Recreational water quality and seafood safety, Derwent Estuary Tasmania

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The Derwent Estuary in Tasmania faces several water quality challenges that impact directly on human health: high levels of heavy metals in shellfish, elevated mercury levels in finfish, and intermittently poor recreational water quality at several popular beaches in the estuary. The Derwent Estuary Program (DEP) is a partnership organisation working with industries, utilities and Councils that border the Derwent, to improve our understanding and management of these and other issues. Activities undertaken to investigate seafood safety issues include detailed sediment /water column studies, uptake experiments using deployed shellfish, and regular wild finfish and shellfish surveys. Zinifex Hobart Smelter have monitored mercury levels in flathead for the past 22 years, while oysters and mussels have been monitored annually for 13 years for a range of heavy metals (zinc, cadmium, copper, mercury and lead). Deployed shellfish are used to study the rate and degree of metal uptake in areas with contaminated sediments and elevated water column loads. Recreational water quality has been addressed through an intensive weekly monitoring program at nearly 40 sites around the estuary. This program is coordinated by DEP and has been undertaken by Councils and State government since 1990. Weekly monitoring of the faecal indicator enterococci is supplemented by the implementation of sanitary surveys, the development of an Action Plan for investigating sources of faecal pollution, and a signage and public awareness strategy. The release of the new NHMRC Guidelines for Managing Recreational Water Quality has changed the way beaches are assessed, and "raised the bar" for Councils and regulatory authorities in the State. This paper discusses how the DEP, through a partnership approach, is dealing with the management of two long-term human (and estuarine) health issues.

Introduction

The Derwent estuary lies at the heart of the Hobart metropolitan area (Fig 1), and its margins are the home for approximately 40% of Tasmania's population. The estuary is a great natural asset, with diverse ecosystems that support a wide range of habitats and species. The Derwent is an integral part of Tasmania's cultural, economic, and natural heritage, and is widely used for recreation, boating, fishing, marine transport and industry. The catchment provides most of Hobart's drinking water supply, and is a major source of hydro-electric power.

The Derwent estuary is affected by elevated levels of heavy metals in water, sediments and biota, largely the result of past industrial practices (Coughanowr 2006). Improved environmental performance from small and large industries over the past 30 years has resulted in dramatic decreases in pollutant loads to the estuary. Gradual improvements in estuarine condition have been monitored by the Derwent Estuary Program (DEP), through a partnership approach to monitoring and management of environmental issues. Our partners include the six Councils that border the Derwent (Brighton, Clarence, Kingborough, Hobart, Glenorchy and Derwent Valley), two major industries (Norske Skog Paper and Zinifex Hobart Smelter), two utilities (Hobart Water and TasPorts), and State government (Department of Tourism, Arts and Environment).

Two significant human health issues continue to be of concern in the Derwent however; metal levels in biota, and pathogen levels at beaches and popular recreation sites around the Derwent.

Recreational Water Quality

The Recreational Water Quality (RWQ) program has been conducted as a joint monitoring effort between Councils, the Department of Health and Human Services (DHHS) and State Government since 1987. From 1990 to 2001, both faecal coliforms and enterococci were monitored. The program switched to solely monitoring enterococci in 2002 as a result of interference from pulp-mill derived non-faecal thermotolerant bacteria, in particular *Klebsiella*. The Public Health Laboratory (DHHS) uses the Enterolert methodology for 24-hour confirmed results (IDEXX). Prior to 2002, enterococci results used the membrane filtration method to report presumptive results (Australian Standards 1995).

Currently, a total of 38 sites are monitored, which includes 17 sites at popular beach and swimming locations within the estuary (see Figure 1). 14 sites are located in embayments around the estuary, while 3 sites reflect freshwater inputs from rivulets and rivers. The remaining 4 sites reflect monitoring conducted for cross-river swim and triathlon events. Samples are collected weekly from November through March of each year, giving approximately 21 samples per season at each site. Monitoring is conducted by Council Environmental Health Officers at 25 of the sites, while the remaining 13 sites are sampled by DEP staff using the Environment Division sampling vessel "Aqua".

Other monitoring conducted by Councils includes effluent quality from the 10 sewage treatment plants that discharge to the Derwent, 2 of which are treated to tertiary standard. A further two sewage treatment plants are on 100% effluent re-use programs (see Figure 2).

DEP also coordinates an extensive Stormwater and Rivulet Monitoring Program encompassing 34 sites in creeks, rivulets, drains, rivers, drains and dams (DEP, 2006). Results from this monitoring program show a decline in water quality with increased urbanisation, where runoff from a large array of land surfaces contributes to streamflow (see Figure 3). Stormwater inputs of faecal contamination include sewer blockages and overflows, illegal stormwater-sewerage connections and animal faeces (DEP 2006).

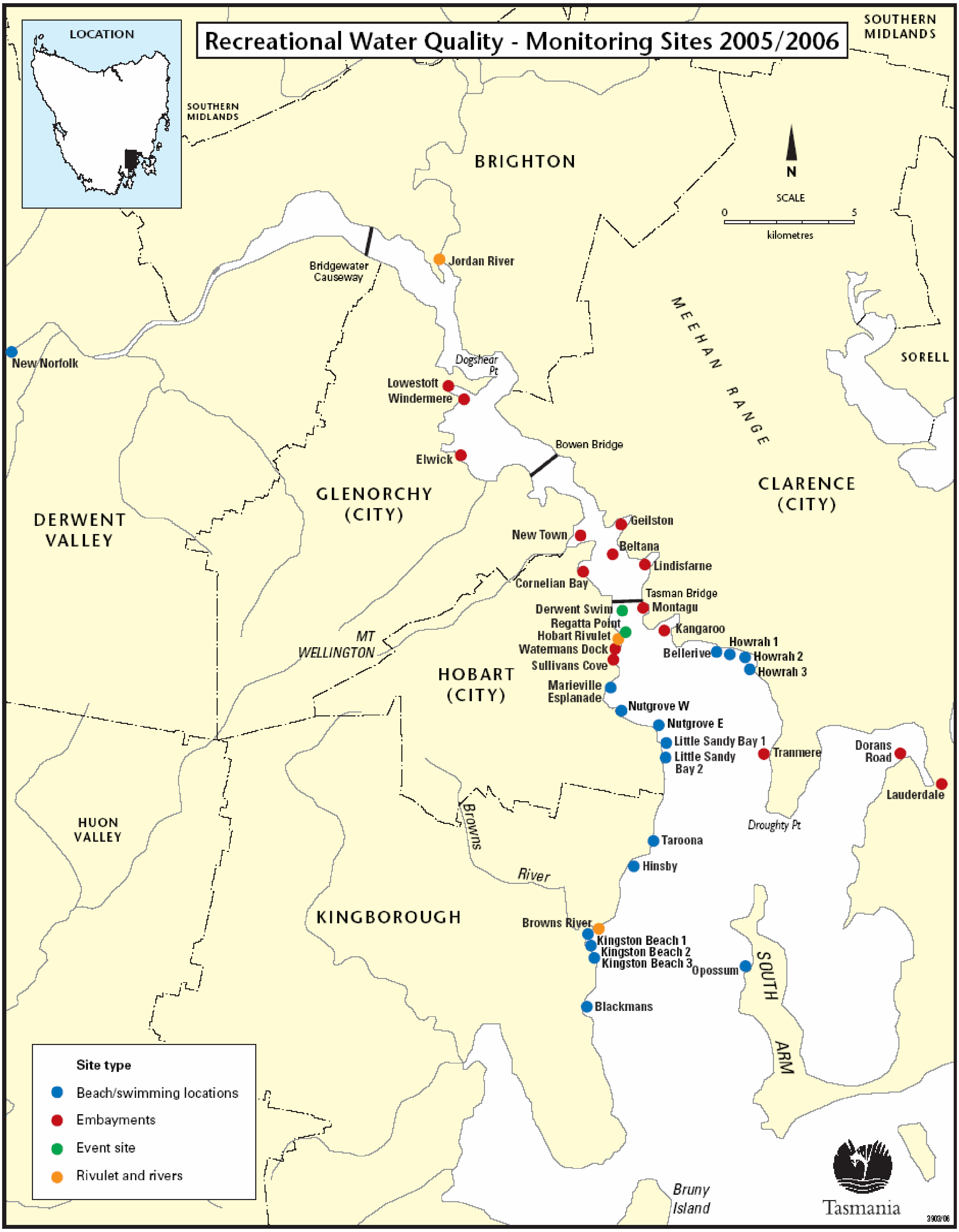


Figure 1 Location of beach, embayment and other monitoring sites in the Derwent estuary Recreational Water Quality Program.

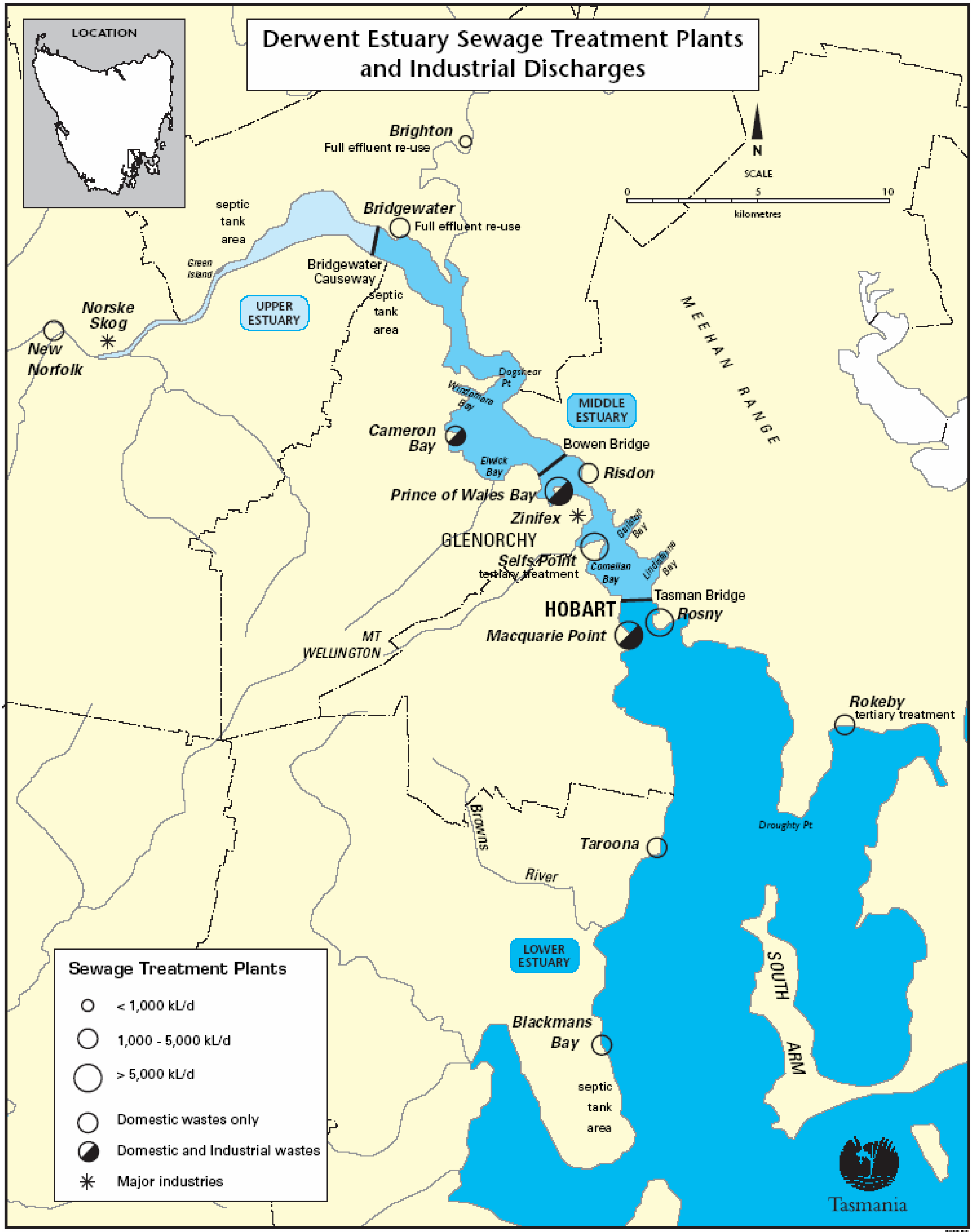


Figure 2 Location of sewage treatment plants and major industry in the Derwent estuary.

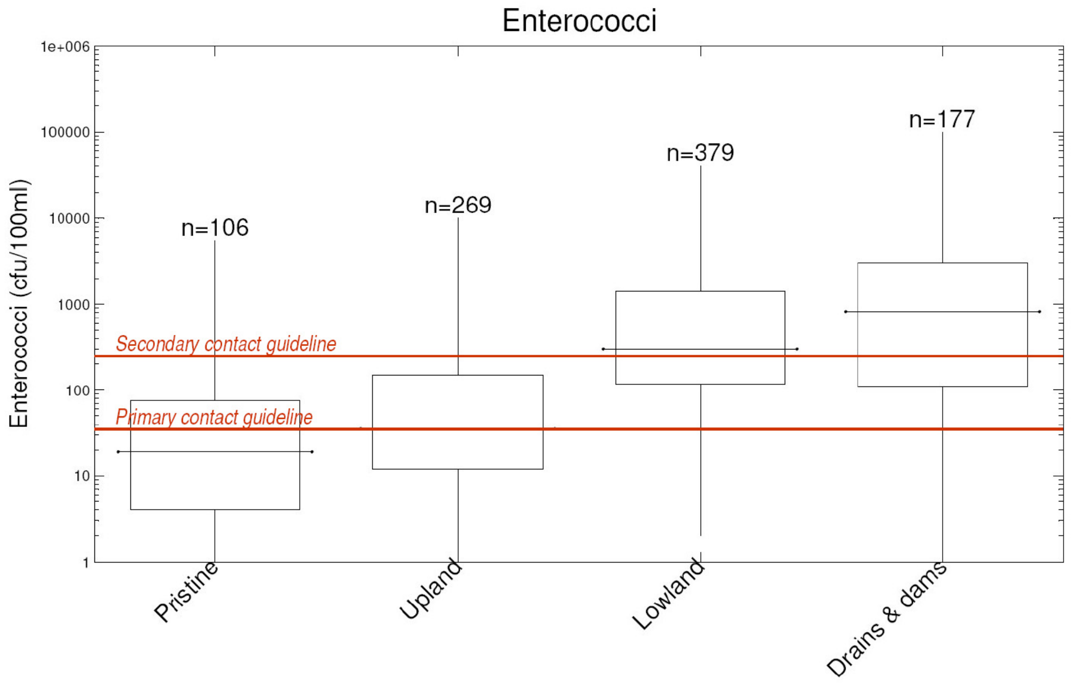


Figure 3 Enterococci results from pristine, upland, lowland, and drains and dam sites in the greater Hobart catchment. Guidelines refer to ANZECC (2000) National Water Quality Management Strategy primary contact level of 35 enterococci/100 mL (season median) and secondary contact level of 230 enterococci/100 mL (season median).

Season trends for enterococci over the past 3 years have been assessed using both the geomean (NHMRC 1990;Public Health Act 1997) and the World Health Organisation risk-based criteria recently adopted by the NHMRC (NHMRC 2005). The transition to risk-based assessment using a combination of Microbiological Assessment Categories (MAC) and sanitary surveys has raised a number of concerns. The majority of the main recreation beaches in the Derwent, which would have received a pass under guidelines based on a season geomean of 33 enterococci/100 mL, now receive a "C" or "D" rating (see Figure 4). The perception has been that there is a decline in water quality at previously "good" beaches, when in reality the new ranking better reflects the risks bathers are exposed to, based on monitoring data.

The DEP has facilitated, through a consultative and partnership approach with Councils, a program to investigate sources of faecal contamination at identified hot-spots (based on microbiological assessment) in the estuary. Detailed sanitary surveys were conducted at Nutgrove Beach, Kingston Beach and Howrah Beaches using the NZ Microbiological Water Quality Guidelines (MoE 2002; Eriksen and Richards 2005) and the Recreational Water Quality Assessment software "Bathewatch" available from the NZ Ministry of the Environment website (MoE 2002). As part of this process, a "Faecal Tracking Action Plan" (FTAP) has been developed for the Hobart region (DEP 2006). This paper describes the investigations undertaken at one of Hobarts most popular beaches, Nutgrove Beach, in line with strategies identified in the FTAP.

Stakeholder meetings were held to review the results of the sanitary surveys, and the following areas identified as the most likely sources of faecal pollution at Hobart beaches:

1. Polluted stormwater during wet weather
2. Catchment infrastructure during dry weather
3. Animal droppings
4. Polluted water ingress as a result of tidal and wind influences

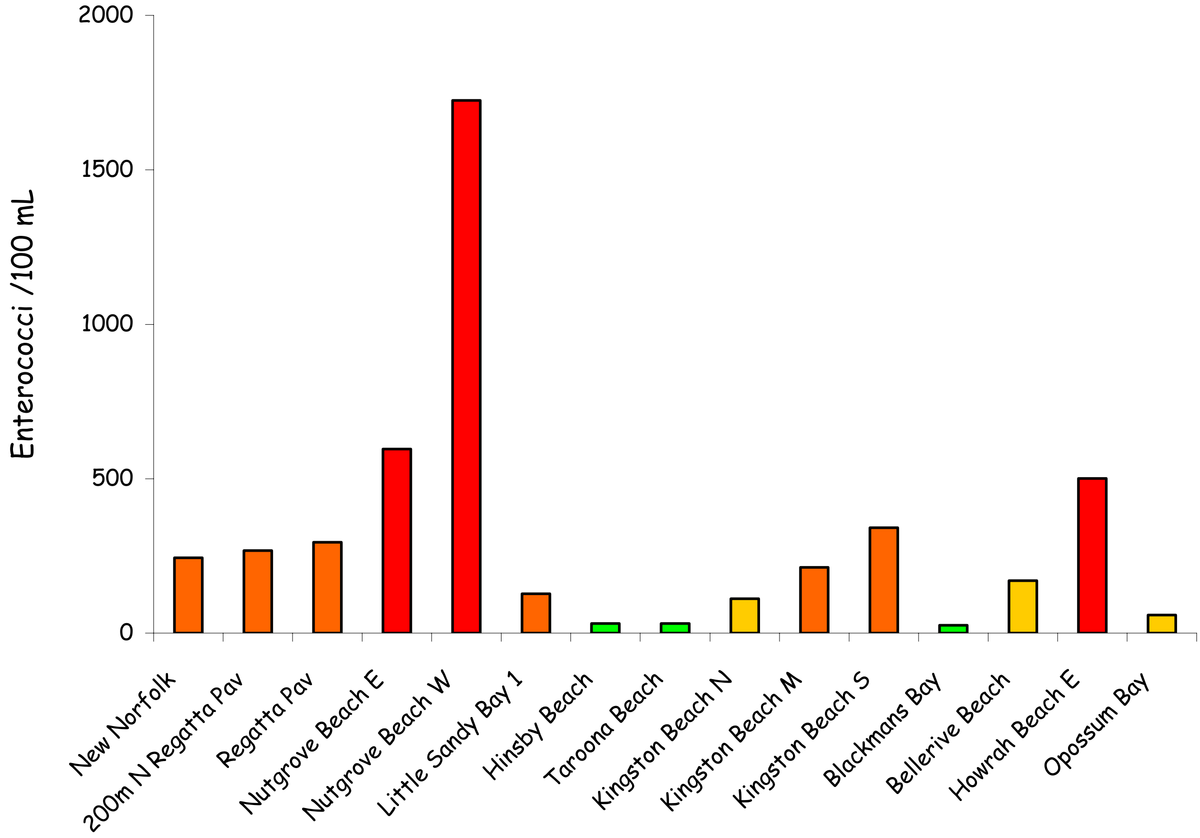


Figure 4 Recreational Water Quality rankings for Hobart beaches and swimming sites. Rankings based on 95th Hazen percentile statistic, using 3 years data (03/04, 04/05, 05/06). Green (A) = < 40, yellow (B) = 40 – 200, orange (C) = 200 – 500, red (D) > 500 enterococci/ 100 mL.

Hobart City Council engineering staff developed a "fishbone" or cause and effect diagram as an umbrella document that identified how each of the above likely causes could be identified, and investigated (DEP, 2006). Areas targeted for the summer of 2005/06 included investigating and managing catchment infrastructure, and improving the spatial and temporal resolution of faecal contamination at Nutgrove by undertaking an intensive monitoring program. This Hobart City Council study was combined with a faecal sterol investigations to determine if faecal contamination was derived from animals or human sources. A total of 10 monitoring sites were sampled along Nutgrove Beach, and nearby Little Sandy Bay Beach (see Figure 1). Sites included the existing 4 RWQ sites (Nutgrove E and W, Little Sandy Bay 1 and 2), plus 6 new sites along the shoreline and stormwater infrastructure. Samples were collected at each site for enterococci, turbidity, salinity and temperature. A single sample for faecal sterol analysis was collected daily from one site (Site 5), which has previously been associated with high enterococci results traced to stormwater contamination.

Faecal sterol analysis can be used to identify the main group of animals responsible for faecal contamination since humans, dogs, cows, birds etc all produce different sterol profiles as a result of different digestive and metabolic processing of dietary sterols. Due to the expensive nature of the analysis, the volume of water that must be collected, and the need for relatively high concentrations of faecal markers to positively identify the source of faecal material, only

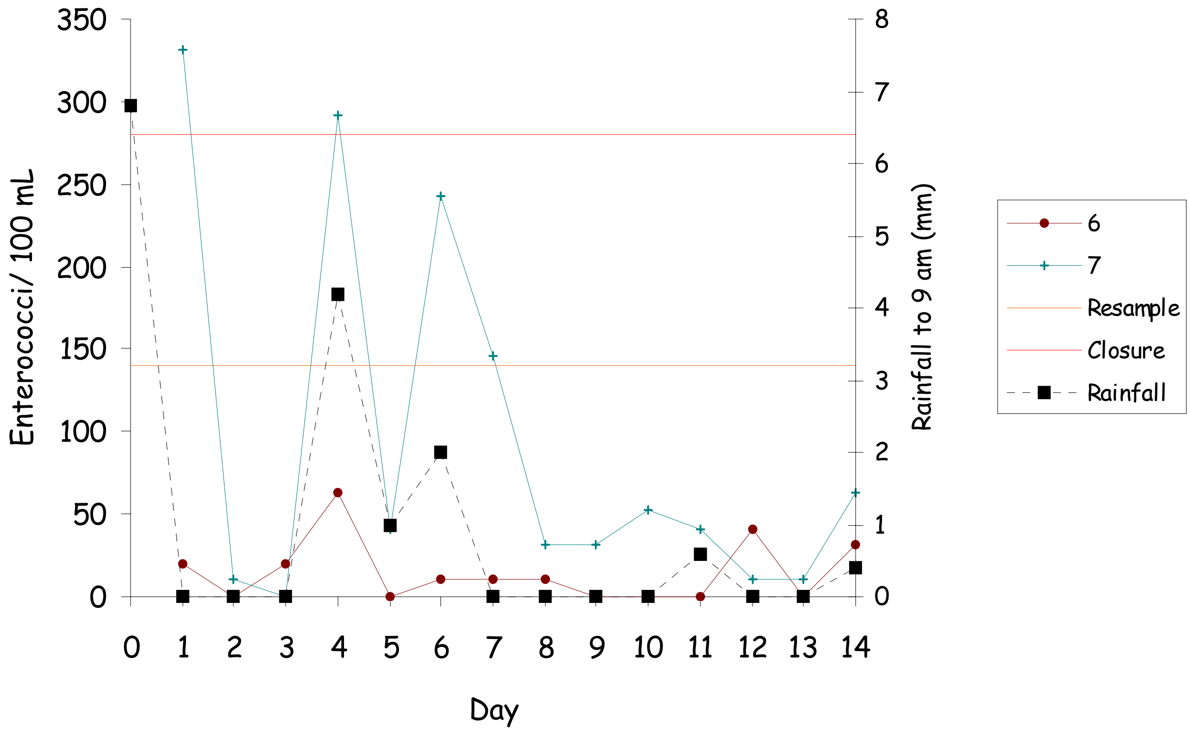


Figure 5 Enterococci data from selected sites during Nutgrove Beach intensive monitoring program, and rainfall data to 9 am during program.

one site was targeted for sterol analysis. The results of the samples collected for enterococci analysis over the study period are shown in Figure 5. Rainfall during the intensive monitoring period are also shown. The triggers for resample and closure designated in the Tasmanian *Public Health Act 1997* are also illustrated.

During the period of the intensive survey, levels of enterococci remained largely at baseline levels (< 50 enterococci/100 mL) on the majority of sampling occasions, for 8 of the 10 sites in the study (data not shown for clarity). High enterococci levels (> 100 cfu/100 mL) were not found at the site used for collecting faecal sterol samples, and therefore samples from Site 5 could not be submitted for analysis. The highest concentration of enterococci detected during the survey was 330 cfu/100 mL, at Site 7. This site was located directly in front of the Lipscombe Rivulet, which collects water from an 81 ha catchment. Whilst concentrations measured at this site were high enough to trigger a closure, the typically poor water quality experienced in the past (see Figure 5) at Nutgrove West (site 6) was not observed during this study. There is however, some indication that rainfall may trigger elevated faecal levels in the Lipscombe Rivulet since higher levels were preceeded by rainfall in the 24 –48 hours prior to sampling. Generally there is poor correlation between enterococci levels and rainfall when monitoring is limited to weekly sampling. This may be due to multiple sources of faecal contamination (rather than just stormwater loads), and suggests that intensive follow up sampling during and after rain events at hotspots is required to improve our ability to predict poor water quality. Prediction capacity is an important component for Councils and regulatory authorities to reduce the risks of illness to beach users. A general warning to avoid swimming at urbanised beaches for several days after significant rain has been incorporated into annual publications and web-based fact sheets prepared by the DEP (DEP, 2006).

The lack of “events” resulting in the detection of enterococci levels that have typically been recorded at Nutgrove Beach during the swimming season was a frustrating experience for staff investigating water quality at Nutgrove Beach. Detailed tracking undertaken in the catchments above the beach revealed some minor cross connections, but no major infrastructure failure that would account for the high levels recorded for the past 5 years. Since December 2005, Nutgrove Beach has been temporarily signposted as "Not Suitable for Swimming". Current investigations by Hobart City Council include the use of caffeine as an alternative, more cost effective tracer of human sewage, and it is hoped that this technique may be used in the coming summer monitoring period. Other management issues also under investigation are the declaration of the area as a dog-free zone, however the issue of animal droppings in the rest of the catchment is still an issue. It is hoped that other Councils will benefit from, and continue to contribute to the development of the Faecal Tracking Action Plan, and the more detailed studies undertaken by Hobart City Council in 2005.

Seafood Safety in the Derwent

A number of large industries are situated on the Derwent, the largest being the Norske Skog paper mill at Boyer, and the Zinifex Hobart Smelter near the city centre (see Figure 2). Heavy metal contamination- particularly zinc, cadmium, lead and mercury- is one of the Derwents' most persistent and severe environmental problems, with metal concentrations in sediments and biota amongst the highest in Australia (Coughanowr 2006). Major sources of heavy metals currently released to the estuary include contaminated groundwater from the Zinifex site at Risdon, and urban stormwater. Metal levels in water and stormwater have been monitored through the DEP's Ambient Water Quality Program (AWQ) and the Rivulet and Stormwater Monitoring Program (Green and Coughanowr 2003).

Extensive biota monitoring programs undertaken by Zinifex Hobart Smelter for the past 23 years include annual wild shellfish (oysters and mussels) and finfish (flathead) surveys. The metal concentrations in biota are used as an indicator of estuarine health, and provide a picture of how the ecosystem as a whole is responding to the loads of contaminants entering the estuary. More recently Zinifex have also undertaken deployment programs where caged oysters sourced from outside the estuary are translocated to various sites around the estuary. These studies have shed light on the rate of metal uptake by oysters, and the relationship between ambient water column metal concentrations, and the concentration in individual oysters.

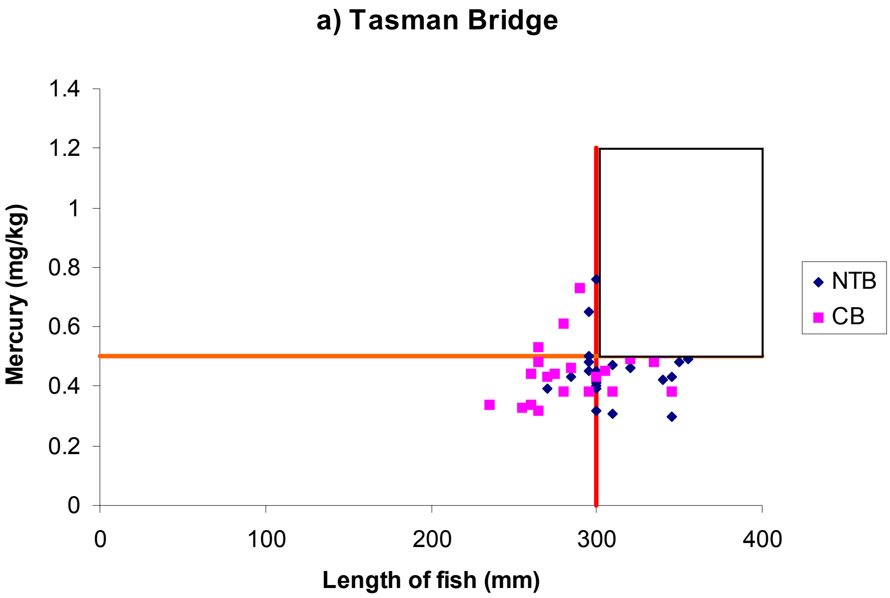
Flathead (*Platycephalus bassensis*) have been used in the Derwent as a fish indicator species, as their role as locally resident benthic dwellers reflects exposure to both water column and sediment sources of heavy metals. They are widely distributed, easily caught and their popularity as a recreational fishery means data on the suitability of flathead for human consumption is required on a regular basis. Flathead sampling is conducted annually from August to November, and the most recent surveys have been expanded to include other recreationally targeted fish species (Zinifex 2005). Metal concentrations in all flathead caught, and the component of legally sized fish are compared to the ANZFA Maximum Levels (ML) and Generally Expected Levels (GEL) recommended for human consumption (ANZFA 2000). Mercury in flathead is of particular interest from a human health and estuary management perspective.

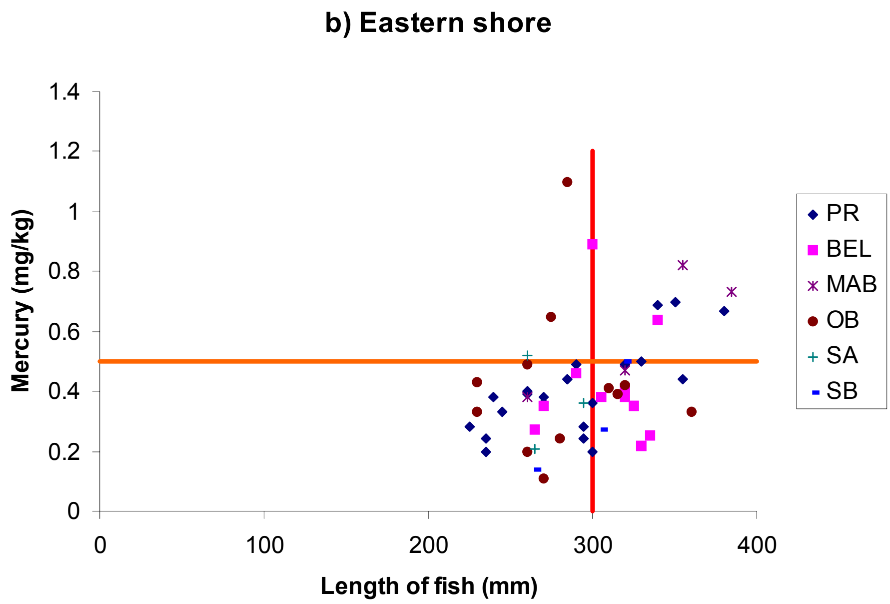
The ANZFA ML and GEL for cadmium, lead, mercury, copper and zinc are shown in Table 1 for shellfish (oysters) and finfish.

Seafood type	*Maximum Level (mg/kg)*			*Generally Expected Level (mg/kg)*	
	Cadmium	*Lead*	*Mercury*	*Copper*	*Zinc*
Oysters	*2*	*2*	*0.5*	*30*	*290*
Fish		*0.5*	*0.5**	*0.2*	*15*

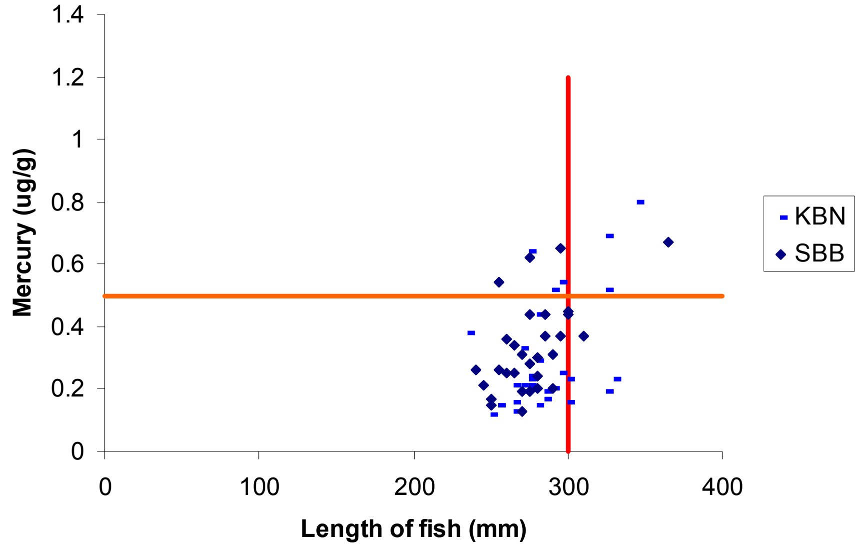
*Table 1 Australian and New Zealand Food Authority guidelines for shellfish and finfish. * for all fish other than gemfish, billfish, marlin, southern bluefin tuna, barramundi, ling,orange roughy, rays and sharks.*

Shellfish accumulate higher concentrations of metals per unit of body mass than fish, and as result, GEL values are higher for shellfish. Some shellfish preferentially accumulate specific metals, and in the Derwent, mussels are monitored for lead content, while zinc is found in higher concentrations in oysters.



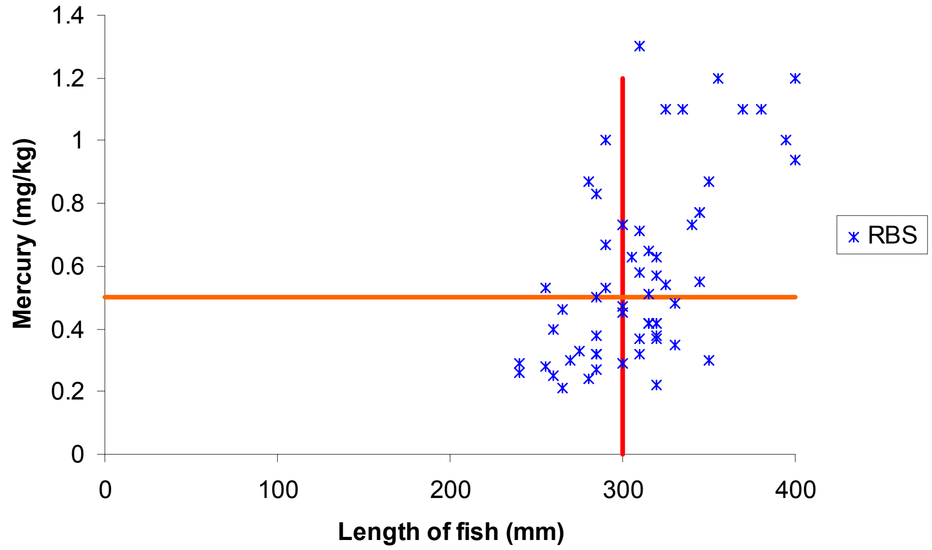


c) Western shore



Mercury
(mg/kg)

d) Ralphs Bay



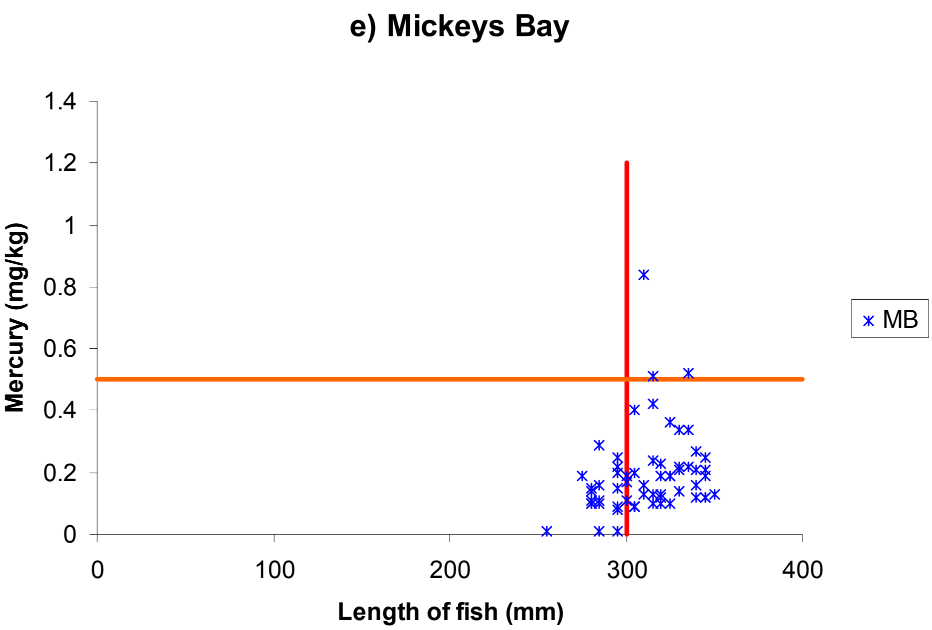


Figure 6 Concentration of mercury in flathead caught in the Derwent estuary at a) Above Tasman Bridge b) Western shore below Tasman Bridge c) Eastern shore below Tasman Bridge d) Ralphs Bay and e) background location at Mickeys Bay, Bruny Island. Legal size (300 mm) and ANZFA ML of 0.5 mg/kg also shown.

The results of 3 years monitoring data for flathead are shown in Figure 6, for five regions in the estuary. Flathead are grouped by region as they are not migratory and are therefore resident in the estuary for the duration of their life cycle. The specific location of sample sites within each region is shown in Figure 8. A summary of the flathead results for mercury are shown in Table 2 below. Results include all fish caught, and for those fish of legal size (> 300 mm). There was a positive correlation between size and mercury content for all regions sampled. Previous work by Zinifex has established a significant correlation between age (measured by otolith sections) and total length in flathead in the Derwent, and therefore it is assumed for simplicity that mercury accumulation is a function of age and therefore metal exposure.

Region	Hg, all fish (mg/kg)			Hg, fish > 300 mm (mg/kg)		
	Median	Average	Range (n)	Median	Average	Range (n)
a) above Tasman	0.48	0.54	0.3–1.1(60)	0.51	0.57	0.3 – 1.1(39)
b) Western shore	0.25	0.32	0.1–0.8 (60)	0.44	0.46	0.16-0.8 (11)
c) Eastern shore	0.38	0.42	0.11–1.2 (60)	0.41	0.47	0.2 – 1.2 (29)
d) Ralphs Bay	0.51	0.58	0.21–1.3 (60)	0.58	0.65	0.22 – 1.3 (39)
e) Mickeys Bay	0.16	0.19	0.01–0.84 (60)	0.19	0.23	0.09 – 0.84 (60)

Table 2 Mercury results for flathead caught between 2002 and 2004, by region in the Derwent estuary. Maximum Level for flathead is 0.5 mg/kg mercury.

Fish caught in the immediate vicinity of the zinc smelter (a, above Tasman Bridge) contained elevated levels of mercury, with an average concentration of 0.54 mg/kg. Approximately 65% of the fish caught were above legal size, and those fish contained an average mercury concentration of 0.57 mg/kg. Fish on the western shore (b, below Tasman Bridge) contained an average concentration of 0.46 mg/kg for legally sized fish, while fish on the Eastern shore (c, below Tasman Bridge) contained on average, 0.47 mg/kg mercury for legally sized fish. Fish caught in Ralphs Bay, a large semi-enclosed embayment on the Eastern shore, had the highest concentrations of mercury in legally sized fish at 0.65 mg/kg, and the highest mercury content in any one individual fish (1.3 mg/kg).

“Background” fish were collected from Mickeys Bay, Bruny Island to allow comparison of mercury concentrations in fish not resident within the estuary. Mercury concentrations were significantly lower, with an average of 0.23 in legally sized fish. With the exception on one individual fish at 0.84 mg/kg, all fish caught in the Mickeys Bay area contained less than 0.52 mg/kg.

The average concentration for all fish caught of legal size within the estuary (excluding Mickeys Bay) was 0.49 mg/kg mercury, which is just within the ANZFA Maximium Level.

In terms of recreational fishing, flathead caught above the Tasman Bridge, and in Ralphs Bay present the highest risk of containing greater than 0.5 mg/kg mercury for legally sized fish. This is depicted in Figure 6 as that proportion of the total catch that fall in the shaded area (> 300 mm, > 0.5 mg/kg Hg). The lowest risk of consuming fish with mercury levels above the ANZFA ML comes from fish caught on the western shore, although only 11 fish from the total catch were of legal size (ie a smaller proportion of the total catch than for other regions). There is no clear long-term decline in mercury in fin-fish, despite significant reductions in the load of mercury delivered to the estuary, and associated reductions in water column concentrations.

Steps to inform the public of the health implications associated with elevated mercury levels include the publication of the results of the annual monitoring program through annual report cards and specific brochures on seafood safety in the Derwent. Stakeholders are also working on the issue of signage at appropriate jetties and wharves around the estuary, and the inclusion of guidance on fish consumption in Marine and Safety Tasmania and Sea Fisheries mailouts. Current advice for the Derwent is to limit the consumption of flathead caught within the Derwent to 2-3 times per week, or 1 meal per week for pregnant women and young children.

Current advice on consumption of shellfish is that no shellfish should be collected and consumed from anywhere in the Derwent. This advice is based on annual monitoring of wild oysters and mussels by Zinifex Hobart Smelter over the past 13 years (ZHS, 2005). Results of this monitoring program have consistently shown that mussels contain elevated levels of lead, and on average contain 6 times the ANZFA GEL of 2 mg/kg. Levels of cadmium, copper, mercury and zinc in mussels were well below the guideline values shown in Table 1. Oysters sampled from the Derwent show preferential accumulation of zinc, with wild oysters having on average 10 -20 times the ANZFA GEL of 290 mg/kg. The GEL is not derived from toxicity or health data, as is the case with mercury, but rather is based on baseline survey data from Australia and New Zealand. Exceedances do not necessarily indicate a health concern, but rather identify pollutant issues, and should trigger further monitoring and investigation.

Recent shellfish monitoring conducted by Zinifex Hobart Smelter has focused on understanding the rate of bioaccumulation of heavy metals, and the relationship between ambient water column concentrations, sediment loads of heavy metals and oyster response. Oysters sourced from clean culture conditions on the East Coast of Tasmania were bagged and deployed at 12 locations within the Derwent estuary, and also at Mickeys Bay, Bruny Island (see Figure 8). These oysters contained, on average, less than 200 mg/kg Zn prior to relocation to the Derwent. Bags were retrieved after 6 weeks, *from* all sites and analysed for a suite of heavy metals. Significant accumulation of metals occurred, with oysters from all sites in the Derwent exceeding the ANZFA GEL of 290 mg/kg Zn after the exposure period. A staged retrieval of bags located in the middle estuary showed that the oysters rapidly accumulated metals in the first 4 weeks of deployment, and actually decreased in concentration at the final sampling of 6 weeks (see Figure 7).

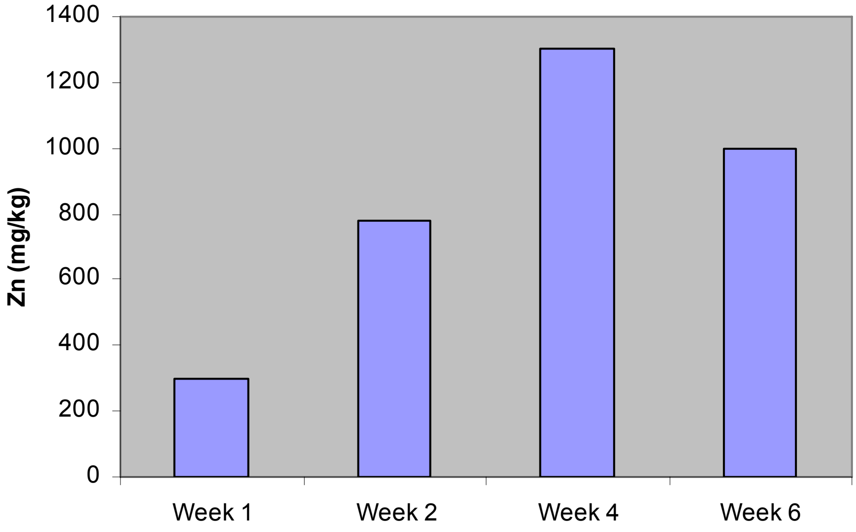


Figure 7 Accumulation of zinc by deployed oysters during staged retrieval from the middle Derwent estuary.

The maximum level of zinc recorded over the deployment experiment was 1300 mg/kg Zn, which represents an almost 7 fold increase in metal body burden. Wild oysters within the sampling region contain on average 6000 to 7000 mg/kg Zn, and previous monitoring work by Zinifex has shown that uptake of metals declines with age. Additional studies include the effect of position in the water column (ie proximity to sediments) on metal uptake, and time-averaged estimates of metal exposure through the use of gel-based passive samplers (results not discussed here).

The monitoring studies on shellfish and finfish undertaken by Zinifex are an important source of information on the impacts of a heavily urbanised and industrialised catchment on the aquatic environment. Management implications arising from the monitoring results are significant, as there is currently an estuary-wide ban on consumption of shellfish, and recommendations to limit the consumption of flathead caught from specific regions within the Derwent. Historical monitoring indicates that there has been a significant reduction in metal loads to the estuary over the past 30 years, and this is reflected in concomitant reductions in water column concentrations measured through the DEP Ambient Water Quality Monitoring Program. Zinifex have successfully undertaken major on-site works to intercept diffuse and point source heavy metal contamination before it enters the river, and implemented stormwater management plans for the site. Stormwater contributions from the catchments surrounding the estuary are more difficult to manage due to the multiple of diffuse sources, however several rivulet and catchment management plans have been developed through DEP stakeholders. Bioaccumulation of metals in aquatic fauna has been identified as one of the most significant issues in the estuary (Coughanowr 2006). A Water Quality Improvement Plan for heavy metals has been developed for the estuary, through federal NHT funding of the Coastal Catchments Initiative. Detailed chemical, physical and biological studies of the contaminated sediments were integrated with predictive modelling tools developed by CSIRO Marine Research. A major outcome of the project was to identify management priorities. These include continued focus on groundwater management at the Zinifex Hobart Smelter, the development of Derwent-specific dredging guidelines, and increased focus on water quality and management of nutrient loads to the estuary. More detailed surveys of heavy metals in fish and biota are planned to feed into a

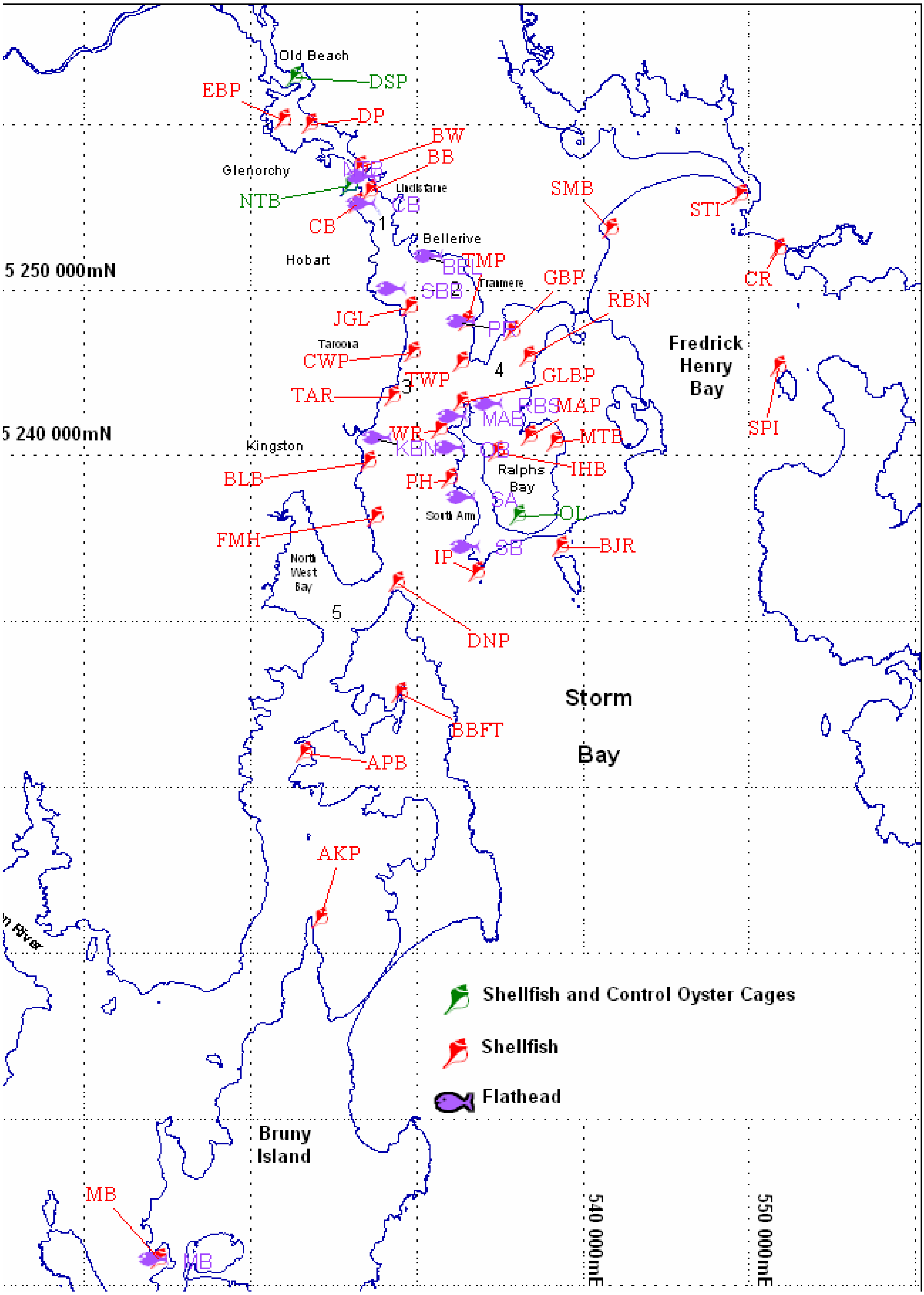


Figure 8 Location of flathead and shellfish monitoring sites in the Derwent estuary, as surveyed by Zinifex Hobart Smelter. MB = Mickeys Bay, reference site at Bruny Island.

biogeochemical model of metal uptake and pathways in the estuary, as well as a continued focus on community information and awareness about seafood safety.

This paper has briefly described two of the most challenging health issues, both estuarine and human, facing stakeholders involved in the management of the Derwent estuary. It is envisaged that continued detailed scientific research and monitoring strategies will underpin the development of a decision support system for these priority issues.

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