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The Present State of Knowledge on Commercial and Recreational Fisheries in Port Phillip Bay, Victoria, and their Interactions with Nutrients and Toxicants

G.J. Nicholson
Marine Science Laboratories
Deaprtment of Conservation and Natural Resources
P.O. Box 114
Queenscliff, Victoria, 3225, Australia

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CSIRO Institute of Natural Resources and Environment
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Melbourne, Victoria 3000.

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EXECUTIVE SUMMARY

Port Phillip Bay is an almost land-locked marine embayment of 1950 km^2 with urban and industrial development from the cities of Melbourne (pop. 3,000,000) and Geelong (pop. 200,000) surrounding most of the Bay.

It supports Victoria's largest commercial and saltwater recreational fisheries. The commercial fishery annually harvests up to 1900 t of finfish, 2000 t of scallop meat, 650 t of mussels and 52 t of abalone with a wholesale market value of $37 million. The recreational fishery annually catches an estimated 1070 t of finfish.

The main freshwater discharges of anthropogenic-sourced nutrients entering the Bay are the Yarra River, the Werribee Sewage Treatment Complex and the Patterson River. The effects of this nutrient input could be associated with seagrass dieback caused by excessive epiphytic growth, algal blooms introducing bitter taste and PSP toxins in shellfish, and fish mortalities.

Toxicants such as metals and organics enter the Bay from sources such as discrete licensed industrial discharges, urban runoff, the Werribee Sewage Treatment Complex, creeks and rivers, and atmospheric transport. Shellfish and fish in the Bay have been found to contain toxicant levels which in some instances exceed the maximum permitted levels in food for human consumption. Toxicants have also been implicated in causing fish kills within the Bay.

Current studies in the Bay have focussed on mercury, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc, petroleum hydrocarbons, selected pesticides, PAHs and PCBs in water, sediments, sand flathead and mussels. Considering that approximately 70,000 synthetic chemicals in commercial use enter coastal waters, further studies could be developed to consider aspects of contamination away from the traditional compounds mentioned previously and in other species of biota.

A series of parameters suitable for predictors and for observing a 50% increase in nutrients in the Bay would be to measure dissolved oxygen in the water column, organic N levels and chlorophyll levels.

Surface water microlayer sampling and dialysis bags are probably the quickest and simplest methods of monitoring toxicant levels in the Bay, as they directly monitor the water column. The surface microlayer sampler collects water samples from the top 50 m of the water surface, where contaminants are highly concentrated. The partitioning effect on the contaminant in the water column concentrates contaminants within the dialysis bag.

Sand flathead and mussels are considered good indicator organisms for the Bay. Both of these organisms could be monitored on a consistent basis to observe any increase in selected contaminant parameters.

CONTENTS

1.0. GENERAL INTRODUCTION

The Port Phillip Bay (PPB) Environmental Study aims to determine the environmental status of the Bay in relation to nutrients and toxicants. One of the element tasks in the Study is investigation of the impact of nutrients and toxicants on the major commercial and recreational fisheries in the Bay. Port Phillip Bay is the most important bay and inlet commercial fishery in Victoria. The major commercial species are flathead (sand flathead, long-nose or yank flathead and rock flathead), snapper, King George whiting, southern anchovy, pilchard, calamari, mussels, scallops and abalone. This literature review will attempt to provide the following information:

1) To document the existing state of knowledge on commercial and recreational fish and molluscs and their fisheries, with respect to general biology, spatial and temporal dynamics, trophic interactions, biomass and productivity, including the identification of extant databases or maps.

2) To identify and where possible quantify key physical, chemical or biological processes controlling the natural interactions of commercial and recreational fish and molluscs and their fisheries with nutrients and toxicants.

3) To identify the key processes and level of knowledge needed to predict the impact of a 50% increase in nutrients and/or toxicants on commercial and recreational fish and molluscs and their fisheries in Port Phillip Bay.

Port Phillip Bay, located on the central south coast of Victoria, Australia, is an almost land-locked marine embayment with an area of 1950 km^2 and a maximum depth of 24 m. Urban and industrial development surrounds most of the Bay, with the city of Melbourne (pop. 3,000,000) along the northern and eastern shorelines and the city of Geelong (pop. 200,000) sited in the south-west. Both of these cities have extensive port facilities and support manufacturing industries, including petrochemical and fertiliser industries. Water exchange with Bass Strait is restricted by the 3 km wide entrance to the Bay.

In terms of finfish production, Port Phillip Bay rates low in comparison with other Australian locations such as Sydney Estuary, Jervis Bay, Botany Bay, Tuggerah Lakes and Cockburn Sound (Gwyther, 1990). However, when the shellfish contribution to total production of the Bay is considered, Port Phillip Bay compares far better with other locations in terms of fishery production. This could be considered supportive of the view that scallop, mussel and oyster growth rates within Port Phillip Bay are related to the levels of anthropogenic nutrient inputs into the Bay (Gwyther, 1990). Studies over a 20 year period show evidence of an increase in growth rate, possibly related to density-dependent effects resulting from 20 years of commercial fishing, as well as increased nutrient input from the catchment area of the Bay (Gwyther and McShane, 1988).

Port Phillip Bay is the most productive bay and inlet commercial fishery in Victoria (Table 1), with over 60 species of finfish being recorded from commercial catches (Hall and MacDonald, 1986). In 1989-90 1900 t of finfish with a wholesale market value of about $5 million was obtained from the Bay (NREC, 1991).

Table 1: Mean annual catches in tonnes weight of commercial finfish for each decade beginning from 1940 for Port Phillip Bay, Gippsland Lakes, Western Port and Corner Inlet.

Location	1940	1950	1960	1970	1980	1990
	mean annual catch wt (tonne) per decade					
Port Phillip Bay	1135	981	1106	1133	1450	1675 (90-91)*
Gippsland Lakes	325	366	550	801	773 (81-82)*	
Western Port	632	558	399	237	159 (84-85)*	
Corner Inlet/ Nooramunga	373	315	306	222	194 (81-82)*	

* indicates relevant period over which catch figures apply.

1.1 Commercial Fishery

During the period between 1940 and 1990 total annual commercial catches of finfish from Port Phillip Bay varied between 740 and 1907 t. Clupeoids (pilchards, anchovies and sprats) have contributed about 50% and more by weight of the total catch since 1980-81. The total annual commercial catch from the Bay has generally increased from 1256 t in 1980-81 to 1907 t in 1988-89. However, if the clupeoid catch weight is not considered, then the mean annual commercial catch of finfish from the Bay from 1980-81 to 1989-90 has been about 600 t (NREC, 1991).

Several species of shellfish and crustaceans are also commercially harvested from the Bay (Hall and MacDonald, 1986). According to Parry *et al.* (1990), there are 19 scallop fishers licensed to dredge Port Phillip Bay only, with a further 65 licensed to dredge the Bay as well as all other Victorian waters. Annual catches of up to 2000 t of scallop meat have been taken from the Bay (Parry *et al.*, 1990), with a wholesale market value of about $30 million (Greg Parry, personal communication) but from 1987 to 1991 the abundance of harvestable scallops was very low and there was little or no harvesting at all (NREC, 1991).

Mussels and abalone are other commercially important shellfish species in the Bay, with most of the mussels (about 650 t annually, approximate value $1.6 million) being harvested from culture farms. The mean annual catch of abalone from Port Phillip Bay over the last 6 years has been 52 t with an approximate annual wholeale value of $1 million.

There are 127 commercial fishers with endorsements on their Master Fisherman's Licence to catch and sell finfish from Port Phillip Bay. Table 2 indicates annual catch weights in tonnes and trends of several commercial species within the Bay. The fishermen operate from 18 recognized ports around the Bay and use a number of different fishing methods. The main fishing methods are long-lines, haul and purse seine nets and mesh nets. Less important methods include squid jigs, hand-lines and hoop nets (NREC, 1991).

An explanation of the major fishing methods as described in NREC (1991) are as follows:

1) Long-lining. This method of capture depends on baited hooks, which are attached to snoods or secondary lines which are in turn attached to and spaced apart along a mainline. The mainline is set in a straight line between two vertical end lines held in place by buoys and anchors. This method catches predominantly shark, ling, rock cod and snapper.

2) Seine netting. A seine net is a rectangular net with weights on the bottom and floats on the upper long edges and hangs vertically in the water. A seine net may be hauled by hand or by power winches, usually from shore or over shallow banks. The passage of the weighted line along the seabed often churns up the upper layer of substrate. The catch is usually sorted in shallow water to remove undersized and non-target fish while still alive. If netting from a boat, the boat must be anchored otherwise the practice amounts to trawling, which is prohibited in Bays and inlets. The usual species caught are mullet, rock flathead, whiting, squid, Australian salmon, flounder, tommy rough, pike and garfish.

3) Mesh (gill) netting: These nets are rectangular with an upper float line and a weighted lead line. However, instead of being hauled, these nets are set in a straight line and usually anchored in place. Fish become entangled in the net by the head or gills, with the type and size of the fish being caught determined by the size of the mesh. Few under-sized fish and non-target species are caught. The quality of the fish caught remains high if the net is retrieved after a few hours; otherwise fish that are caught in the net are subject to attack by sea lice. The species usually caught by mesh netting are mullet, rock flathead, whiting, flounder, pike, stranger, shark and snapper.

1.2. Recreational fishery

Port Phillip Bay is Victoria's largest saltwater recreational fishery with an estimated 328,000 people having fished there during the year ending February 1977 (Beinssen, 1978). A twelve month survey of recreational fishing in Port Phillip Bay during 1982-83 yielded an estimate that day-time recreational anglers spent 3.1 million hours catching 4.16 million fish with a total catch weight of about 1050 t (MacDonald and Hall, 1987). Snapper was the species most sought after by boat-based anglers, followed by flathead and King George whiting. Flathead represented more than 50% of the total day-time angling catch by shore-based and boating anglers. Other species which had high catch numbers were garfish (14%), King George whiting (9%), mullet (6%) and calamari (5%). Snapper constituted only 2% of the total catch numbers (MacDonald and Hall, 1987).

There are no restrictions on the number of recreational fishers permitted to fish the Bay. Each angler is allowed to use a maximum of 6 lines with a maximum of 3 hooks on each, or two squid jigs, at any one time (MacDonald and Hall, 1987; NREC, 1991). Bag limits apply for King George whiting, snapper and calamari and size limits apply for most fish species caught in the Bay (DCE, 1992).

Table 2: Annual commercial catch weights (in tonnes) of several major species taken from Port Phillip Bay for the fiscal years 1980-81 to 1989-90 (NREC, 1991).

Species	80 -81	81 -82	82 -83	83 -84	84 -85	85 -86	86 -87	87 -88	88 -89	89 -90
	commercial catch (tonne)									
Anchovy	130	135	173	130	67	70	135	92	27	16
Flathead*	50	42	40	50	50	60	50	40	48	25
Pilchard	500	500	505	550	495	600	1000	1005	1400	750
Snapper	210	170	145	125	110	115	105	115	165	115
KG whiting	50	35	40	40	30	72	60	60	72	130
Calamari	21	37	40	63	56	18	17	24	17	21

* For all flathead species

2.0. PORT PHILLIP BAY COMMERCIAL AND RECREATIONAL FISHERIES.

2.1. Species.

2.1.1. Flathead

Platycephalus bassensis (sand flathead)
Platycephalus speculator (yank flathead)
Platycephalus laevigatus (rock flathead)

General Biology

Introduction and species description. A number of flathead species are found in Port Phillip Bay. Of major recreational and to a lesser extent commercial importance are the sand flathead (*Platycephalus bassensis*), long-nose or yank flathead (*Platycephalus speculator*) and rock flathead (*Platycephalus laevigatus*) (Hall and MacDonald, 1986; MacDonald and Hall, 1987). Flathead are distinctive fishes with elongate dorso-ventrally compressed bodies and eyes situated dorsally on depressed heads. There is a range of colour between species; the general pattern is dark dorsally and light ventrally. Sand flathead have a dorsal surface which is usually pale brownish or grey with many small reddish brown spots, with larger spots on the sides forming a broken longitudinal stripe. The ventral surface is white. Yank flathead have a dorsal surface which is usually dusky grey with small darker grey-green spots. The ventral surface is white. Rock flathead have a dorsal surface which is dark brownish-black. The sides, head and jaws are bright yellow with brownish-black spots. The ventral surface is yellow or cream (Last *et al*., 1983).

Length, weight and life span. Sand flathead grow to about 43 cm long and attain a weight of up to about 3 kg at 8 to 9 years of age. Yank flathead grow to 90 cm long and 8 kg at approximately 14 years of age. Rock flathead can grow to 50 cm long and weigh up to 2 kg. No age estimates were found for rock flathead (Brown, 1977; Last *et al.,* 1983; Barker, 1992).

Distribution. Sand flathead are found from southern New South Wales to South Australia and Tasmania, and are most common in inshore bay and inlet areas although they are found to depths of 100 m in Bass Strait. They are the most common species of flathead found throughout Port Phillip Bay, appearing to prefer depths of more than 15 m. Yank flathead are found from Victoria through to southern Western Australia and Tasmania. Rock flathead are found from southern New South Wales through to southern Western Australia and Tasmania (Brown, 1977; Last *et al.,* 1983; Barker, 1992).

Habitat and feeding. Sand flathead are demersal, non-migratory finfish (Dix *et al*., 1975). They are opportunistic ambush feeders, preferring fine mud substrate, where they lay camouflaged or partly buried in soft bottom sediments, feeding at day and night (Hall and MacDonald, 1986). Within Port Phillip Bay, the adult diet consists mainly of crustaceans (flatbacked crabs) and small fish (pilchard, sand sprat, banded goby and sea moth), and supplementary small invertebrates (Andrews, 1988).

Yank flathead live mainly on shallow sandy patches between seagrass beds (Last *et al.*, 1983), and are predominantly piscivorous (Brown, 1977). Rock flathead live in shallow water habitats on reefs or among seagrasses and algae (Last *et al.*, 1983). Smaller rock flathead in Corner Inlet preferred a diet of fish, squid and shrimp, whilst larger individuals fed mostly on the rock crab with some fish (Klumpp and Nichols, 1983).

Spawning time and maturity. Sand flathead spawning period in PPB is between September and October. Brown (1977) estimated that sand flathead are mature enough to spawn at two years of age. Yank flathead spawn in the Bay between October and December (Brown, 1977). There is no information for rock flathead spawning in Port Phillip Bay, but rock flathead from Corner Inlet are known to have a November-December spawning period (Klumpp & Nichols, 1983).

Biomass estimates. None currently available, although a database is in preparation at the Marine Science Laboratories, Department of Conservation and Environment, Victoria.

Commercial fishery

Fishing method. Mesh netting accounted for 65% of the total flathead catch during the mid-1970's to the mid 1980's, and remains the most important method for catching rock and yank flathead. However, during recent years, catches of sand flathead by netting have declined to the extent that approximately 30% of the catch is now taken by hand-lining and 30% by long-lining (Hall and MacDonald, 1986).

Annual catch. Sand flathead contributed more than 90% of the mean annual catch in Port Phillip Bay of 171 t of all flathead species during the 1950's, declining to 33% of the mean annual catch of 50 t of all flathead species during the early to mid 1980's. During the 1983-84 season, sand flathead, yank flathead and rock flathead constituted 38%, 25% and 37% of the total flathead catch, respectively. There could be three reasons for this change in species abundance: a change in relative abundance; a change in the targeting of species; or simply an improvement in species identification which reflects a catch composition that has existed all along (Hall and MacDonald, 1986). From 1983-84 to 1988-89 the annual commercial flathead catch from the Bay remained at around 50 t. However, the flathead catch dropped to 25 t during 1989-90 (NREC, 1991). Competition resulting from the availability of other types of high quality table fish is believed to have contributed to the reduction in total annual catch weight (Hall and MacDonald, 1986), rather than a marked drop in abundance. The minimum legal size is 25 cm (DCE, 1992).

Catch distribution. Most of the commercial catch of flathead (all species) are taken during the late autumn and winter. This catch distribution reflects regulations prohibiting the use of mesh nets from late spring to early autumn. Sand flathead are taken in all areas of Port Phillip Bay, with most being taken in near-shore, shallow waters over little or no vegetation (Hall and MacDonald, 1986).

While the previous statement appears to contradict Brown (1977), who found that sand flathead appear to prefer habitats in water more than 15 m deep, it may actually be a reflection of either the form of fishing used in this fishery, or that sand flathead are also suitably abundant in grounds not far from the fishers home port. More than 60% of the rock flathead and yank flathead are taken from the Geelong Arm (Hall and MacDonald, 1986).

Recreational Fishery

Fishing method. Shore-based and boat-based angling were the predominant forms of fishing, with nearly 98% of the total flathead catch being caught by boat-based anglers (MacDonald and Hall, 1987).

Catch. The recreational catch for all species of flathead during a 12 month survey beginning from October 1982 was estimated to be 437 t. The estimated recreational catch was more than the the corresponding commercial catch, and it appears this trend will continue because commercial fishing is contained by licensing schemes whereas angling effort is relatively unimpeded, except for the minimum legal size of 25 cm.

Catch distribution. Data from the 12 month survey beginning from October 1982 indicates that the greatest catch rate for all species of flathead by recreational anglers occurred during December, January and June. The better catch rates for flathead were obtained in the eastern and southern regions of the Bay. The modal size of flathead (all species) caught was 28 cm (MacDonald and Hall, 1987).

2.1.2. Snapper *Chrysophrys auratus*

General Biology

Introduction and species description. Snapper are an important component of the commercial catch from Port Phillip Bay and are also actively sought by recreational anglers. Snapper have moderately elongate, moderately compressed bodies. The dorsal profile of adults is strongly arched in front, and the ventral profile is almost straight. Very large individuals often have a prominent hump on the top of the head and a pronounced bulge on the snout (Last *et al.,* 1983; Hall and MacDonald, 1986). The body of snapper is mostly reddish pink, with many bright blue spots on the sides. First year fish are often barred, and very old fish occasionally possess no spots (Last *et al.*, 1983).

Length, weight and life span. Snapper grow to up to 120 cm long, weigh up to 20 kg and have a life span exceeding 35 years. It appears that annual growth rates of snapper up to 30 cm long in Port Phillip Bay and Western Port are 17 - 20% higher than for oceanic snapper (Last *et al.,* 1983; Francis and Winstanley, 1989; Barker, 1992).

Distribution. Snapper are distributed south from the Queensland coast through to Western Australia and Tasmania, as well as from Lord Howe Island, Norfolk Island and New Zealand (Last *et al.,* 1983).

There are two stocks in Victorian waters. An eastern stock ranges between far eastern Victoria and northern New South Wales, and a western stock ranges from Western Port to eastern South Australian waters (Sanders and Powell, 1979). During spring a portion of the western stock moves east along the coast into Port Phillip Bay and Western Port for spawning, returning west in late autumn. However, snapper are present in Port Phillip Bay all year (Winstanley, 1981). Juveniles inhabit sheltered bays and estuaries but disperse into deeper coastal waters as they mature (Hall and MacDonald, 1986).

Habitat and feeding. Snapper congregate in the vicinity of broken reef or seagrass. In Port Phillip Bay, snapper between 10 and 30 cm long feed mainly on small crustaceans, isopods, amphipods and polychaete worms. Snapper between 30 and 50 cm long feed mainly on butterfly shells (*Electroma georgiana*), mussels, other molluscs and crabs. Larger snapper feed mainly on crabs, mussels, bubble shells (*Philine angasi*), other mussels and small fish (Winstanley, 1983).

Spawning time and maturity. Snapper in Port Phillip Bay spawn between October and early March. Snapper mature at three to four years of age at a size of about 27 cm (MacDonald, 1982; Hall and MacDonald, 1986). Larger fish can produce up to six million eggs when spawning (Barker, 1992).

Biomass estimates. None currently available, although a database is in preparation at the Marine Science Laboratories, Department of Conservation and Natural Resources, Victoria.

Commercial Fishery

Fishing method. Most of the commercial catch of snapper taken from the Bay during 1973-74 to 1983-84 were caught using long-lines (78%). Lesser proportions of the commercial snapper catches were taken using haul seines (13%), mesh nets (3%) and hand-lines (2%) (Hall and MacDonald, 1986).

Annual catch. The mean annual catch of snapper from Port Phillip Bay during the period 1973-74 to 1983-84 was 195 t. In 1983-84 the catch in Port Phillip Bay was 127 t, which represented 80% of the total Victorian catch of snapper. The catch per unit effort (CPUE) of snapper has been decreasing since 1980-81. It is uncertain whether this trend reflects a periodic fluctuation or a longer term decline in snapper abundance (Hall and MacDonald, 1986). From 1983-84 to 1989-90 the catch was stable at about 120 t except for 1988-89 when 170 t was landed (NREC, 1991). The minimum legal size is 27 cm (Hall and MacDonald, 1986; DCE, 1992).

Catch distribution. During October to December approximately 55% of the total annual catch of snapper in Port Phillip Bay are taken, with a further 34% taken during the remaining summer and early autumn. Only 2% of the total catch is taken during the winter. More than 75% of the annual catch is taken from water less than 12 m deep, over vegetated reef habitats as well as clear soft-bottom habitats. Substantial quantities of snapper are taken from the northern and eastern near-shore areas of the Bay and from the eastern section of the Geelong Arm (Hall and MacDonald, 1986).

Recreational Fishery

Fishing method. Night angling for snapper was not investigated during the survey by MacDonald and Hall (1987) in spite of the fact that a large proportion of angling for snapper in the Bay is usually conducted at night. As a result their catch estimates for snapper probably under-estimate of the total recreational snapper catch. Day-time boat-based anglers caught 82% of the estiamted total recreational catch of snapper. Snapper is the species most sought after by boat anglers.

Annual catch. It was estimated that recreational anglers accounted for at least 50% of the total Bay snapper catch during the 12 month survey period beginning from October 1982. The minimum legal size for snapper is 27 cm. Bag limits apply; a maximum of 5 fish over 40 cm in length can be taken daily, or a maximum of 10 fish if less than 40 cm long (MacDonald and Hall, 1987; DCE, 1992).

Catch distribution. Data from the 12 month survey indicates that the greatest angling success rates for recreational anglers fishing for snapper was during February, March and September. The modal size distribution of snapper caught was between 20 - 40 cm fork length. The bulk of the snapper caught were from the southern part of the Bay (MacDonald and Hall, 1987).

2.1.3. King George Whiting *Sillaginodes punctatus*

General Biology

Introduction and species description. King George whiting is the largest species of whiting found in Australian waters. It is a prized table fish for both recreational and commercial fishers and is caught in many southern Australian bays and estuaries (Hall and MacDonald, 1986). The King George whiting has an elongate, slender and slightly compressed body and a tapering head. The dorsal surface is light brown to brownish black, with many small dark spots along the sides. The ventral surface is silver (Last *et al.,* 1983).

Length, weight and lifespan. King George whiting grow to 69 cm long and up to 4.8 kg. Current literature indicates that whiting live for about 6 years (Gilmour, 1969; Last *et al*., 1983; Hall and MacDonald, 1986).

Distribution. King George whiting are found in the coastal waters of Tasmania, Victoria, New South Wales, South Australia and West Australia (Last *et al*., 1983).

Habitat and feeding. The diet of King George whiting varies with age. In a study based in Western Port younger juveniles were found to inhabit heavily grassed patches of seagrass and fed predominantly on harpacticoid copepods and amphipods. As the fish grew older they inhabited less dense grassy areas and the ghost prawn (*Callianassa australiensis*) became the major diet item (Robertson, 1977).

Spawning time and maturity. Mature whiting at 4 years of age are believed to move out of Port Phillip Bay during winter to spawn. Water currents carry fertilized eggs and larvae back inshore (Hall and MacDonald, 1986). Smaller sized spawning adults produce about 100,000 eggs, while larger fish can produce up to 500,000 eggs (Barker, 1992).

Biomass estimates. None currently available, although a database is in preparation at the Marine Science Laboratories, Department of Conservation and Natural Resources, Victoria.

Commercial Fishery

Fishing method. Haul seine nets are the most popular method of capture, followed by mesh netting. Hand-lining accounts for only a small portion of the total commercial catch of King George whiting from Port Phillip Bay (Hall and MacDonald, 1986).

Annual catch. In the early 1970's, annual King George whiting catches of more than 100 t were obtained. Catches then declined to 43 t in 1983-84, which represented 40% of the Victorian catch of King George whiting for that year. However, the annual catch increased to about 130 t in 1989-90, which may have reflected an exceptionally good spawning season several years earlier (NREC, 1991). The reason for declines are not clear. It is worthwhile noting that reduction in catches of King George whiting in Western Port correlated with increasing dieback of seagrass (Hall and MacDonald, 1986). The minimum length for King George is 27 cm (DCE, 1992)

Catch distribution. The largest catches of King George whiting in Port Phillip Bay are taken during late autumn, although they can be caught throughout the year. The lowest catches are usually taken during late winter and early spring. Almost 70% of the annual whiting catch is taken from channels, 25% from other deep water habitats and 6% from shallow water habitats. It is likely that a larger portion of the catch is taken from shallow areas and that this anomaly is the result of misinterpretation by fisherman on filling out catch returns. The anomaly may also be a reflection of the fact that seine nets set in deep water are hauled into more shallow waters for final sorting of the catch (Hall and MacDonald, 1986).

Recreational Fishery

Fishing method. Boat-based anglers caught 96% of the recreational catch of King George whiting (MacDonald and Hall, 1987).

Annual catch. The recreational catch of King George whiting during a 12 month survey beginning from October 1982 was 84 t. King George whiting is one of most sought after species by boat anglers (MacDonald and Hall, 1987).

Catch distribution. Data from the 12 month survey beginning from October 1982 indicates that the best catch rate by recreational anglers fishing for King George whiting in the Bay was in October.

Other months in which relatively good angling catch rates were obtained were November to June (MacDonald and Hall, 1987). King George whiting were major contributors to angling success in the southern region of the Bay. The modal fork length of King George whiting taken by anglers during this period was 28 cm (MacDonald and Hall, 1987).

2.1.4. Pilchard *Sardinops neopilchardus*
Southern Anchovy *Engraulis australis antipodum*

General Biology

Introduction and species description. Pilchards and anchovy have historically been taken from the Bay for use as both baitfish and for human consumption. The pilchard has a moderately elongate and moderately compressed body. The pilchard has a steely blue dorsal surface and silvery-yellow ventral surface. The anchovy has a moderately elongated and rounded body with a large mouth that extends behind the eye. The anchovy has a purplish-green dorsal surface and a silver ventral surface with a broad silver band along the side (Last *et al*., 1983).

Length, weight and lifespan. Pilchards reach a length of 20 cm at 6 years of age. Anchovies attain a length of 15 cm and have a similar life span (Winstanley, 1979; Hall and MacDonald, 1986).

Distribution. Pilchard and anchovy are distributed along the Australian coastline from southern Queensland through Tasmania to Western Australia, and New Zealand (Last *et al*., 1983).

Habitat and feeding. Pilchards are most abundant in Port Phillip Bay during August to May. Pilchards feed on copepods, ostracods, euphausiids and other crustaceans, mollusc larvae, diatoms and other planktonic organisms. Younger anchovies prefer inlets and estuarine environments, with three year old fish moving out to sea. Adult anchovies feed primarily on zooplankton (Winstanley, 1979; Last *et al*., 1983; Hall and MacDonald, 1986).

Spawning time and maturity. The pilchard spawning and surface shoaling season is spring and summer; they appear to mature at two years of age (Winstanley, 1979). The mean batch fecundity of the pilchard *Sardinops ocellatus* from the northern Benguela system in Africa was 33,800 eggs (Le Clus, 1988). The anchovy is sexually mature at one year of age, and spawning occurs mainly in bays, inlets and estuaries (Winstanley, 1979).

Biomass estimates. None currently available.

Commercial Fishery

Fishing method. Purse seining is the major method of capture used for these two fish, followed by haul seining (Hall and MacDonald, 1986).

Annual catch. The mean annual catch of pilchards from Port Phillip Bay over the period 1973-74 to 1983-84 was 324 t. During this period there was a general increase in the annual catch of pilchard with 584 t landed in 1983-84, which was 45% of the total Port Phillip Bay catch of all species (Hall and MacDonald, 1986). From 1984-85 the annual catch increased to peak at 1,375 t in 1988-89, and then dropped to about 750 t in 1989-90 (NREC, 1991).

The mean annual catch of southern anchovy from Port Phillip Bay over the period 1973-74 to 1983-84 was 147 t. The catch of 129 t from the Bay during 1983-84 represented 75% of the total Victorian production of anchovy. Catches decreased by 50% during the six years to 1983-84 (Hall and MacDonald, 1986). Except for an increase in 1986-87 to 140 t, the decline was constant, with a catch of about 20 t in 1989-90 (NREC, 1991). Data are insufficient to pin-point the reason, but catches may have declined because of natural fluctuations in year-class strength, excessive fishing pressure, targeting of pilchards or deteriorating environmental conditions in Hobsons Bay with reduced spawning success and survival (Hall and MacDonald, 1986; NREC, 1991).

Catch distribution. Pilchards are taken throughout the year from the Bay, with the largest proportion being taken during autumn. About 70% of the pilchard catch comes from the northern-most areas of the Bay, with 17% from the Geelong Arm and 10% from the east of the Bay. Anchovy are taken all year and throughout the Bay. The largest proportion of anchovies are taken during winter, especially from along the western shoreline and where freshwater flows into the northern parts of the Bay (Hall and MacDonald, 1986).

Recreational Fishery

Fishing method. Pilchard and anchovy are a source of bait for recreational fishers. Bait drag nets may be used by recreational fishers with an amateur fishing license in specific waters (Barker, 1992).

Annual catch. Not available.

Catch distribution. Not available.

2.1.5. Southern Calamari *Sepioteuthis australis*

General Biology

Introduction and species description. The southern calamari has an oblong, cylindrical body which is truncated in front and bluntly pointed behind. The lateral fins are broad and extend the full length of the mantle. It has an internal shell which is reduced to a long thin chitinous shaft, 10 arms, two of which are long and tentacular and terminate in a large nodule containing a series of large suckers. The colour is white, transluscent, with irregular red, pink or black spots (Macpherson and Gabriel, 1962).

Length, weight and lifespan. The southern calamari grows to a length of 60 cm (Macpherson and Gabriel, 1962). The lifespan of this species is unknown, but Forsythe and Van Heukelem (1987) note that few cephalopod species live longer than two years.

Distribution. Southern calamari occur in the waters, bays and inlets of the Australian coastline ranging from southern West Australia to New South Wales. They are found in Port Phillip Bay throughout the year (Hall and MacDonald, 1986).

Habitat and feeding. In Port Phillip Bay, southern calamari inhabit vegetated and reef areas. Their diet has not been investigated in Victorian waters (Hall and MacDonald, 1986). The stomach contents of a species of *Sepioteuthis*, caught off the east coast of South India, indicated that it is largely piscivorous (Nixon, 1987).

Spawning time and maturity. Southern calamari spawn during late winter and spring in the Port Phillip Heads region. Spawning condition is reached 12 months after hatching (Hall and MacDonald, 1986). It is generally thought that cephalopods are fast growing animals that reproduce once and then die (Mangold, 1987).

Biomass estimates. None currently available.

Commercial Fishery

Fishing method. The predominant form of capture is haul seine nets, accounting for 62% of the mean annual catch, while 22% of the remaining catch was taken using squid jigs (Hall and MacDonald, 1986).

Annual catch. The mean annual commercial catch of southern calamari from Port Phillip Bay during the 1960's was 60 t. There was a slight decline in catch during the 1970's followed by an increase to 63 t in 1983-84, which represented 73% of the total Victorian calamari catch for that year (Hall and MacDonald, 1986). Annual catches of calamari have since declined to just over 20 t in 1989-90 (NREC, 1991). Again, insufficient data are available to decide whether the decline is due to reduced fishing effort, over-fishing or environmental changes (NREC, 1991).

Catch distribution. Although calamari are taken from Port Phillip Bay throughout the year, highest catches are obtained during September and October. More than 50% of the annual commercial catch is taken along the southern shores of the Geelong Arm and 32% is taken near Port Phillip Heads (Hall and MacDonald, 1986).

Recreational Fishery

Fishing method. Boat-based anglers caught 84% of the total recreational catch of calamari during the survey period 1982-1983 (Hall and MacDonald, 1986).

Annual catch. During the 12 month survey period from October 1982, 130 t of calamari was caught (Hall and MacDonald, 1986).

Catch distribution. Data from the 12 month survey indicates the greatest catch rate for calamari was taken during June to August in the Geelong Arm and near the Port Phillip Bay Heads. The modal mantle length of calamari caught was 18-20 cm (MacDonald and Hall, 1987).

2.1.6. Blue Mussel *Mytilus edulis planulatus*

General Biology

Introduction and species description. The blue mussel is a bivalve mollusc and as an adult has a shell which is somewhat wedge shaped and moderately inflated. The shell is rounded near the anterior to allow passage of byssus threads, by which it is attached to substrate. The interior of the shell is bluish white. The mussel shell colour in the juvenile state is brown while the adult shells are purplish black (Macpherson and Gabriel, 1962).

Length, weight and lifespan. The blue mussel attains a maximum size of about 13 cm (Macpherson and Gabriel, 1962). Mussel growth varies depending on the favourability of the local conditions or otherwise. Seed (1976) has indicated that individuals of *Mytilus edulis* from overseas locations have attained a maximum age of 16 years.

Distribution. The blue mussel is common along the coastline from New South Wales to West Australia, including Tasmania. It is extremely common in Port Phillip Bay (Macpherson and Gabriel, 1962).

Habitat and feeding. Mussels are generally found in littoral and shallow sublittoral waters, although they have been recorded from deeper water. The species lives on a variety of substrata, such as rock, stones, shingle, dead shells, compacted mud and sand, pier pilings and harbour walls (Seed, 1976). Mussels are filter feeders. Food particles such as phytoplankton in the water are pumped through the mussel, bind to mucus strings on the gill lamellae, which are then transported to the mouth (Bayne *et al*., 1976).

Spawning time and maturity. The blue mussel appears to have two spawning periods; an initial spawning period in early winter followed by a second extended period from late winter to spring (Hickman *et al*., 1988).

Biomass estimates. None currently available.

Commercial Fishery

Fishing method. All commercial wildstock dredging for mussels in the Bay was phased out in 1987 (Arnott *et al*., 1990). Mussels are commercially harvested in Port Phillip Bay from mussel farms using a rope culture method. Commercial size mussels at the farms are stripped from ropes and processed on a purpose-built vessel, usually at the site (Arnott *et al.,* 1991a). There are three endorsements for commercial divers to collect wild mussels (NREC, 1991).

Annual catch. Production increased from limited quantities in 1984-85, during the inception of mussel farming, to 650 t in 1988-89 and 1989-90. Mussels grow from seed to commercial size in 12 to 15 months (Arnott, 1990a).

Catch distribution. Mussel harvesting commences in July-August and continues through to February (Arnott *et al*., 1990). The mariculture areas for mussels in the Bay are Portarlington, Clifton Springs, Beaumaris and Dromana Bay (Arnott, 1990a).

Recreational Fishery

Fishing method. Mussels are generally collected manually from shoreline rocks, jetties and piles.

Annual catch. Not available.

Catch distribution. Not available.

2.1.7. Scallops *Pecten alba*

General Biology

Introduction and species description. The scallop is very abundant in Port Phillip and supports the major fishery in the Bay. The scallop is a bivalve mollusc and has a strong orbicular shell, with one valve flattened and the other convex. The surface of the shell is rayed with ribs. The prevailing colour of the scallop shell is light brown although shades of brown, yellow, orange, pink and flesh colour are also found (Macpherson and Gabriel, 1962).

Length, weight and lifespan. The scallop can attain a maximum size of about 13 cm diameter (Macpherson and Gabriel, 1962).

Distribution. The scallop is found in Port Phillip Bay, Western Port and Bass Strait (Macpherson and Gabriel, 1962).

Habitat and feeding. *Pecten* is a filter feeder; faster growth rates are supported by mixtures of algal species (Bayne, 1976). They lie on sandy substrates into which they work themselves, 'blowing' out sand to create a suitable depression (Yonge and Thompson, 1976).

Spawning time and maturity. Scallops in Port Phillip Bay spawn from August to October (Sause *et al*., 1987), with spawning maturity occurring during the second year (Dix, 1982). Each adult scallop has the potential to produce millions of eggs during its natural life span (Barker, 1992).

Biomass estimates. The January 1992 dive survey estimated the scallop population in Port Phillip Bay to be 2.6 billion (Gorfine *et al*., 1992). There are annual population estimates of scallop numbers in the Bay extending back to 1982.

Commercial Fishery

Fishing method. Scallops are harvested using a benthic dredge which is towed from the stern of a fishing vessel with wire cable and recovered with a winch (Dix, 1982).

Annual catch. The scallop fishery began in Port Phillip Bay in 1963. A feature of this fishery has been large annual fluctuations in abundance because of highly variable recruitment, which is reflected in catches (Dix, 1982; Hall and MacDonald, 1986). The estimated population of harvestable scallops for 1992 in the Bay was 2.6 billion. However, the commercial harvestable population from 1982 onwards has varied from 20 million to the current high value, with the 1989 and 1990 seasons considered not good enough for fishing (Gorfine *et al*., 1992).

Catch distribution. The scallop fishing season in Port Phillip Bay lies within the period April to December, although the exact time of the opening and closure of the season is dependant on monitoring scallop size, condition and catch rate. The optimum sites are locations on the east and west sides of the Bay in water deeper than 10 m (Hall and MacDonald, 1986; Coleman and Saddlier, 1989).

Recreational Fishery

Fishing method. Scallops are collected by divers. There is a bag limit of 100 scallops per day.

Annual catch. Not available.

Catch distribution. Not available.

2.1.8. Abalone *Haliotis ruber*

General Biology

Introduction and species description. The abalone is a gastropod mollusc and has large obliquely wrinkled, ovate, spirally ridged shell. The abalone shell is scarlet red and streaked with light green (Macpherson and Gabriel, 1962) and with a distinctive black mantle between the base of the foot and the shell.

Length, weight and lifespan. The abalone can grow up to 14 cm in length and may live for more than 10 years (McShane and Smith, 1986; McShane, 1989).

*Distribution***.** The blacklip abalone occurs along the southern Australian coastline and in Port Phillip Bay (Macpherson and Gabriel, 1962; Shepherd, 1973). Approximately 8 km^2 of low relief reef supports the abalone population in Port Phillip Bay (McShane *et al*., 1986).

*Habitat and feeding***.** Blacklip abalone inhabit reef environments, preferring caves, crevices or vertical faces from 1-2 m to 10 m deep and rarely to 25 m. The feeding of the blacklip abalone varies according to habitat. Generally they show a preference for red algae as well as feeding on drifting seagrasses and their associated epiphytes. They also feed on decaying *Posidonia*, detritus, animal matter and small lithophytic algae (Shepherd, 1973). Sticks reef in Port Phillip Bay is a shallow reef (4 m) and has flourishing macro-algal communities. It is an example of the typical reef environment inhabited by abalone in the Bay (McShane and Smith, 1986).

*Spawning time and maturity***.** The main spawning period for abalone is December, although there appears to be episodic minor spawning throughout the year (McShane and Smith, 1991). The fecundity of abalone depends on age, with abalone becoming reproductively mature after four years of age. Spawning animals produce one million eggs (McShane, 1989).

*Biomass estimates***.** None currently available.

Commercial Fishery

*Fishing method***.** Abalone are harvested by divers using 'hookah' diving apparatus working from small high-speed boats (McShane *et al*., 1986).

*Annual catch***.** The Victorian abalone fishery started in the early 1960s, with license limitation introduced in 1968. The Port Phillip Bay fishery is part of the Central Zone (McShane, 1989). The annual catch from Port Phillip Bay between 1985 to 1991 varied between 34 t to 90 t live weight, with a mean of 52 t (Harry Gorfine, personal communication).

*Catch distribution***.** Abalone are harvested all year. The three major reefs in Port Phillip Bay that provide the bulk of the abalone catch are located on the western side of the Bay between Point Cook and Kirks Point, bounding the Werribee Treatment Complex (McShane *et al*., 1986).

Recreational Fishery

*Fishing method***.** Abalone are collected by divers. There is a bag limit of 10 abalone per day.

*Annual catch***.** Not available.

*Catch distribution***.** Not available.

3.0. INPUTS OF NUTRIENTS AND TOXICANTS AND THEIR EFFECTS ON FINFISH AND SHELLFISH.

This section contains an overview of nutrient levels and the main toxicant types found in Port Phillip Bay, their concentrations in fish and shellfish and their effects on fish, shellfish and fisheries within the Bay.

3.1. Nutrients

3.1.1. Introduction:

The bulk of the nitrogen (N) entering the Bay is as ammonium. This is rapidly converted to particulate and dissolved organic N (DON). In the water column DON makes up about 90% of the total N. This organic N is in many refractory forms; this means the N is bound up in such a manner that, as part of an organic molecule, it is difficult for most organisms to isolate and utilize it. Some phytoplankton can digest certain organo-N molecules, but these plankton require special enzymes to do this. While the chemical and biological properties of DON are poorly known (Valiela, 1984), it is felt that most of the DON in Port Phillip Bay has a long breakdown period and is eventually exported to Bass Strait (Newell, 1990). An idea of the breakdown time of DON can be gained by noting that 95% decay times for dissolved organic carbon can be up to 3800 days (Hargrave and Phillips, 1989).

The N present as "particulate" is non-dissolved organic form and is present as either an organic/bacterial film over a mineral particle, or a piece of detritus, such as a piece of decaying flesh. In this instance, depending on how big the particle is, it could be considered as a food source for primary and secondary trophic levels. However, the major nutrient form of N in the Bay is dissolved inorganic N (DIN), and is considered as the combination of ammonium, nitrate and nitrite. It is this form (< 10% of the total N) that is predominantly and rapidly utilized at the primary trophic level. The bulk of the phosphorus (P) present is as dissolved inorganic P, with very little dissolved organic P - almost the converse of N. In the Bay, N is the limiting nutrient (Longmore *et al.*, 1989).

The annual fresh water flow into Port Phillip Bay is about 5.5% of the mean Bay volume and approximates annual evaporative losses, with most of the freshwater entering from the Yarra River and it's tributaries, the Werribee Treatment Complex (WTC) and the Patterson River. The residence time for water in the Bay varies from about 2 weeks in the southern segment to about 12 months in the northern segment (Longmore *et al.*, 1989).

Surface concentrations of DIN in the Bay water column originating from the freshwater plumes of WTC and Patterson River varied seasonally, with higher amounts entering the Bay during winter, whereas the Yarra contribution of DIN in Hobsons Bay was consistently high during summer and winter.

The extent and effects of the fresh water plumes and their associated DIN from the Yarra River and the WTC during winter affected at least half the surface water in the Bay, with the plume from the WTC being detected near seagrass beds off Portarlington. When compared to the limits set in the Port Phillip Bay State Environment Protection Policy, the growth of phytoplankton in the Bay is considered excessive (Longmore *et al.*, 1989).

3.1.2. Effects.

Epibenthic microalgal biomass and productivity were found to be five times greater at Werribee than at a control station. Among the macrophyte community, there was decreased species diversity, dominance of opportunistic species, loss of large brown algal species and occasional algal blooms (Axelrad *et al.*, 1981).

A potential problem associated with higher nutrient inputs could be enhanced epiphyte growth and biomass accumulation on seagrasses, causing a shading of the leaf surface which results in the decline of seagrasses. Bulthuis and Woelkerling (1983) noted that higher nutrient levels in the water at a Port Phillip Bay site may have accounted for the observed higher rates of epiphyte biomass accumulation on seagrasses. Anthropogenic-originated nutrient effects on seagrasses can become threatening to commercial and recreational fisheries, as seagrasses are important in providing food, shelter and nursery grounds to a many species of fish (Klumpp and Nichols, 1983; Robertson and White, 1986). A decline in fish catch occurred simultaneously with a dieback of seagrass in Corner Inlet (Klumpp and Nichols, 1983).

During late August to mid-October, 1987, a bloom of the diatom *Rhizosolenia chunii* occurred in Port Phillip Bay. Mussels, scallops and flat oysters (*Ostrea angasi*) throughout the Bay developed a bitter taste. In the case of mussels, the taste was so persistent that they were unmarketable for 7 months. High mortalities of mussels, scallops, and oysters was noted throughout the Bay, as well as suggestions of stunted growth. The bloom of *R. chunii* was associated with salinity stratification caused by a large discharge from the Yarra River following heavy rainfall on 28-29 July, 1987, with eastern coast sites being the first exposed to this discharge (Parry *et al.*, 1989). It has also been noted previously in this report that surface concentrations of DIN originated with fresh water plumes, and that higher amounts enter the Bay during winter (Longmore *et al.*, 1989).

A bloom of a toxic dinoflagellate algae (*Alexandrium catenella*) occurred in April 1986 in Port Phillip Bay (Hallegraeff *et al.,* 1988), while Arnott (1990b) considered that Victoria's first recorded bloom of algae (*Alexandrium* species) toxic to humans was observed on 8 January 1988 in northern Port Phillip Bay. Filter-feeding shellfish such as mussels, scallops and oysters feeding on the algae can accumulate the toxins within their digestive systems. Consumption of tainted shellfish by humans can in the worst instances result in death (Canahui *et al.*, 1989). The 1988 bloom was restricted to Hobsons Bay and nearby localities, and by 1 July 1988 it was considered to be finished.

Six 'early-warning' sampling stations have been established in northern Port Phillip Bay, where *Alexandrium* is known to re-appear annually, and where toxins have previously been found in shellfish (Arnott, 1990b). Devassy & Bhat (1991) note that red tides break out under favourable environmental conditions such as calm, sunny weather and gentle breezes, or when two dissimilar water masses meet, or when factory effluents, domestic sewage or agricultural fertilizers are released into the sea. It would appear that the optimum conditions in January of calm weather, long daylight hours, long water residence time, a continuous supply of DIN from the Yarra and salinity stratification (Cannon, 1990) encourage annual blooms around the north of the Bay. The iron content in the freshwater section of the Yarra ranges between 1 to >6 parts per million, although the bulk of it is removed from the water column in the estuarine region by aggregation processes (Nicholson, 1987). However, the mouth of the Yarra may still be relatively high in iron, and a certain level is required for optimal growth of *Alexandrium* species (Wells *et al*., 1991).

The bloom also affects planktivorous fish, with one pilchard sample believed to be captured from Hobsons Bay in 1992 being found to contain a level of the toxin at the minimum detection limit (Graeme Arnott, personal communication). There are instances of people from South-East Asia being poisoned by eating planktivorous fish contaminated with dinoflagellate toxin (Oshima, 1989; ThianMing & Tung-SangJ, 1989). However, Hwang *et al*., (1990) note that fish have a far higher susceptibility to paralytic shellfish poison (PSP) toxins than do shellfish and generally die before being caught. This may explain why there are more instances of PSP poisoning of humans consuming shellfish than fish.

3.2. Toxicants/Contaminants

3.2.1. Introduction.

The catchment area of Port Phillip Bay is about 9800 km^2 and is drained predominantly by the Yarra River, with other contributory inputs from the Maribyrnong, Werribee, Patterson, and Little Rivers, and Kananook and Kororoit Creeks. Contaminants historically entered the Bay from these sources, as well as from discrete licensed industrial discharges, WTC output and from diffuse sources such as urban (street) runoff and atmospheric transport (Burns and Smith, 1982; Holsen *et al*, 1991). Most industries now discharge to sewer (Nicholson *et al*., 1991a).

The absorption and accumulation of toxicants/contaminants from anthropogenic sources by marine organisms forms the basis of two concerns. Firstly, there are the acute and chronic effects of toxicants on marine animals, and secondly, the accumulation by commercial species of toxicants that might prove harmful to humans when eaten.

Sediments are considered as a reservoir for all classes of pollutants. Organic hydrocarbons, metals and nutrients are adsorbed on sediment particles and persist long after the original source has ceased input.

The contaminants are then cycled in the aquatic ecosystem by biologically mediated processes such as bioaccumulation, trophic transfer and biomagnification, biodegradation and bioturbation. The suggested route for the accumulation in fish is from water to sediment to benthic invertebrates to fish (Reynoldson, 1987).

There is a wealth of literature, mostly from the northern hemisphere, which associates contaminant levels in fluvial and marine systems with the occurrence of diseases in fish populations. Numerous studies have shown sediments to be reservoirs for contaminants. Fish accumulate many of the chemicals from polluted environments. A number of pathological diseases have been observed in marine fish from polluted coastal waters and estuaries. The highest prevalence of disease was found to occur in bottom-dwelling fish from areas with bottom sediments highly contaminated with metals, petroleum hydrocarbons, pesticides, polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs). Conditions such as fin-rot, neoplasms, lesions, diminished reproduction success and lens cataracts were common (Malins *et al.*, 1984; Hargis and Zwerner, 1988; Spies and Rice, 1988; McCain *et al.*, 1992) in fish inhabiting estuaries and bays with high contaminant loadings. Behavioural changes are the most prevalent effects in marine species at the lowest concentrations of petroleum (Malins and Hodgins, 1981).

During February 1984, dead and dying fish were washed ashore along the western Port Phillip Bay shoreline between Altona and Werribee. The most affected fish were the demersal species such as sand flathead, flounder (*Ammotretis* spp) and the spiky globefish (*Diodon nicthemerus*). Skin ulcerations were present in most of the flathead and flounder observed, and the spiky globefish showed extensive areas of interstitial haemorrhage. While a survey of visible damage to fish was conducted and dead fish were pathologically examined, no fish tissue was collected for chemical analysis. Another fish kill was reported during September 1984. There was little positive information to indicate the cause of the fish kill or the external lesions, particularly with the globefish, although a toxicant of some kind is suspected (Gibbs *et al.*, 1986). It has been suggested that skin tumour incidence in certain fish species may correlate with the presence of specific chemicals as contaminants in the environment, these either acting directly on the host or permitting the activation of a latent oncovirus (Hard *et al.*, 1979). Initially, the greatest incidences of skin lesions in flathead were found at stations from the northern and eastern parts of the Bay, although subsequent surveys indicated the Bay-wide levels were almost zero (Wankowski and Andrews, 1985). A 17 month study of superficial tumours in common demersal fish species in Port Phillip Bay was conducted during 1976-1977. Only two true neoplasms were encountered in over 5000 sand flathead examined (Hard *et al.*, 1979).

Haemosiderosis, the deposition of haemosiderin in viscera, was present in flathead and globefish and has been reported in association with infectious diseases and pollutant exposure. The high degree of haemosiderosis found in flathead from the Bay was considered an indication of suboptimal health status. No infectious cause was identified so pollution-related causes are believed responsible (Langdon, 1986). It is suspected, by circumstantial evidence, that the haemosiderosis in flathead is caused by PAH in the sediment (Gibbs *et al.*, 1986).

A comprehensive tabulated summary of metal and organic hydrocarbons in shellfish from Port Phillip Bay was prepared by Fabris (1991).

3.3. Metals

3.3.1. Introduction.

Heavy metals are regarded as serious pollutants of marine ecosystems. There are numerous references reporting toxic effects of metals on marine and fluvial biota. In fish, for example, copper has been found to cause haemolysis (El-Domiaty, 1987), damage to gills and excessive mucus and blood deposited on gills (Rajbanshi and Gupta, 1988), excessive mucus on the skin and external haemorrhaging (Durve *et al.*, 1980). Copper can cause mortality to abalone larvae (Martin and Stephenson, 1977) and induce excess mucus on the gill surface of adult abalone with consequent suffocation (Yaffe, 1979). Cadmium, chromium and zinc are acutely toxic to marine fishes (Negilski, 1976). Lead induces pathological effects in fish (Hodson *et al.*, 1984), as does mercury (Farmanfarmaian and Socci, 1984). Tributyltin is toxic to salmon (Short and Thrower, 1987) and to shellfish larvae (Laughlin *et al.*, 1989) and has been implicated in reduced scallop recruitment in Ireland (Minchan *et al.*, 1987). Tributyltin use has been prohibited in Port Phillip Bay waters since 1989, except for vessels more than 25 m long (VG, 1989).

Mercury, cadmium and lead are metals which have been implicated in instances of human deaths and physiological disorders. Ingestion of contaminated foodstuffs by humans is a major pathway. The first reported major incident of mercury poisoning arising from the discharge of industrial wastes into the sea occurred in Japan. Fish and shellfish which bioconcentrated the mercury were consumed by people. This began to be manifested by (at the time) an unidentified disease of the nervous system. The cause was pinpointed to consumption of seafood which was excessively contaminated with mercury (WHO, 1972).

A specific disease, also observed in Japan, has been attributed to cadmium. The epidemic was related to the contamination of water and rice paddies by cadmium in a released mine effluent. One of the main symptoms of the disease was multiple fractures of bones arising from osteomalacia. There is evidence that cadmium is implicated in human prostate carcinoma. The major source of lead intake in adults who are not industrially exposed to lead is food, and lead appears to affect the brain and nervous system (WHO, 1972).

Table 3. A listing of the permitted levels in Victoria of metals present as contaminants in fish products, where applicable (NHMRC, 1987).

Metal	Permitted level (ppm wet weight)
Cadmium	0.2 (Fish) 2.0 (Mollusc)
Copper	70 (Mollusc)
Lead	2.5 (Canned fish) 2.5 (Mollusc)
Mercury	0.5 (Fish) 0.5 (Mollusc, being reviewed)
Zinc	1000 (Oyster) 150 (Fish)

3.3.2. Species

3.3.2.1. *Flathead*

There have been few studies of metal levels within flathead from Port Phillip Bay. Walker (1982) showed that the flesh of sand flathead within Port Phillip Bay had a mean mercury level of 0.50 parts per million (ppm) wet weight, which is the maximum permitted concentration in food for human consumption in Australia (Table 3). The flesh of yank (or long-nose) flathead from the Bay had a mean mercury level of 0.56 ppm, which was more than the maximum permitted concentration. A general trend was noted for concentrations of mercury in fish to decrease from north to south and from east to west in the Bay (Walker, 1982; Walker, 1988). Mercury in sand flathead and yank flathead from Corio Bay had mean values of 0.33 and 0.52 ppm. A more recent survey in Corio Bay found that there had been a significant decrease in mercury levels in sand flathead from Corio Bay to those sampled 9 years previously (Nicholson *et al.*, 1990). In a comprehensive study conducted during 1990, Fabris *et al.* (1991) found the overall mean mercury concentration for 417 sand flathead collected from 22 sites and for 50 yank flathead taken from 5 sites during 1990 throughout Port Phillip Bay was 0.23 and 0.33 ppm respectively. Sand flathead from deeper sites had slightly higher mean mercury concentrations than those from the more shallow sites.

Lead in the opercular bones and cadmium in the livers of sand flathead from Port Phillip Bay were found to be significantly higher than for sand flathead from Bass Strait (Fabris and Gibbs, 1985).

3.3.2.2. *Snapper*

During the years 1973-1978 the mean mercury level for snapper from the Bay with a size range from 20 to 80 cm was 0.5 ppm. Thirty snapper from Port Phillip Bay with a mean length of 66 cm had a mean mercury concentration of 0.63 ppm (Walker, 1988). Five snapper caught in Corio Bay had a mean length of 53 cm and a mean mercury concentration of 0.52 ppm (Nicholson *et al*., 1990).

3.3.2.3. *King George whiting*

Ten samples of King George whiting from Port Phillip Bay had a mean mercury concentration of 0.06 ppm (Walker, 1988). Ten samples from Corio Bay had a mean mercury concentration of 0.12 ppm (Nicholson *et al*., 1990).

3.3.2.4. *Southern anchovy and pilchard*

No references relating to metal contaminants in anchovy or pilchard from Port Phillip Bay could be found, although Walker (1988) obtained a mean mercury concentration of 0.03 ppm in southern anchovy caught in Bass Strait.

3.3.2.5. *Calamari*

Nine southern calamari from Victorian waters had a mean mercury concentration of 0.11 ppm (Walker, 1988).

3.3.2.6. *Mussels*

The common blue mussel has characteristics that make them suitable as an indicator organism. The use of mussels as monitors of contaminants in the coastal zone is well established, and is the basis of the US "musselwatch" (Murray *et al*., 1991). Blue mussels have the ability to accumulate contaminants, they have a wide distribution throughout Port Phillip Bay, they are sessile and they are robust. Consequently there is a body of literature dealing with metal contaminants in mussels in Port Phillip Bay.

It was brought to the notice of the EPA in 1974 that there was a severe problem with cadmium contamination in mussels in Corio Bay, with values of 41.5 ppm and 28.8 ppm obtained in mussels collected from Rippleside pier and Rippleside jetty respectively (Adler, 1975). As the maximum permitted concentration for cadmium in mussels is 2 ppm (Table 3), the Public Health Department issued a warning that the mussels from Corio Bay were unfit for human consumption. A primary source of contamination was effluent from a paint pigments factory. For 8 years the company had been discharging effluent containing cadmium (and to a lesser extent, lead) into Corio Bay through the stormwater system and Rippleside drain (Nicholson *et al*., 1991b).

In studying the reports of various researchers dealing with cadmium contamination of mussels in Corio Bay from 1974 onwards (Phillips, 1976; Fabris *et al.*, 1978; Walker, 1979; Smith *et al.*, 1981; Fabris *et al.*, 1986; Nicholson *et al.*, 1991b) it is apparent there is a trend of decreasing levels of cadmium in mussels. Currently cadmium levels in blue mussels from Port Phillip Bay are below the maximum permitted concentration.

Mean cadmium concentrations in mussels from offshore areas of Port Phillip Bay exclusive of Corio Bay do not appear to have changed from 1975 to 1988, and are well below the statutory maximum. Concentrations of copper and zinc within mussels from Port Phillip Bay have remained relatively constant from 1975 to 1988 and never exceeded health regulations. Lead concentrations in mussels collected from Rippleside in Corio Bay were elevated compared to other areas. Phillips (1976) obtained elevated values of lead in mussels taken from several shoreline locations, however lead concentrations for mussels collected away from the shore were relatively low and below health regulations. Mussels do not accumulate mercury to the same extent as do finfish - the sparse data that are available indicate that concentrations are one-tenth or less of the statutory maximum (Fabris, 1991).

3.3.2.7. *Scallops*

The mean mercury and cadmium concentrations in the edible tissues of scallops caught during 1973 from 67 dredge sites in Port Phillip Bay was 0.02 and 1.0 ppm respectively. Both of these concentrations are below statutory limits. The level of mercury in scallops from the Bay decreases from north to south and from east to west. The level of cadmium was highest in the mid-eastern region, intermediate in the northern, north-eastern and western regions and lowest in the southern region (Walker *et al.*, 1982).

3.3.2.8. *Abalone*

During 1974, blacklip abalone were collected by divers from five locations in Port Phillip Bay, from Hobsons Bay and ranging along the east coast to Point Nepean. The mean mercury concentration in edible abalone tissue from the five sites was between 0.1 and 0.3 ppm (Walker, 1982).

3.3.2.9. *Other species*

Walker (1988) tabulated mercury concentrations of a number of vertebrate and invertebrate species from Port Phillip Bay and south-eastern Australian waters. Some species, such as the draughtboard shark, rusty catshark, common saw shark, white-spotted dogfish and banded ling showed elevated mercury concentrations.

3.4. Organics

3.4.1. Introduction

Fish may be exposed to a wide variety of petroleum hydrocarbons, polynuclear aromatic hydrocarbons (PAHs) and organochlorine hydrocarbons, such as polychlorinated biphenyls (PCBs) and pesticides. These compounds are more concentrated in the surface film of the sea and adsorbed on particles in the water column and the sediment than they are in the dissolved state (Howells *et al.*, 1990). Fish exposed to petroleum and organochlorine hydrocarbons in water, sediments and food supply readily take up hydrocarbons through the gills and gut and accumulate them in certain organs and fatty tissues (Malins and Hodgins, 1981; Clark *et al.*, 1990; Howells *et al.*, 1990). This accumulation is most critical for hydrophobic, slowly clearing, non-metabolizing compounds, such as organochlorines (Clark *et al.*, 1990). Some of these may be severely toxic to marine organisms (Youngblood *et al.*, 1971), or may cause increased parasitism on affected fish (Khan, 1990), or reproductive abnormalities leading to population declines (Spies and Rice, 1988). Problems for humans consuming affected fish may range from flavour impairment (Parker *et al.*, 1990) to a significant health hazard through ingestion of potential carcinogens or disease initiating substances (Foran *et al.*, 1989; Gossett *et al.*, 1989).

Table 4: Permitted levels of specific organochlorine contaminants in edible portions of fish (NHMRC, 1987; 1988).

Contaminant	Level ($\mu g\ g^{-1}$ wet weight)
DDT (incl. DDE and DDD)	1.00
Dieldrin	0.10
Heptachlor (incl epoxide)	0.05
Lindane	1.00
PCB	0.50

There are no defined criteria for contaminant levels of petroleum hydrocarbons in fish. However, taint in fish has been detected at a threshold level of 10 ppm (Connell and Miller, 1981). There has been sporadic anecdotal evidence of fish captured from Corio Bay having a petroleum-type tainted odour. Analysis of an Australian salmon (*Arripis trutta*) caught from Corio Bay was found to have a phenol content of 30 ppm (Nicholson *et al.*, 1991a). However, there are no maximum permitted concentrations of phenol in food (NHMRC, 1987; 1988).

Chlorinated pesticides as a whole generally have unwanted environmental persistence and unfavourable biological effects. Dieldrin is a very persistent compound in the environment and exhibits a high level of bioaccumulation through the food chain (Sato and Schnoor, 1991). Its use as an insecticide throughout Victoria, however, was revoked in December 1989 (Lee, 1990). Dieldrin was regularly used in the production of potatoes on land adjacent to the Geelong Arm (i.e. the south-west shoreline of Port Phillip Bay). Then, in 1987, high concentrations of dieldrin residue were found in some beef cattle and soils in the region and further local use was banned from that time (Arnott *et al.*, 1991).

DDT accumulates very rapidly into fish lipid where it is converted into the metabolites DDD and the less toxic DDE. In a number of circumstances the greatest contributor of total DDT body burden in marine organisms is DDE (Sericano *et al.*, 1990; Georgakopoulis-Gregoriades *et al.*, 1991). The use of DDT as an agricultural chemical was revoked in January 1987 (Lee, 1990).

PCBs are highly stable chlorinated aromatic hydrocarbons, and although their use is diminishing world-wide, there is a history of extensive use in industrial applications (Richardson and Bremner, 1983). They are known to accumulate in the fatty tissues of animals (Georgakopoulis-Gregoriades *et al.*, 1991). Manifestations of PCB poisoning in humans are body weight loss, hair loss, periorbital edema, acneforms lesion, liver damage and immunosuppression (Takayama *et al.*, 1991).

PAHs are known products of the combustion of fossil fuels and wood. They have a low water solubility and accumulate in the bottom sediments (Gschwend and Hites, 1981). Fish actively accumulate higher molecular weight PAHs which are metabolized to products that may be more harmful than the parent compound (Krahn *et al.*, 1984). This process may be the cause of tumorous lesions that are sometimes found in fish from locations where elevated levels of PAH are in the sediment (Malins and Hodgins, 1981).

The amount of work done on organic contaminants in biota in general in Port Phillip Bay is very little.

3.4.2. Species

3.4.2.1. *Flathead*

The only comprehensive study of organic contaminants in flathead from Port Phillip Bay is that of Nicholson *et al* (1991a). This study investigated the level of petroleum hydrocarbons, selected chlorinated pesticides (DDT, DDD, DDE, dieldrin, lindane and heptachlor), PCBs and PAHs in the liver and fillet of sand flathead collected from 10 sites throughout the Bay during March 1990.

The greatest load of petroleum hydrocarbons in flathead fillets was from a site situated in the Geelong Arm, 8 km east of Corio Bay, with a concentration of 46 ppm. The greatest level in liver samples was 641 ppm and was from flathead caught in Corio Bay. The Shell Oil Refinery is located on the north-west shoreline of Corio Bay, and each day recycles 250,000 m^3 of Corio Bay water for works cooling purposes (Nicholson *et al.*, 1991a). No aroma of petroleum hydrocarbons and no physical abnormalities were noticed during the processing of captured fish.

While all dieldrin levels in flathead fillet were less than 0.01 ppm, which is less than the maximum permitted concentration (Table 4), the higher levels occurred at sites within and just outside the Geelong Arm. All liver samples were below the maximum permitted concentration, except from the site within the Geelong Arm where a level of 0.23 ppm was found (Nicholson *et al.*, 1991a).

Total DDT was omnipresent throughout the sample range of flathead in the Bay, although none approached the maximum permitted concentration (Table 4). The fact that total DDT was present in all samples and in quantities greater than for the other pesticides analysed indicates widespread historical usage and environmental persistence of this pesticide (Nicholson *et al.*, 1991a). In the same study, lindane and heptachlor were found to be intermittently present in fillet and liver samples. The level of heptachlor in liver from the Geelong Arm site was 0.059 ppm which exceeded the maximum permitted concentration (Table 4).

PCBs were found in flathead fillet and liver from all sampling sites in Port Phillip Bay. Levels in fillet from all sites were less than the maximum permitted concentration of 0.5 ppm. However, PCB levels above the maximum permitted concentration were in liver from sites in Corio Bay and the Geelong Arm with concentrations of 0.71 ppm and 0.58 ppm respectively (Nicholson *et al.*, 1991a).

All the fillet and liver samples analysed by Nicholson *et al.* (1991a) contained very low or undetectable levels of PAHs. This is in agreement with the findings of a number of other studies that the majority of marine fish contain very low or undetectable levels of PAHs (Neff and Anderson, 1981). Only three samples from the Bay were found to contain the PAH metabolite 9-hydroxy benzo[a]pyrene and these were at very low levels (Nicholson *et al.*, 1991a).

Generally, it was the deeper sites (22 m) which were significantly more contaminated than the shallow sites (7 and 12 m), and it was conjectured that this was due to sediment transport and residence time.

3.4.2.2. *Mussels*

There has been some work with organic contaminants in mussels from Port Phillip Bay.

Richardson and Waid (1980) investigated PCB levels in mussels from waters close to Melbourne and Geelong. Highest concentrations of PCBs were found in localities adjacent to industrial activity, particularly for inshore Corio Bay.

Petroleum hydrocarbon levels in mussels from Port Phillip Bay and Western Port were investigated by Burns and Smith (1982) to assess the impacts of petroleum hydrocarbons on coastal waters and to identify problem areas. Hobsons Bay and Corio Bay were identified as suffering severe and chronic inputs of fossil fuel hydrocarbons, with mussels from these locations having mean levels of approximately 141 ppm and 128 ppm respectively. The major source of contamination in Corio Bay was refinery effluent, and samples contained high levels of crude and refined petroleum products up to several kilometres away from discharge points. Levels of contamination by fossil hydrocarbons were similar in Hobsons Bay, although the complexity of the hydrocarbon composition made the relative ranking of importance of various diffuse urban/industrial sources difficult.

Selected chlorinated pesticides, PCBs and petroleum hydrocarbons were investigated in mussels collected from Corio Bay by Fabris and Theodoropoulos (1990). Mussels collected during 1987 had a mean level of fossil fuel hydrocarbon contamination of approximately 114 ppm. A number of organochlorine, organophosphate and organophosphorus pesticides were analysed; in all cases the concentrations were low and less than the maximum permitted concentration in food. Traces of PCBs were found in mussels throughout Corio Bay. However, all concentrations were less than 0.005 ppm, which is well below the maximum permitted concentration of 0.5 ppm.

Murray *et al*. (1991) investigated bioconcentration factors for petroleum hydrocarbons, PAHs and linear alkyl benzenes in mussels from Port Phillip Bay. Mussels from Corio Bay had a mean total fossil fuel hydrocarbon level of approximately 50 ppm, while mussels from Hobsons Bay and from the middle region of Port Phillip Bay had levels of approximately 19 and 12 ppm respectively.

The EPA Victoria did some analyses of dioxins and furans in mussels from Port Phillip Bay, but the levels are unknown (Gus Fabris, personal communication).

3.4.2.3. *Other species*

During 1988 levels of selected organochlorines and PCBs were investigated in oysters (*Ostrea angasi*) from the Geelong Arm and from eastern Port Phillip Bay (Arnott *et al*., 1990; Arnott *et al*., 1991a,b). The levels of both types of contaminants in oysters were very low, with the total concentration for all 11 organochlorine pesticides being 0.029 ppm.

4.0. PATHWAYS

Sediments are sometimes considered to be the ultimate sink for all classes of pollutants; however, the accumulated pollutants may persist in the sediment long after the original source has ceased discharge (Salomons, 1985; Reynoldson, 1987).

4.1. Fish

The pathway of contaminants through trophic levels to carnivorous fish species could be considered thus:

Benthic invertebrates can accumulate contaminants from sediment by adsorption on the outside surfaces, absorption through the integument or respiratory surfaces, and ingestion of food, sediments or water followed by uptake through the gut wall (Reynoldson, 1987). The vertical flux of contaminated sedimentary organic material is assumed responsible for the total annual turnover of 15.2 t PCBs and 250 kg of chlorinated pesticides in zooplankton from the North Sea (Krause and Knickermeyer, 1992). Factors which affect bioaccumulation of contaminants from sediment are the chemical structure of the contaminant, organism size, exposure or contact time of the biota to the sediment, and the particle size and organic content of the sediment (Reynoldson, 1987).

Nishimura and Kumagai (1983) suggested a pathway of mercury contamination from sediment to fish was via suspended particulate matter and zooplankton. Many benthic invertebrates are important food sources for bottom-feeding fish and are pivotal in biomagnification and trophic transfer of contaminants. PCB concentrations were much higher in predatory flatfish than in the deposit or filter-feeding benthic invertebrates (Reynoldson, 1987). Another suggested route of contamination for fish is by the gills. However, generally evidence does suggest there are biomagnification effects, with contaminant levels in each trophic level higher than the preceding level (Reynoldson, 1987). Age, food web/diet and habitat are important factors relating to contaminant levels in fish. Carnivorous species which have a long life span contain higher levels of contaminants due to longer exposure time. Piscivorous fish have higher mercury concentrations than fish which prey on invertebrates, and herbivorous fish accumulate the least amount of mercury. Also, species which are demersal generally have higher levels of contamination than the pelagic species and this was used as a partial explanation as to why King George whiting had less mercury contamination than did flathead (Nicholson *et al*., 1990).

4.2. Mussels

Mussels, and presumably other filter feeding organisms, accumulate heavy metals and petroleum hydrocarbons directly from the water in which they live and not from their food. If the food itself is enriched with contaminants, then the food becomes a significant source (Fabris, 1991). Hydrocarbons and other lipophilic compounds in mussels are accumulated by the simple equilibrium of relative solubilities in seawater and body lipids (Murray *et al.*, 1991). Presumably other filter feeding organisms accumulate contaminants in much the same way.

5.0. SUGGESTED FURTHER WORK

Malins *et al.* (1984) estimated that there are approximately 70,000 synthetic chemicals in commercial use which enter coastal waters from a number of sources. Many of the organic compounds are subject to chemical and biological transformations in the environment which result in a host of new compounds. Little is known about the toxicity of most of the chemicals or their transformation products.

Potential projects in Port Phillip Bay could relate to metals other than mercury as contaminants in more species of biota than flathead and mussels. The same could be said for organics such as dioxins and furans, particularly when it appears that the study of the spatial trend of organic contaminants in flathead (Nicholson *et al.*, 1991a) is the first of its kind.

Another potential project is to sample the air-sea surface - known as the surface microlayer - for contaminants by using a rotating drum sampler as used by Nichols and Espey (1991). As is explained by Hardy *et al.* (1990), the surface microlayer is about 50 m thick and serves as a concentration point for metal and organic contaminants that have either a low water solubility or are associated with floating particles. Microlayer concentrations of PCBs and pesticides have been found between one to ten million times greater than for the underlying water. The sampling and analysis of the surface microlayer provides a sensitive tool for source identification and monitoring of potentially harmful aquatic pollution (Hardy *et al.*, 1990).

The upper few centimetres of the water column can serve as an important habitat for a community of biota, including the eggs and larvae of commercially important fish and shellfish species which float on the surface in contact with the surface microlayer. Kocan *et al.* (1987) and Westernhagen *et al.* (1987) noted the enhanced effects of higher mortalities, longer hatching times and increased number of larval deformities in marine fish embryonic eggs in contact with the surface microlayer.

Another potential project is to suspend dialysis bags full of an organic solvent such as hexane in the water column near suspected sources of contaminants with low water solubility. The partitioning effect on the contaminant (i.e. the preferred solvent effect) between the water and the hexane means that there will be a concentration of the contaminant in the hexane many times grater than in the water column.

Furthermore, the very slight diffusion of the organic solvent through the dialysis bag will act as a biocide on the bag's outside surface (Batley and Apte, 1992).

6.0. PREDICTORS OF A 50% NUTRIENTS AND TOXICANT INCREASE

A 50% enrichment of nutrients may have an effect on both eutrophication within and fish yields from the Bay. Given the low conversion efficiency of primary production to fish production, any adverse effects would be noticed first with water quality parameters. A simple series of parameters for monitoring this would be to measure dissolved oxygen in the water column (localised eutrophic conditions), organic N levels and chlorophyll levels.

In considering the historical and present levels of contamination in flathead and mussels from Port Phillip Bay, it could be concluded that the Bay is chronically contaminated. Sand flathead and mussels are considered good indicator organisms for the Bay. The sand flathead is demersal, non-migratory and exists at a high trophic level within the Bay. It has been used in the past as an organism for monitoring levels of mercury and hydrocarbon contamination. The use of mussels as monitors of contaminants is well established and is the basis of the US "musselwatch". The mussel is widely distributed throughout the Bay.

As mentioned in the potential projects section above, sampling of the surface microlayer provides samples with concentrations far greater than in the bulk water. The use of surface microlayer sampling and dialysis bags have potential for being quick and easy methods of being able to observe trends in contaminant entry to the Bay.

The level of hepatic cytochrome P-450 and sorbitol dehydrogenase in sand flathead as an indicator of contamination-induced stress could also be used as an indicator of increasing but non-specific levels of contamination. Experimental work studying this technique is currently being undertaken at the RMIT Key Centre for Applied and Nutritional Toxicology, Melbourne.

7.0. STATUS OF DATABASES AT THE MARINE SCIENCE LABORATORIES

7.1. Fisheries

Catch and Effort Unit: The unit processes catch and effort returns from all Victorian commercial fisheries, including those from Port Phillip Bay. Some data verification procedures need to be undertaken before data for the period 1985 - 1991 for Port Phillip Bay can be released in final form.

Bay and Inlet Fisheries Program: This program gathers, processes and analyses commercial and recreational fisheries data specifically from Victorian bays and inlets. Current projects include:

1) Catch composition and biological sampling of commercial and recreational fisheries, began in 1992.
2) Catch and effort data and catch sampling data for recreational fisheries, began in 1990.
3) Trawl survey of demersal fish communities, began in 1990.
4) Snapper tagging program.

Collection of data for the current Port Phillip Bay recreational fisheries work began in January 1990. Processed output of this data for catch composition and numbers, estimated total effort, catch per unit effort, size distribution within the catch, spatial and temporal distributions and catch method could be expected by early 1993. Data from a previous 12-month survey of recreational fishing catch and effort in Port Phillip Bay (1982-83) have been published, but the raw data are not yet available on a database.

The computerised data base for commercial catch and effort within Port Phillip Bay has been kept up to date and extends back to 1978. Processed output of this data for Port Phillip Bay is expected in 1993 and will provide information on catch per unit effort, catch composition and numbers, total effort, size distribution within the catch, spatial and temporal distributions and catch method. Catch data from 1914 to 1984 and effort data from 1973 to 1984 have been published, but the data prior to 1978 is not available on a data base.

Catch composition and some biological sampling were carried out on Port Phillip Bay commercial fish catches between 1978 and 1985.

7.2. Contaminants and Nutrients

Victorian Shellfish Quality Assurance Program: This program maintains an up to date computerised database of work conducted in Port Phillip Bay extending back to 1987:

1) Phytoplankton species and abundance. This ongoing database is constantly updated with samples being collected and processed every two weeks from 15 permanent sites within the Bay.

2) Algal biotoxins in shellfish. Algal biotoxin data is updated during occurrences of toxic algal blooms within the Bay.

3) *E.coli* bacteria in mussels and seawater. The *E.coli* levels are measured during major rainfall events which is usually about five times per year.

Chemistry Section: The chemistry unit maintains an ongoing computerised database. The current form of database extends back to 1985. There is data stored as hard copy extending back to 1975. The databases contain:

1) Water quality in Port Phillip Bay. This database contains levels of nutrients, chlorophyll-*a*, dissolved oxygen, salinity, metals and hydrocarbons within the water column of the Bay from a number of sampling sites.

2) Sediments. Levels of metals and hydrocarbons in the sediments of the Bay from a number of studies are stored on the database.

3) Biota. Contaminant levels in various species of biota within Port Phillip Bay, although predominantly mussels and flathead, are maintained.

7.3. Other Relevant Databases

Port Phillip Bay Ecology Program (fish lesions): This ongoing database contains information on the incidences of lesions on fish, particularly spikey globefish, trawled from the Bay, and extends back to March 1990.

Dredge Effects Study Program: This program began in 1991 and is investigating the effects of scallop dredging in the Bay on sediment transport, the abundance of benthic infauna and epifauna, and on the abundance and diets of demersal fish from three sites within the Bay. The data is incomplete.

8.0. SYNOPSIS

The synopsis is structured to provide comments on topics and the relevant reference articles concerned with studies in Port Phillip Bay covered in this report relating to ecology and fish kills, fisheries, nutrients, organics and metals.

Ecology/Fish kills

Topic	Reference	Comment
Flathead feeding	Andrews, 1988	PhD thesis on feeding behaviour of sand flathead in PPB
Flathead ecology	Brown, 1977.	PhD thesis on ecology of 3 species of flathead in PPB.
Fish lesions	Hard *et al.*, 1979	17 month survey of fish spp from PPB into lesions and neoplasms. Of historical interest.
Fish kill	Wankowski and Andrews, 1985	Limited internal report investigating incidence of lesions in several fish spp in PPB.
	Gibbs *et al.*, 1986	Inconclusive tech. report on fish kill in PPB.
Haemosiderosis	Langdon, 1986	A report of some interest on haemosiderosis in flathead and globefish in PPB.

Fisheries

Topic	Reference	Comment
Abalone	McShane & Smith, 1986	Report on starfish predation on abalone at a PPB reef.
	McShane *et al*., 1986	Resume on abalone reefs in Victoria, including PPB.
	McShane, 1989	Compilation of a number of works by McShane on abalone in Victoria. Of limited scope for PPB.
Commercial fisheries	Hall & MacDonald, 1986	Major review on fishery situation in PPB but a bit dated now.
	NREC, 1991	Overview of fisheries in Victorian bays and inlets. Has some PPB content.
Fish resources	Winstanley, 1981	General overview of major spp in Victorian waters. Of limited interest for PPB.
	Barker, 1992	Overview document of Victoria's marine and estuarine fish resources. Not highly relevant for PPB.
Fishing guide	DCE, 1992	Current departmental public brochure advising of recreational fishing rules.
Identification	MacPherson & Gabriel, 1962	Older mollusc identification text.
	Last *et al*., 1983.	Fish identification text.
Mussels/mariculture	Hickman *et al*., 1988	Initial report on mariculture of mussels and oysters in PPB. Of limited interest.
	Arnott, 1990a	Introductory tech report on the program to monitor the health and suitability of mussels from mussel growing areas. Of limited value to this review.
	Arnott, 1990b	Introductory internal report on the response and monitoring for toxic algal blooms in PPB.
	Arnott *et al*., 1990	Review of Beaumaris growing area in PPB.
	Arnott *et al*., 1991a	Review of Dromana Bay growing areas in PPB.
	Arnott *et al*., 1991b	Review of Geelong Arm growing areas in PPB.
Pilchards & anchovies	Winstanley, 1979	One of the few works on pilchard and anchovies. Has some limited information for PPB.

cont'd

Fisheries (cont'd)

Topic	Reference	Comment
Recreational fisheries	MacDonald & Hall, 1987	Detailed review of recreational fishery situation in PPB, but a bit dated (1982/83).
Scallops	Dix, 1982	General situation report on scallop fishery. Limited PPB content.
	Sause *et al.*, 1987	Scallop spawning, relevant to PPB.
	Gwyther & McShane 1988	Researched report on changes in growth in scallops from PPB.
	Coleman & Saddlier 1989	Scallop abundance and predictions for 1989 fishery. Tech report. Of limited historical interest.
	Gorfine *et al.*, 1992	Unpublished tech. report on most current scallop abundance figures in PPB.
Snapper	Sanders & Powell, 1979	Older work investigating growth rates in snapper. Of limited interest for PPB.
	Winstanley, 1983	Food of snapper in PPB. Relevant to PPB.
	Francis & Winstanley 1989	Study reporting on growth rates in snapper from different stocks, including that which migrates into PPB.

Nutrients

Topic	Reference	Comment
Algal blooms	Hallegraeff *et al.*, 1988	Reported work on blooms of toxic algae. Of some interest to PPB.
	Parry *et al.*, 1989	Detailed report of cause of bitter taste in mussels in PPB
Fish productivity	Gwyther, 1990	Detailed report on nutrient inputs and potential/probable effects in PPB.
Seagrass	Bulthuis & Woelkering, 1983	Paper on seagrass. Not very detailed for PPB.
Water Quality	Longmore *et al.*, 1989	Detailed report of water quality in PPB with respect to anthropogenic nutrient inputs.
Werribee	Axelrad *et al.*, 1981	Effects of Werribee sewage on Port Phillip Bay. OK but an older study.
	Newell, 1990	A contemporary and detailed review on the effects of Werribee on PPB

Organics

Topic	Reference	Comment
Flathead	Nicholson *et al*., 1991a	Most current and detailed work on organic contaminants in flathead in PPB.
Mussels	Richardson & Waid 1980	Old but detailed report of PCBs in mussels throughout PPB.
	Burns & Smith, 1982.	Detailed work on organic contaminants in sediments and mussels from Westernport and PPB. Older data, though.
	Fabris & Theodoropoulos, 1990	Detailed work on organics in mussels but only from Corio Bay.
	Murray *et al*., 1991	A current work but of limited sampling range in PPB
Shellfish	Fabris, 1991	Detailed summary of data from reports investigating organic contaminants in mussels, scallops, oysters and abalone in PPB.
	Arnott *et al*., 1990	Review of Beaumaris growing area in PPB. Contains some limited data on contaminants in mussels and oysters.
	Arnott *et al*., 1991a	Review of Dromana Bay growing areas in PPB. Contains some limited data on contaminants in mussels and oysters.
	Arnott *et al*., 1991b	Review of Geelong Arm growing areas in PPB. Contains some limited data on contaminants in mussels and oysters.

Metals

Topic	Reference	Comment
Flathead	Nicholson *et al*., 1990	Of some interest and looks at 14 spp altogether but limited to Corio Bay and small sample size.
	Fabris *et al*., 1991	Detailed and most current wide ranging investigation of mercury levels in sand and yank flathead in PPB.
Flathead & Globefish	Fabris & Gibbs, 1985	Limited detail report on cadmium and lead in flathead and spiky globefish. Related to fish kills in PPB.
General (4 spp or more)	Walker, 1982	Older report of mercury in 2 mollusc spp and 2 flathead spp from PPB. Of some interest historically.
	Walker, 1988	Reporting values in spp within and out of PPB. Also repeating some data from 1982 report above.
Mussels	Phillips, 1976	Of historical interest for metal levels in mussels in PPB.
	Fabris *et al*., 1978	Earlier detailed report of metals in mussels in PPB.
	Smith *et al*., 1981	Concerned with Corio Bay only. Older work.
	Fabris *et al*., 1986	Detailed report on metals in mussels but only for Corio Bay.
	Nicholson *et al*., 1991b	Updated detailed report on metals in mussels but only for Corio Bay.
	Walker, 1979	Older document reporting levels of metals in mussels from PPB. Of minor interest.
Scallop	Walker *et al*., 1982	Cadmium and mercury in scallops in PPB. Of relevance to PPB though an older report.
Shellfish	Arnott *et al*., 1990	Review of Beaumaris growing area in PPB. Contains some limited data on contaminants in mussels and oysters.
	Arnott *et al*., 1991a	Review of Dromana Bay growing areas in PPB. Contains some limited data on contaminants in mussels and oysters.
	Arnott *et al*., 1991b	Review of Geelong Arm growing areas in PPB. Contains some limited data on contaminants in mussels and oysters.
Snapper	Walker, 1981	Mercury in snapper throughout Victoria, rather than PPB.

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