Ongoing monitoring needed to explain species decline in Port Phillip Bay
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Monitoring and research needed to explain species decline in Port Phillip Bay

Sand Flathead were once considered to be the most abundant fish species in Port Phillip Bay, but their numbers are estimated to have fallen by 80% since the 1970s.

In the 70s, female sand flathead reached legal size (27cm) in three years and males in seven, but growth rates have slowed, particularly in the first four years of life. Today, females take four years and males up to 12 years to reach legal size.

The reasons for the population decline and slower growth rate are unknown. Studies in the 1980s concluded that pollution was a likely cause of 'severe visceral haemosiderosis' compared to 'low background levels' in Sand Flathead taken from outside the Bay. This finding 'suggested that high levels of haemosideron in fish species normally displaying low levels indicate a suboptimal health status of fish populations'.

The marine environment has historically been considered so vast that it could absorb pollutant inputs with negligible effect.

But in the 1970s, world-wide human health concerns prompted studies on mercury contamination in sand flathead in Port Phillip Bay, finding concentrations exceeding the National Health & Medical Research Council (NHMRC) limit[1]. Industrial inputs were identified as the source of mercury.

Studies of the Bay in the 1980s reported a range of pollutants, including elevated concentrations of cadmium and lead. Dieldrin, DDT,DDD, and DDE were widespread contaminants in fillet and liver from fish throughout the Bay, the highest concentrations being in fish from the Geelong Arm[2].

Meanwhile, international studies found that disease was most prevalent in bottom-dwelling fish from estuaries and bays with highly contaminated sediments. Despite this knowledge, there appear to have been very few subsequent studies to assess ecological effects of toxins in the Bay.

Mercury concentrations in flathead had declined by 1990, following the introduction of EPA regulations requiring industrial effluent to be disposed to the sewer as opposed to the stormwater system. The 1996 CSIRO Port Phillip Bay Environmental Study found that the decline in mercury concentrations had been sustained.

Subsequently, government response to contaminants in Port Phillip Bay has tended to focus on implications for human health and overlooked impacts on marine species. The 'human health' focus is confirmed in the CSIRO Study, which states: "*Fish livers preferentially concentrated zinc, copper, cadmium, and mercury… MPC concentrations for cadmium were often exceeded, but fish livers are rarely consumed by humans.*"[3]

Comparison of benthic ecology studies conducted in the Environmental Study of Port Phillip Bay 1968-71 and the Port Phillip Bay Environmental Study (CSIRO 1996) reveals a significant ecological shift. A dramatic decline (cause unknown) in mud ghost shrimp and sand flathead populations occurred over this time.

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[1] Port Phillip Bay Environmental Study: Status Review. Technical Report # 9. CSIRO.December 1992.
[2] Port Phillip Bay Environmental Study Status Review. Technical Report #9. CSIRO. December 1992.
[3] P. 122 Port Phillip Bay Environmental Study Final Report. CSIRO June, 1996.

The 1968-71 Environmental Study of Port Phillip Bay found mud ghost shrimp to be either the most common or the second most common species in sediments at sampling stations around the Bay, [4] including near the northern Dredge Material Ground (DMG).

The species was not reported at all in this area in 2006[5]. However, they were recorded near the south-eastern dredge material ground (offshore from Mt Martha) where only 'clean' dredge material has been dumped.

Despite various studies (in different years and seasons, with different objectives and methodologies) of Port Phillip Bay since the 1970s, substantial knowledge gaps remain, highlighting the need for an ongoing research program to monitor benthic habitats and communities in order to adequately assess the ecological health of the Bay and identify threatening processes.

To provide for early identification of threats a more proactive and cohesive approach to research is warranted. Commitment of ongoing funding is required to monitor benthic habitats and associated communities throughout the Bay.

Major studies of Port Phillip Bay

There were no comprehensive studies of the Bay when it was in a relatively 'pristine 'state. The Bay seabed had been subjected to the effects of scallop dredging and uncontained dumping of dredged Yarra sediments for many years before the first baywide environment study (1968 -71) was undertaken. The practice of dumping dredged sediments in the Bay was conducted for half a century with little consideration of the ecological effects. The prevailing view was that due to its size the marine environment could absorb contaminants and any effects would be negligible.

The two major Port Phillip Bay environment studies conducted to date are: the Environmental Study of Port Phillip Bay, Report on Phase 1, 1968-71, conducted by Melbourne Metropolitan Board of Works; and the CSIRO released the Port Phillip Bay Environmental Study 1996 (CSIRO Study).

Comparison of benthic surveys conducted for the two major studies reveals a significant ecological shift had occurred in the two decades between the studies. The CSIRO Study found that only 3 of the 10 most abundant benthic species recorded in 1968-71 were among the 10 most abundant recorded in 1994-96. Mud ghost shrimp (*Neocallichirus limosus*), the second most abundant benthic species in the 1970s, were 700 times less abundant in 1991-92; but the Study did not discuss why this change had occurred.

Sand flathead (*Platycephalus bassensis*) are known to prey on MGS and were formerly the most abundant fish in PPB. Primary Industries research Victoria (PIRVIC) estimates that the sand flathead population in the Bay has declined up to 80% since the 1960s. However, there appears to have been no subsequent investigation of the decline of MGS or the possible link to decline of sand flathead.

Possible causes mooted in the various studies include: long term cyclical trends, reduced nutrient influx to the Bay from Werribee sewerage treatment plant, introduced

[4] Environmental Study of Port Phillip Bay Report on Phase One 1968-71. MMBW
[5] Baseline Benthic Fauna Surveys for the Port of Melbourne DMG, SE DMG and Yarra River Estuary. Sinclair Knight Merz. September 2006.

pest species, over-fishing, and scallop dredging. But none of the studies draw clear conclusions on the cause of these population declines.

Impacts of scallop dredging

The Port Phillip Bay scallop dredging fishery had been active for at least 5 years prior to the first systematic benthic survey (1968-71). Consequently, there is no baseline data for communities that existed prior to scallop dredging and it is not possible to conclusively measure the impact of this activity. However, there is evidence that scallop dredging was not directly implicated in the reduction of the MGS population.

The Port Phillip Bay scallop dredge fishery commenced in 1963 and closed in 1997. All but the shallowest regions of the bay were dredged during the 34 year history of dredging, but most dredging was concentrated at depths between 10-20m. The first five years of the fishery was especially intensive and lead to a crash in scallop stocks by 1968. Despite this intensive period of dredging mud ghost shrimps were recorded in the 1968-71 study as the second most abundant benthic species in the Bay.

Currie and Parry (1999 cf Peterson 1977) found evidence that MGS survived the physical disturbance to the seabed by scallop dredging. Their study involved before and after examination 30 sites in the Bay. They[6] found the bedforms at St Leonards were dominated by volcano-like mounds (up to 10cm high) and depressions formed by burrowing MGS. Dredges had a grader-like impact; MGS mounds were removed and depressions filled but most MGS appeared to survive and mounds were being rebuilt.

Impacts of introduced species

European fan-worm (*Sabella spallanzani*) rapidly colonised the Bay in the late 1980s and a few North Pacific Seastars (*Asterias amurensis*) were first recorded in the Bay in the mid 1990s. Both of these pests have undoubtedly resulted in ecological change, particularly to the benthic communities. However, the decline of sand flathead was identified well before either of these pest species were recorded in the Bay.

Reduced nutrient influx from Werribee Treatment Plant

The CSIRO study found that reducing nitrogen loads to the Bay by 1000 tonnes a year (13%) would greatly improve the health of the Bay. Consequently, activated sludge technology was introduced at Western Treatment Plant in 2005 to remove as much nitrogen from treated effluent as possible. The new technology has cut nitrogen output to the bay by more than 500 tonnes a year.

Prevailing 'human health' focus in relation to toxicants in fish in Port Phillip Bay

Most available data for metals in fish from the Bay relate to mercury concentrations. Local studies were prompted by world-wide human health concerns in the 1970s. Walker (1982) found mercury concentrations in sand flathead in the Bay exceeding the National Health & Medical Research Council (N.H & MRC) limit[7] and industrial inputs were identified as the source of the mercury.

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[6] Impacts and efficiency of scallop dredging in different soft substrates. David. R. Currie & Gregory. D. Parry. Can J Fish & Aquatic Sci. 56. (1999).

[7] Port Phillip Bay Environmental Study: Status Review. Technical Report # 9. CSIRO. December 1992.

Meanwhile, international research found the highest prevalence of disease was found to occur in bottom-dwelling fish from areas with 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 in fish inhabiting estuaries and bays with high contaminant loadings (Malins *et al*., 1984; Hargis and Zwerner, 1988; Spies and Rice, 1988; McCain *et al*., 1992)[8].

The CSIRO Study reported that there have been 2 major reviews of toxicants by Coller et al (1991) and Phillips et al (1992), but did not discuss the ecological implications of these studies, noting "*Consumption of fish from the Bay is considerable and it is important for regulators to assess the potential risk of adverse effects to consumers from toxic substances accumulated by the fish*."[9]

By 1990, mercury concentrations in flathead had declined to a Bay-wide mean of 0.23 µg/g ± 0.18 µg/g and results from the PPBES study indicate that the decline has been sustained (Fabris 1995). The CSIRO study also noted "*Fish livers preferentially concentrated zinc, copper, cadmium, and mercury… MPC concentrations for cadmium were often exceeded, but fish livers are rarely consumed by humans."*[10]

Analyses of toxicants in PPB fish have tended to focus on measuring human health concerns and not seriously investigated the effects on marine organisms. The Channel Deepening project is the most recent example. Fish tissue tested for the Lower Yarra Fish Study[11] tested "skinless fillets" (considered more likely to be eaten by people) rather than fish organs such as livers (where contaminants would be more concentrated). A six square km Dredge Material Ground (DMG) was constructed in 2009 as part of the Channel Deepening project to contain 4 million m3 of contaminated dredged sediments, with no provision for systematic monitoring of nearby seabed.

Evidence of Sand Flathead population decline

In the 1970's, female sand flathead reached legal size (27cm) in 3 years and males in 7 years, but growth rates have slowed, particularly in the first four years of life. Today, females take 4 years and males up to 12 years to reach legal size. In fact, while both sexes may live to 23 years, many males never reach 27cm (and few live to reach 30cm) while females may reach 35cm[12]. As a result, retained catches, especially of flathead above 30cm, are dominated by females, while the population of sub-legal sized flathead is dominated by males[13].

The slow growth rates and small sizes in the Bay contrasts with growth in Bass Strait where sand flathead have been recorded to 60cm. While there is no evidence of flathead moving in or out of the Bay[14] there is anecdotal evidence of a "3 feet long" flathead

[8] The Present State of Knowledge on Fish Stocks and Commercial and recreational Fisheries in Port Phillip Bay, Victoria, and their Interactions with Nutrients and Toxicants. G.J. Nicholson. Technical Report #7. CSIRO Port Phillip Bay Environmental Study, September 1992.

[9] P. 121, Port Phillip Bay Environmental Study Final Report. CSIRO 1996.
[10] P. 122, Port Phillip Bay Environmental Study Final Report. CSIRO 1996.
[11] Lower Yarra Fish Study: Contaminants in Fish. Victorian EPA. 2009
[12] There is an anecdotal record of a 60cm sand flathead caught off Dromana in 1966.
[13] Ross Winstanley. 2008. Sand flathead Stock Assessment Workshop at Primary industry Research Victoria.
[14] Ross Winstanley. 2008. Sand flathead Stock Assessment Workshop at Primary industry Research Victoria.

caught in the Bay in 1966[15]. The evidence that recreational anglers are more likely to retained female sand flathead than males suggests that over-fishing may be a factor in the population decline. However, studies of sand flathead in the Bay in the 1980s concluded that pollution was a likely cause of "severe visceral haemosiderosis" compared to "low background levels" found in sand flathead taken from outside of the Bay. This finding "suggested that high levels of haemosideron in fish species normally displaying low levels are indicative of a suboptimal health status of fish populations."[16]

Seasonal availability of prey species is also an important factor in maintaining healthy populations. While mud ghost shrimp have been noted as a prey species of sand flathead they were not recorded in a study of Food Webs of Demersal Fish in Port Phillip Bay[17]. However, the report noted two recently introduced species (European clam *Corbula gibba* and *Pyromaia tuberculata*) which had been incorporated into important trophic links in deep regions of the Bay, highlighting the fact that prey preference can change as abundance alters.

The study also reported that *Philyra undecimspinosa* (pebble crab) was extraordinarily abundant in the diets of many species of fish at deep baywide stations during February 1994 (Parry et al 1995). Pebble crabs were important prey of sand flathead and sparsely spotted stingaree at the deep St Leonard's station. Feeding rates for sand flathead were higher during winter due to higher consumption of fish (Officer & Parry 1995) and coincided with the period of rapid gonad growth. (Brown 1977). This suggests that sand flathead are reliant on seasonal abundance of suitable prey to sustain reproduction. However, without further studies, no clear conclusions are possible.

Sand flathead and mud ghost shrimp exposure to dumped dredge material

Sand Flathead have historically bee considered most abundant in the central bay area where they are known to settle into the soft seabed in order to ambush prey. MGS, a known prey of sand flathead, also burrow into silty sediments. Consequently, the usual behaviour of both species in the vicinity of the northern Dredge Material Ground (DMG) would expose them to direct contact with contaminants.

The Environmental Study of Port Phillip Bay report on phase one 1968-71 found MGS to be the second most common benthic species[18] in sediments at sampling stations around the Bay, including near the northern DMG. The species was not reported at all in this area in 2006[19]. However, the same study found them to be 5.4% of organisms recorded at sites in the Yarra River and at the south-eastern dredge material ground (offshore of Mt Martha) where only 'clean' dredge material has been dumped.

Dumping of dredged sediments from the Port of Melbourne to the spoil grounds in the northern part of the Bay has resulted in elevated concentrations of cadmium, lead, zinc, and other metals including tributyl tin (TBT) in spoil ground sediments (Fabris *et al*. 1995). Nickel and mercury exceeded the accepted quality guidelines in some of the spoil

[15] Jenny Warfe. Pers comm.
[16] Haemosiderosis in *Platycephalus bassensis* and *Diodun nicthemerus* in South-east Australian Coastal Waters. Jeremy S Langdon 1986

[17] Officer R.A & Parry. G.D. 1997. MAFRI Technical report #36
[18] Environmental Study of Port Phillip Bay Report on Phase One 1968-71. MMBW
[19] Baseline Benthic Fauna Surveys for the Port of Melbourne DMG, SE DMG and Yarra River Estuary. Sinclair Knight Merz. September 2006.

ground sediments, but these concentrations are lower than those found in the more contaminated port areas.[20]

The CSIRO Study reports ”Elutriate testing of these sediments suggested that it is unlikely that leaching of metals from the sediments into the water column during dredging and disposal operations would result in elevated concentrations of dissolved metal species in the water column, although particulate metal species may be spread to other parts of the Bay.”

However, a 2006 study found elevated levels of DDT several kilometres south of the northern DMG, and an associated reduction of benthic community diversity[21]. Apart from this study there have been few studies to assess dispersal of contaminants beyond the immediate disposal area. This general absence of studies extends to the recent Channel Deepening project. The Environmental Management Plan for the project does not require testing of sediments to assess contaminant dispersal beyond the DMG.

Maintenance dredging of the Yarra (at least every 2-3 years) and dumping of sediments at the northern DMG has been ongoing since the 1950s. While the 1971 study did not consider this practice, the 2006 study notes a correlation between reduced benthic species diversity and proximity to the northern DMG. Despite this, the Environment Management Plan for the Channel Deepening Project does not require testing for contaminants in sediments in or outside of the DMG; and the practice of dumping Yarra sediments in the Bay continues.

The case for long term systematic monitoring

The absence of long term data means there is no benchmark on which to measure the effects of human-induced change to the Bay, such as reduced nutrient influx from Werribee Treatment Plant or disposal of dredged sediments in the Bay.

Various studies have flagged possible causes of the flathead decline, including longterm cyclical processes, reduced nutrient influx to the Bay, introduction of exotic species, disease, pollution, and fishing pressure. But the ‘available evidence’ is based on disparate studies in different years and seasons, with different objectives and methodologies. This does not provide a sound basis for clear conclusions.

As cyclical changes and random, between-year variation make long term human induced change difficult to detect, longterm monitoring of natural processes is required in order to identify any correlation. The decline of mud ghost shrimp seems to have never been investigated. Whilst the 1996 study noted the decline, no attempt was made to explain it, possibly because the necessary evidence is simply not available.

The unexplained reduction in population of key species described above highlights the need for a systematic longterm study of the PPB seabed to inform management of the Bay. Such a study could document physical and chemical change to the seabed along with benthic and epibenthic fauna communities at several sampling sites in each of the representative habitat zones in the Bay.

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[20] P. 117, Port Phillip Bay Environmental Study Final Report. CSIRO 1996.
[21] Baseline Benthic Fauna Surveys for the Port of Melbourne DMG, SE DMG and Yarra River Estuary. Sinclair Knight Merz. September 2006.

Currie and Parry[22] compared the benthic survey from the 1968-71 study with 13 sites surveyed in 1991-92. They used similar methods and sampled a wide range of sediment types. The study found that composition of communities differed significantly between the surveys. Since the 1968-71 survey they found a further 3 exotic species (*Sabella spallanzanii, Corbula gibba, Euchone limnicola*) had become abundant and were contributing to long term and probably irreversible changes to the ecology of the Bay.

They also noted other changes; and concluded: *"The ambiguity of conclusions from comparison between these studies emphasizes the need for an adequate time-series of benthic monitoring to better define the extent of change and to identify their causes."*

Conclusion and recommendation

Despite substantial public funds being committed to various studies (in different years and seasons, with different objectives and methodologies) in Port Phillip Bay since the 1970s, substantial knowledge gaps remain. To adequately assess the ecological health of the Bay and provide for early identification of threats a more proactive and cohesive approach to research is warranted. Commitment of ongoing funding is required to monitor benthic habitats and associated communities throughout the Bay.

21 Changes to Benthic Communities over 20 years in Port Phillip Bay. David R. Currie & Gregory D. Parry1999. Marine Pollution Bulletin Vol 38. Elsevior Science Ltd.