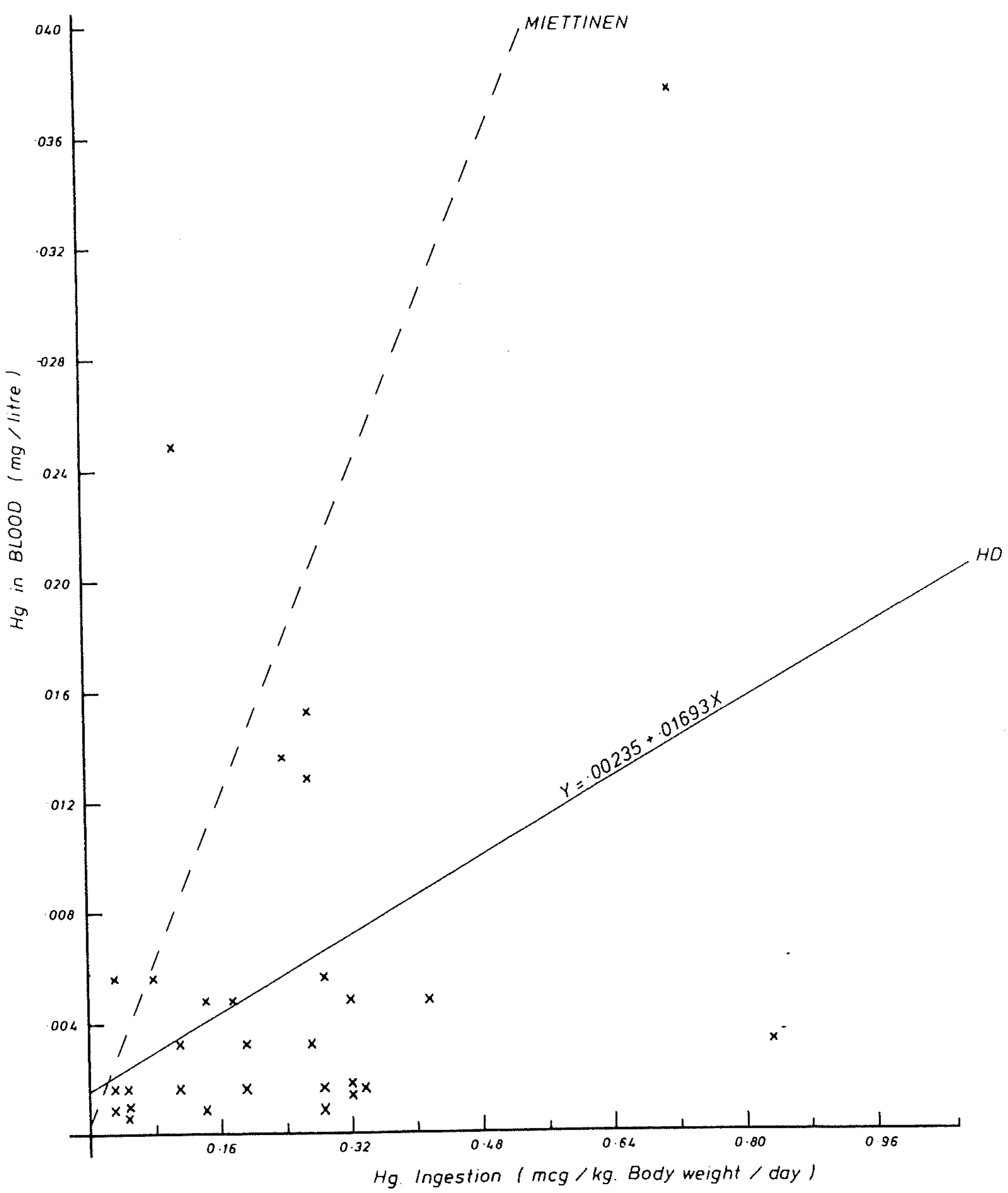



APPENDIX 5B

FIGURE 2

RELATIONSHIP BETWEEN MERCURY CONCENTRATION IN HAIR AND MERCURY INGESTED DURING THE SURVEY WEEK

1. P.A. and Health Department Surveys (Appendix 5B Table 1 refers).



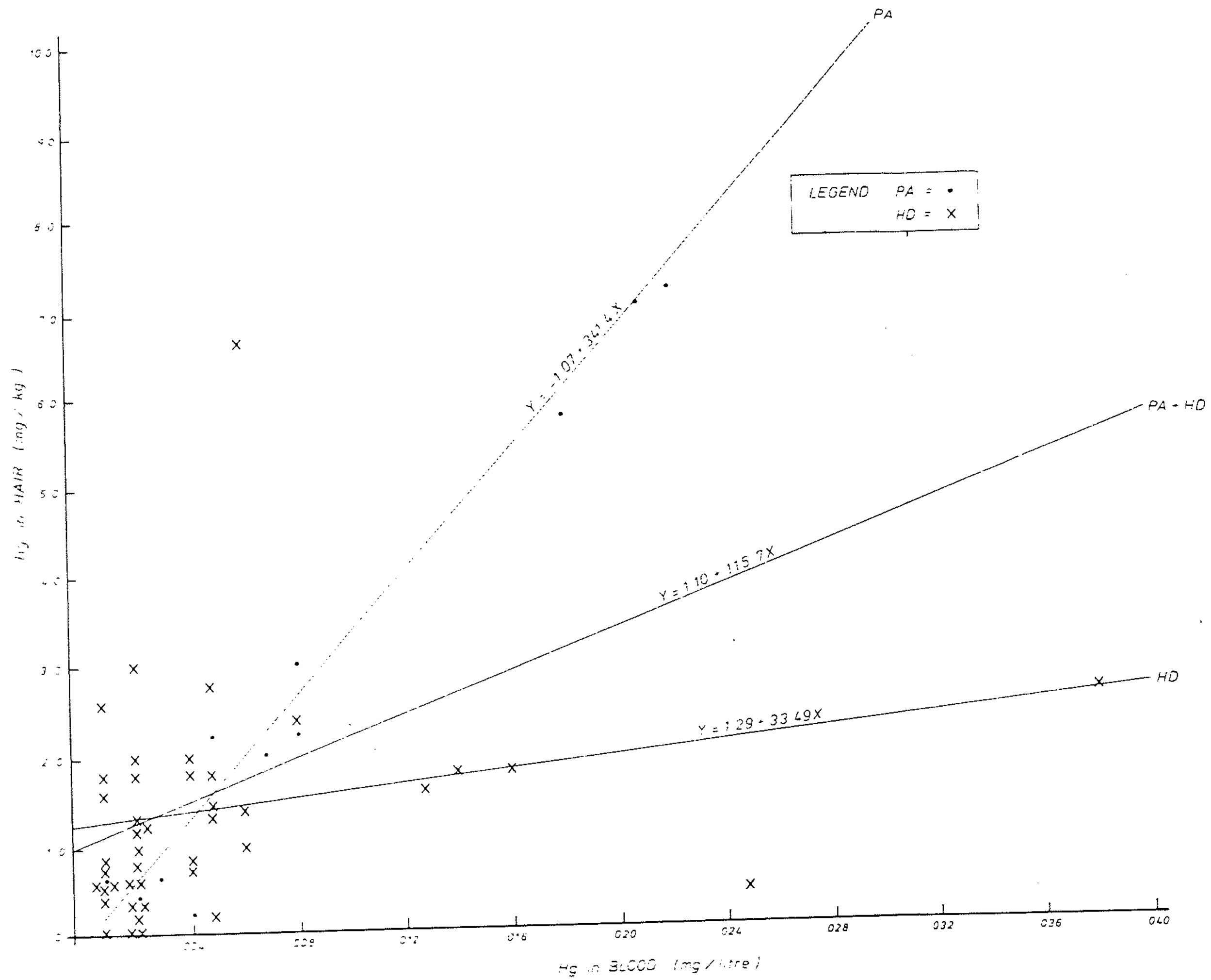

APPENDIX 5B

FIGURE 3

RELATIONSHIP BETWEEN MERCURY IN BLOOD AND MERCURY INGESTED DURING THE SURVEY WEEK

1. Data from the Department of Health Survey only (Appendix 5B Table 1 refers).

2. The relationship observed by Miettinen (see Section 3.4(vii) Figure 5) is given for comparison.




APPENDIX 5B

FIGURE 4

RELATIONSHIPS BETWEEN MERCURY CONCENTRATIONS IN HAIR AND BLOOD

Data from P.A. and Health Department Surveys (Appendix 5B Table 1 refers).

## APPENDIX 5C

Section 3.4

### THE RELATIONSHIP BETWEEN MERCURY IN THE HAIR AND SELENIUM IN THE HAIR

#### Introduction

Selenium readings in hair were collected for 134 respondents. Twenty-seven samples were eliminated from the analysis as they appear to have been contaminated.

Regression analysis based on 107 samples cases was used to test the relationship between hair mercury levels and hair selenium levels.

#### Specification and Data

A linear regression equation was used of the type,

$$y = a + bx + e$$

where y was the selenium level in the hair and x was the mercury level in the hair.

#### Results

The values of b, a and the significance of b as estimated using Student's t are set out below. Also estimated was the extent to which the independent variable 'explains' movements in the dependent variable ($R^2$).

| | | | |
|---|---|---|---|
| b | = 0.03 | a | = 0.45 |
| t(b) | = 2.61 | | |
| $R^2$ | = 0.06 | | |
| n | = 107 | | |

#### Conclusions

The value of b calculated is significant at the 1% level and there is therefore evidence of a positive relationship between hair mercury and hair selenium levels. However, hair selenium 'explains' a very small proportion of the total variation in hair mercury levels.

# APPENDIX 6

## ACTION LEVEL FOR MERCURY IN FISH

## UNITED STATES OF AMERICA

APPENDIX 6

## DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Food and Drug Administration
(21 CFR Part 122)

## ACTION LEVEL FOR MERCURY IN FISH AND SHELLFISH
Notice of Proposed Rulemaking

### Subpart C - Action Levels for Added Poisonous or Deleterious Substances

122,200 **Mercury in fish and shellfish.**

(a) An action level of 0.5 part per million* is established for mercury in fish and shellfish (mollusks and crustaceans), both raw and processed.

(b) Compliance with this section shall be determined as follows:

(1)(i) For processed fish and shellfish, a lot shall consist of a collection of primary containers or units of the same size, type, and style produced under conditions as nearly uniform as possible, designated by a common container code or marking, or, in the absence of any common container code or marking, a day's production.

(ii) For unprocessed fish and shellfish (raw, fresh, or frozen, usually whole), a lot shall consist of a collection of fish or shellfish from a shipment or storage designation, of a uniform size and kind (or species) taken from similar waters of origin. Where the waters of origin are not known, fish or shellfish of the same size and kind will be considered to comprise a lot.

(2) The sample for mercury analysis shall consist of a composite of the edible portion of 12 subsamples (primary packages or units from a lot) chosen randomly to be representative of the lot. The edible portion of vertebrate fish excludes heads, scales, tails, fins, viscera, and inedible bones.

(3) Composites shall be analysed by the official procedure of the Association of Official Analytical Chemists, described in "Changes in Methods: 25.A01-25.A03," Journal of the Association of Official Analytical Chemists (JAOAC), Vol. 54, p. 466 (1971).

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* This level was raised to 1.0 mg/kg on 25 May 1978.

(4) A lot does not comply with the action level established in paragraph (a) of this section if the value of the analysis of the composite of randomly chosen subsamples is greater than 0.50 ppm mercury.

Interested persons may, on or before March 6, 1975, file with the Hearing Clerk, Food and Drug Administration, Rm. 4-65, 5600 Fishers Lane, Rockville, MD 20852, written comments (preferably in quintuplicate) regarding this proposal. Received comments may be seen in the above office during working hours, Monday through Friday.

Dated: November 29, 1974.

A.M. SCHMIDT,
Commissioner of Food and Drugs.

(FR Doc.74-28405 Filed 12-5-74;8:45 am)

FEDERAL REGISTER, VOL. 39, NO. 236 - FRIDAY, DECEMBER 6, 1974.

## APPENDIX 7

## MERCURY ANALYSIS

## FOR A FISH SPECIES

## APPENDIX 7

SECTION 4.2

## MERCURY ANALYSIS FOR A FISH SPECIES

### OBJECTIVES

(1) Obtain a length - Hg level relationship for the fish species of interest with 95% confidence limits for the mean and for the data.

(2) Obtain a length frequency distribution for the species which is representative of the commercial catch.

(3) Obtain a length-weight relationship for the species.

(4) Obtain a weighted mean Hg for the species with respect to the commercial catch.

(5) Obtain the length measurement which predicts the mean Hg concentration of all fish of that length to be equal to a specified Hg concentration, say 0.5 mg/kg for fish of that species.

(6) Obtain the length measurement which predicts that the mean Hg concentration of all fish of that length to be less than a specified concentration, say 0.5 mg/kg with 97½% confidence, for the fish of that species.

(7) Obtain the length measurement which predicts the Hg concentration of an individual fish of that length to be less than a specified concentration, say 0.5 mg/kg with 97½% confidence, for fish of that species.

(8) Obtain the proportion of the commercial catch weight of a species which will be lost if an upper limit is placed on the length (or weight) of fish of the species.

(9) Obtain the length such that the weighted mean Hg level for fish smaller than this particular length will be equal to a specified Hg level, say 0.5 mg/kg.

(10) Obtain the weighted mean Hg level for the combined commercial catch of several species of fish.

(11) Obtain the mean Hg concentration of the fish remaining in the commercial catch of a species if an upper limit is placed on the length (or weight) of the fish species.

(12) Obtain the maximum Hg concentration in the fish remaining in the commercial catch of a species if an upper limit is placed on the length (or weight) of the fish species.

(13) Obtain the weight of a species of fish which is lost through maximum sizes in paras. 5, 6, 7 and 9 above, but which does not exceed the specified Hg level, expressed as a percentage of the total loss.

(14) Obtain the weight of fish lost, but which does not exceed the specified Hg level, expressed as a percentage of the total catch.

## CALCULATIONS

The length and weight measurement used in the following calculations can be either a partial length and partial weight or a total length and total weight depending on how the commercial catch of the particular species of fish is landed.

(1) Five Hg concentration - length equations can be considered for each species of fish:

(a) linear : $Hg = a_1 + b_1\ \text{length}$

(b) semi-log : $Hg = a_2\ b_2^{\ \text{length}}$

(c) log-log : $Hg = a_3\ \text{length}^{b_3}$

(d) adjusted semi-log : $Hg = a_4\ b_2\ \text{length}$

(e) adjusted log-log : $Hg = a_5\ \text{length}^{b_3}$

where $a_i$'s, $b_i$'s are constants.

The logarithmic transformation is carried out to reduce the dependence of the variance of the Hg concentrations on the length of the fish. This dependence is evident in nearly all of the Hg-length scattergrams. In addition, when the Hg concentrations are close to zero and/or the variation in Hg concentrations is large, negative estimates of Hg concentrations and negative lower confidence limits may be obtained using the linear equation; a result which is unrealistic. This latter problem can also be avoided by carrying out a transformation such as a logarithmic transformation.

One disadvantage in using the logarithmic transformation is that when the equation is back-transformed to its original units there is a bias inherent in the equation because of the larger Hg concentrations being given less weight in the Hg-length relationship. Depending on the variation about the Hg-length equation, the bias could be approximately 5-20%. If the equations are used to document a relationship between Hg-length then equations (b) or (c) may be adequate. However, if the equations are to be used to predict the mean Hg concentrations then an approximate correction to the equations (b) and (c) to produce equations (d) and (e) respectively is recommended. This correction is as follows:

$$a_4 = a_2 e^{S_2^2/2}$$

$$a_5 = a_3 e^{S_3^2/2}$$

where $S_2$ and $S_3$ are the mean square deviations from the (natural) logarithmically transformed regression (Baskerville 1972). This approximation will usually be very close to the unbiased estimate of the mean mercury concentrations (Beauchamp and Olson 1973). Confidence limits for the corrected estimates of the mean Hg concentrations can be obtained using Cox's Direct Method (Land 1972). Confidence limits for the estimated Hg concentrations for an individual using equations (d) and (e) would be the same as for equations (b) and (c) respectively.

There does not appear to be any fixed rule about when an equation is suitable for predictive purposes. One criterion which has been proposed states that the F-value which is used as a measure of the significance of the regression equation should be greater than the selected percentage point (F-table value) by about four times (Draper and Smith 1966). However, as can be noted from most graphs of Hg-length equations with its confidence limits, the confidence interval for the estimate of the mean of the Hg concentrations is relatively much smaller than the confidence interval for an individual. Thus even though the variation for an individual may be large the corresponding variation for the mean may be reasonably small (Hocking 1976).

(2) A length frequency distribution for the commercial catch of a species can be obtained from two sources:

(a) measuring the fish landed by boats throughout the year;

(b) measuring the fish passing through the fish markets throughout the year.

Both (a) and (b) can be regarded as approximately the length frequency distribution for the commercial catch of the species.

(10) The weighted mean Hg concentration for several species of fish combined can be obtained as follows:

$$Hg = \sum_j P_j \, Hg_j \quad \left( \sum P_j = 1 \right)$$

where $Hg_j$ is the weighted mean Hg concentration for the jth species and $P_j$ is the proportion which the jth species contributes to the total weight of the combined commercial catch of the species.

(11) If fish above the k th length class are to be rejected then weighted mean Hg concentration of the fish remaining is

$$Hg \text{ (remainder)} = \frac{\sum_{i=1}^{k} f_i \; Wt_i \; Hg_i}{\sum_{i=1}^{k} f_i \; Wt_i}$$

(12) The maximum Hg concentration of fish remaining in the catch if an upper limit is imposed on the fish species can be defined as the upper 95% confidence limit of the Hg concentration at the size of the upper limit.

(13) For each size class above an upper limit, the proportion of fish which would be expected to be below the specified Hg standard can be determined from the Hg concentration - length regression equation and the variation about the regression equation. The overall proportion can then be obtained by a weighted average of the proportion of each of the size classes.

(14) The proportion of the commercial catch which is lost even though it is below the specified Hg level can be obtained by multiplying the proportion of the commercial catch which is above the upper size limit (see 8 above) with the proportion of the catch above the upper limit which is expected to be below the specified Hg concentration (see 13 above).

(3) In order to obtain a weighted average of mercury concentration for the species, it is necessary to estimate the mean weights associated with the mid-points of each class of the length frequency distribution in (2). The equation used is of the form weight = a length$^b$ where a, b are constants.

(4) The weighted mean Hg level for a species is obtained as follows:

$$Hg = \frac{\sum_{i=1}^{n} f_i Wt_i Hg_i}{\sum_{i=1}^{n} f_i Wt_i}$$

where $f_i$ is the number of fish in the ith class;
$Wt_i$ is the estimated mean weight of fish of the ith class;
$Hg_i$ is the estimated mean Hg concentration of the ith class; and
n is the number of length classes.

(5)-(7) Maximum lengths $L_1$-$L_3$ identified as shown in Figure 1.

(8) The proportion of the commercial catch weight which will be lost if an upper limit is placed on the length of a particular fish can be found as follows:

$$\text{Proportion lost} = \frac{\sum_{i=k}^{n} f_i \; Wt_i}{\sum_{i=1}^{n} f_i \; Wt_i}$$

where $f_i$ is the number of fish in the ith class; $Wt_i$ is the estimated mean weight of fish of the ith class; and the lengths of the fish associated with classes k to n are above the proposed upper limit of length.

(9) If the weighted mean Hg level for a species is greater than 0.5 mg/kg, then find k such that

$$\frac{\sum_{i=1}^{k-1} f_i \; Wt_i \; Hg_i}{\sum_{i=1}^{k-1} f_i \; Wt_i} < 0.5 \quad \text{and} \quad \frac{\sum_{i=1}^{k} f_i \; Wt_i \; Hg_i}{\sum_{i=1}^{k} f_i \; Wt_i} > 0.5$$

where $f_i$, $Wt_i$, $Hg_i$ are as defined in (4)

The length can then be found by interpolation on the length range of the kth class.

## APPENDIX 7

### FIGURE 1

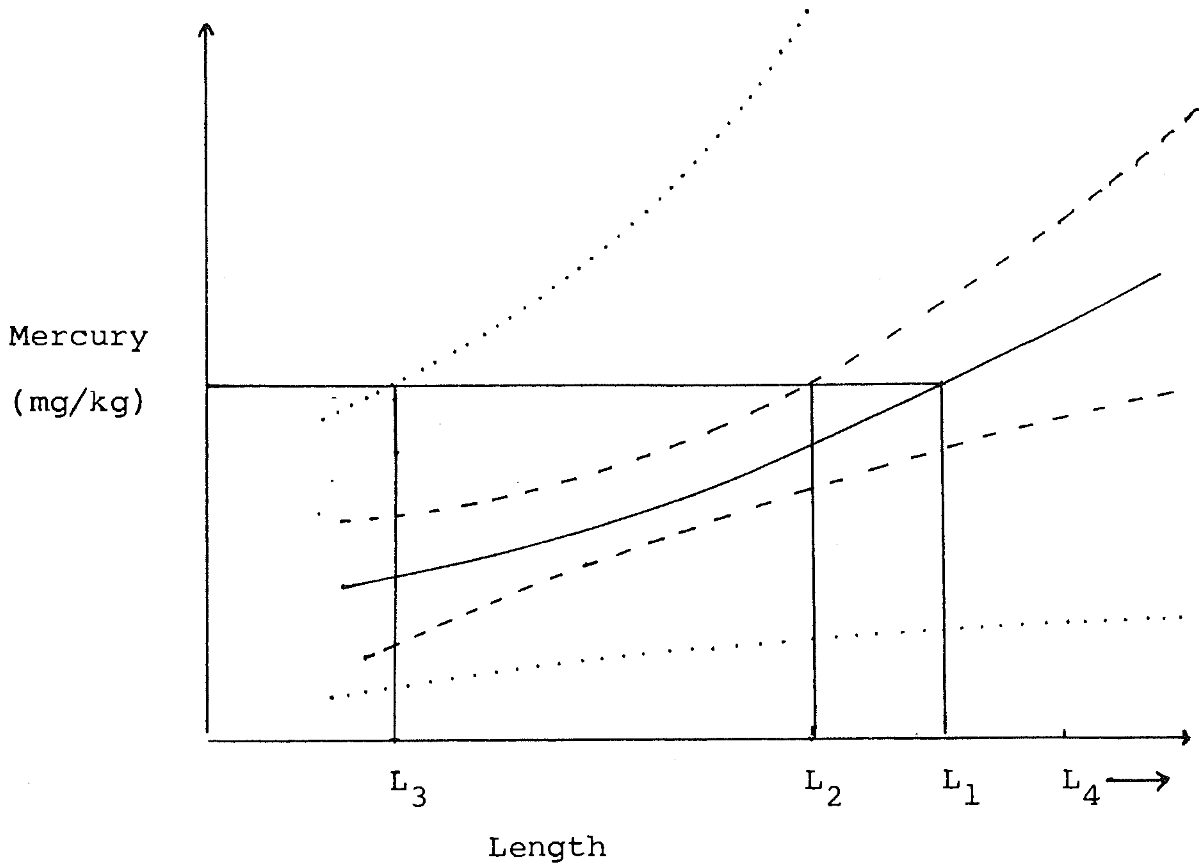


Figure 1 - Relationship between length and mercury level (mg/kg), showing the line (-) fitted by the adjusted curvilinear regression, and its 95% confidence limits for the mean (---) and for individual fish (....).

$L_1$ = maximum length as per (5)

$L_2$ = " " " " (6)

$L_3$ = " " " " (7)

$L_4$ = " " " " (9)

# APPENDIX 8

## PROCEDURES FOR INDIVIDUAL SPECIES

APPENDIX 8

SECTION 4.2(ii)

## PROCEDURES FOR INDIVIDUAL SPECIES

1. Southern bluefin tuna. Most of the mercury data available were derived from canned tuna or from a large sample of tuna fillets intended for export from South Australia. While the average level of 0.22 mg/kg (Tables 19 & 20 in 3.1(iii)) was less than any of the possible mercury standards being considered, it was thought worthwhile in interests of conformity to examine the effects of the various options. However, because of the lack of Hg/length data, the analysis had to be restricted to a "no correlation" approach. In the absence of data from other areas, the analyses in Tables 61-69 could be undertaken only for SA, noting that even though this result was unlikely to be representative of the size composition in other States, it was expected to give a reasonable overall picture because 90% of the Australian total catch of tuna for 1976/7 were landed in SA but the proportion landed in SA in that year was unusually high. In any case, despite a maximum of 0.63 mg/kg, only the most extreme option ($L_3$ at 0.25) was expected to result in any loss of fish.

2. Shark. Good data were available from Victorian (school and gummy) and WA (bronze whaler, whiskery and gummy) shark for which assessments had already been published (Walker 1976; Hancock et al 1977). Size composition data for SA school shark had been collected by Victoria and could be analysed using Victorian mercury concentration data. Without size composition data for Tasmania a similar result to Victoria had to be assumed for the two major species, school and gummy. Analysis of the large NSW catch of predominantly angel, banjo, dog, gummy and school shark was made difficult by the large variety of species with insufficient supporting information. It was therefore assumed for the purposes of computation that the percentage losses of NSW shark would be equivalent to those of the rest of Australia. However, since the major species in NSW (angel) has a mercury level (Section 3.1) lower than the Australian average the effect on NSW shark will have been overstated. Reference to Tables 19 & 20 in 3.1(iii) will give an indication of the range of unweighted mean mercury levels in many Australian shark species. The catch weighted mean for these species of Australian shark for which data were available was estimated to be 0.82 mg/kg (Table 68).

3. Mullet. Account could only be taken of the major species of mullet for each State. For sea mullet, concentrations were so low that no losses were expected. Adequate data for yelloweye mullet were available only for Victoria, from which results were extrapolated to Qld, WA and SA. In the absence of information on flat-tail mullet in NSW, the analysis concentrated on sea mullet which contributed most of that State's catch.

4. Australian salmon. Neither the mercury/length data for Victoria and WA combined (western subspecies) nor data for NSW (Eastern subspecies) gave a significant correlation. Confidence limits of mean and individual mercury analysis were calculated for the two areas, from which the various options could result only in "all or none" lost since no reference sizes could be established.

5. Whiting. As with mullet only major species could be considered. For King George whiting, which had low concentrations of mercury, no losses were expected from any of the alternatives for control. Since suitable data were not available for school whiting from Victoria, golden lined and sand whiting from Qld, nor for western sand whiting from WA, data from NSW sand whiting were used as an approximation for all these situations.

6. Snapper. Combined mercury/length data from NSW, Victoria and SA (all *C. auratus*) were used in conjunction with separate size compositions from each State. Data from NSW were used for Queensland. Complete data were available from WA (*C. unicolor*).

7. Gemfish. Full information was available from this predominantly NSW fishery, but catches have been increasing in other States, in particular in the Great Australian Bight from which data were also presented in the Section on emerging fisheries (Section 4.2(iv)).

8. Flathead. Data were available for major species only, i.e. NSW dusky flathead for which only mercury data were available, but in concentrations too low for losses, and tiger flathead from NSW and Victoria. Data from Victorian sand flathead were used to approximate for northern sand flathead for Queensland.

9. Jackass morwong. Combined mercury/length data from NSW, Victoria and SA were used with supporting data from NSW and Victoria. There were inadequate data to examine the smaller quantity of rubberlip morwong from NSW. Individual mercury data from the Bight fishery did not exceed 0.25 mg/kg.

10. Giant perch. Mercury data were not accompanied by length measurements, so that calculations for Queensland and Northern Territory had, as with A. salmon, to be made as a "no correlation".

11. Redfish. Data from WA redfish ( = nannygai not Bight redfish) were substituted for NSW redfish.

12. Mackerel. No Australian data were available for an assessment for Queensland. The assessment in Table 64 was made using Taiwanese data (Sun and Chang, 1972) for Spanish mackerel - 15 samples, mean 0.11, range 0.05-0.20. Other mackerel species should be low in mercury.

13. Bream. The only complete data were for Victorian black bream, with some substitution for NSW and SA, while NSW mercury data provided a 'no correlation' assessment for yellowfin bream in Queensland.

14. Ruff. Full data for WA but SA had to be based on size composition from Victoria and length/weight from WA. Note that, despite this, similar percentage losses were sustained for the two States.

15. Snoek. Full information was available for assessment of Victorian snoek. Snoek (barracouta) from the Bight contained mean mercury less than 0.5 mg/kg.

16. Luderick. Mercury data published by Bebbington et al (1977) were used to predict no losses.

17. Other species. For remaining species ranked on importance to individual States only Bight redfish had sufficient data for assessment.

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