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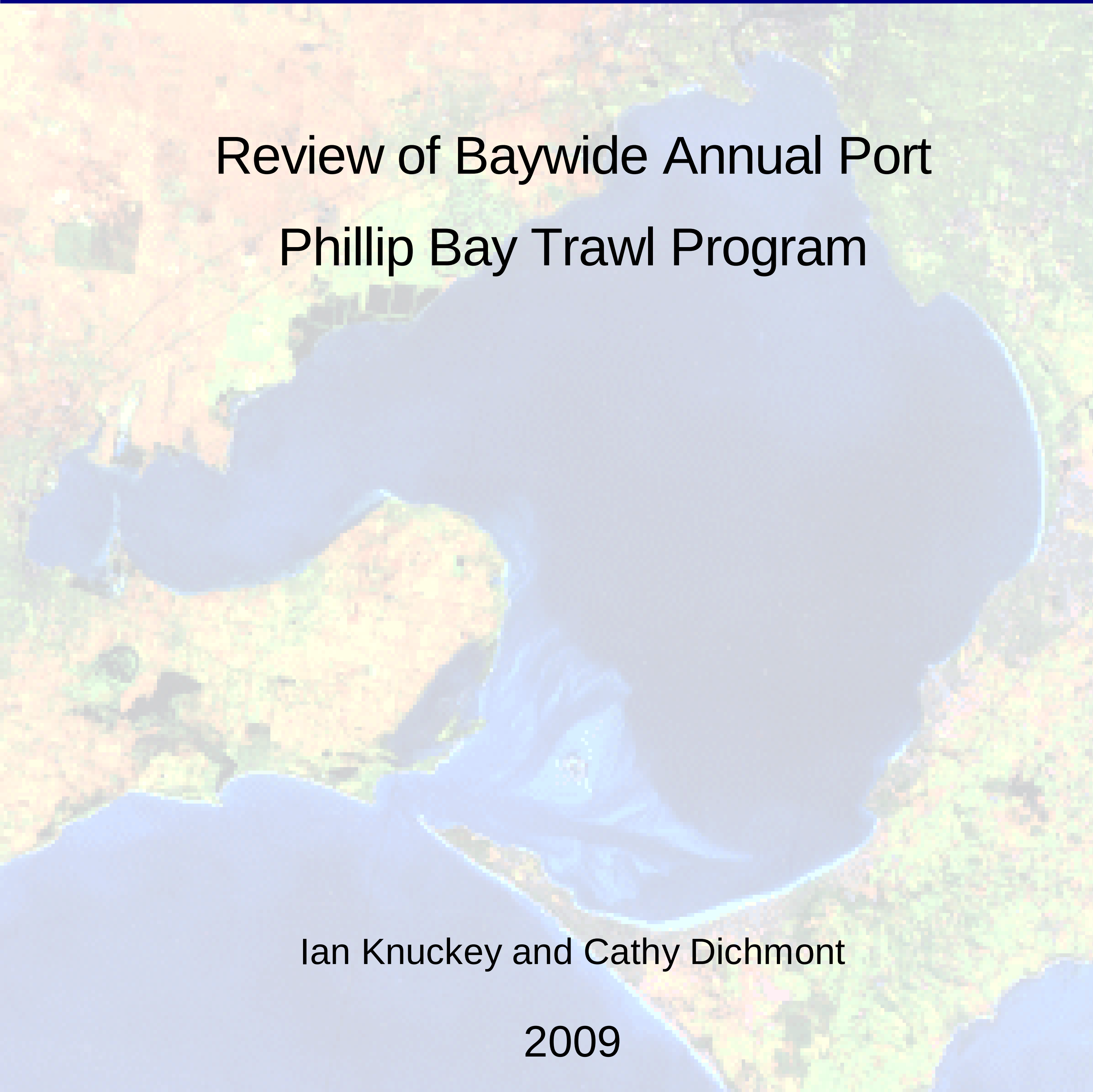

Review of Baywide Annual Port Phillip Bay Trawl Program

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Table of Contents

1. Background

The Port Phillip Bay Annual Trawl Program has been running for almost 20 years and is currently being used as a platform from which to achieve a number of research requirements. Information gained from these annual trawl surveys is being used by Fisheries Victoria to monitor changes in abundance of key species in Port Phillip Bay and separately by the Port of Melbourne Corporation (PoMC), to monitor the potential impact of dredging in the Bay. Details of the history and objectives of these separate research requirements of the Annual Trawl Program are detailed below.

1.1. Survey design

Two, 5-minute tows using a demersal trawl net are undertaken at 22 sites, stratified by depth (7 m, 12 m, 17 m and 22 m) (see Figure 1). These sites were chosen in 1990 and were designed to provide representative spatial coverage of the Bay and are sampled during February–April (usually March) each year. Sampling is conducted during that time of year because of the stability of the weather and the presence of seasonally important species such as snapper. Based on multi-dimensional scaling of Bray-Curtis similarities of fish communities, which corresponded to similarities in infauna, epifauna and sediment type, the Bay has been divided into four ecological types designated as “regions” for analysis, and classified as: ‘shallow’; ‘intermediate’; ‘deep’; and, ‘west’ (Figure 1, from Parry *et al.* 2003).

The survey uses a wing trawl net of stated dimensions: 47 m long, 13 m wing spread, 5 m opening height and 45 m between trawl doors (Figure 3). During the 1990–1997 surveys, the research vessel Sarda was used. Since then, the fishing vessel Castella Rosa has been used. The effect of changing vessels was minimised by selecting a vessel of similar size to Sarda, using the Sarda’s skipper during the first three years’ surveys on the Castella Rosa and by maintaining a similar winch speed on each vessel. The towing speed was maintained at about 3.1–3.2 knots. Warp lengths were altered for different depths (50 m at depths of 7 and 12 m, 75 m at 17 m depth and 100 m at 22 m depth).

1.2. Fisheries Victoria’s Bay & Inlet Monitoring

Trawling has been used as a method to monitor the fish communities in Port Phillip Bay since the early 1970s (Brown 1977). During 1990, Brown’s original sites were re-sampled with similar trawl gear to enable comparisons of changes to the structure of fish communities over the previous two decades (Hobday *et al.* 1999). During the same year, the current demersal trawl monitoring program was established (Parry *et al.* 2003) using a depth-stratified sampling design to sample all soft sediment habitat types in the bay. The annual Port Phillip Bay Trawl Program forms part of Fisheries Victoria's Bays and Inlets Monitoring and Assessment Project.

When it was established, the primary purpose of the trawl monitoring program was to document trends in the abundance, biomass, diversity and (since 1995) size-frequency distributions of fish and selected benthic invertebrates in Port Phillip Bay for fisheries management (Parry *et al.* 2003). More specifically, the original objectives of the trawl monitoring program were:

- ***To monitor trends in the abundance and size of fish and invertebrates in Port Phillip Bay and report with advice to fisheries managers.***

- ***To monitor interannual differences in recruitment of commercial and non-commercial fish species and where possible identify factors responsible for annual differences in recruitment***

- ***To archive stomach contents of the major fish in PPB, so that where marked changes in fish abundance occur, the role of wider ecological changes impacting their diet can be assessed.***

During 2008, the objective of the trawl monitoring program was changed by Fisheries Victoria to:

- ***Monitor trends in the abundance and size of important fish species in Port Phillip Bay and report with advice to fisheries managers.***

Since its establishment, there has been no long-term commitment to fund the annual trawl program. Annual funding has been obtained on a somewhat *ad-hoc* basis and in 1998 and 2001, lack of funding prevented the survey taking place. In the years in which the survey has taken place, there is no annual reporting of the survey results. Instead, reporting of the survey results has tended to be published mainly in internal technical reports on specific aspects of Port Phillip Bay ecology (eg. Hobday *et al.* 1996, Officer and Parry, 1995, Parry *et al.* 1995, Parry *et al.* 1996).

1.3. Channel Deepening Project

The Channel Deepening Project (CDP) is being undertaken to provide vessels calling at the Port of Melbourne with 14 m draught access at all tides. To achieve this, dredging and associated works began during 2008 in parts of the existing shipping channels within Port Phillip Bay. The CDP Risk Assessment as part of the Supplementary Environment Effects Statement (SEES) assessed the impacts of the CDP on the health of Port Phillip Bay. Where significant impacts were predicted, mitigation measures to manage these impacts were incorporated into the project to provide feedback to ensure that any flow-on impacts do not become unacceptable. To support these mitigation measures, a suite of eight Channel Deepening Bay-wide Monitoring Programs were developed to provide broad information on the status of key species, habitats and ecological processes in the Bay and detect changes outside of expected variability – including both natural fluctuations and anticipated CDP-related changes as predicted in the SEES risk assessment. The Fish Stock and Recruitment Bay-wide Monitoring Program (FSR BMP) is one of these Programs and has the objective to detect changes in the distribution, abundance and types of fishes in the Bay, their population structures and larval distribution and abundance, outside expected variability (Houtgraaf 2007).

As part of the delivery of the Bay-wide Monitoring Programs, key service provider DPI (Fisheries Victoria's Fisheries Research Branch - FRB) is responsible for delivery of specific sub-programs to the Port of Melbourne Corporation (PoMC). Five sub-programs form the overall FSR BMP. These are:

1. Annual trawl survey of fish in Port Phillip Bay. This survey will provide information on population trends of species such as snapper, anchovy and sand flathead.

2. a) Egg and larval surveys for snapper and anchovy. These surveys will be undertaken in Port Phillip Bay and focus on snapper and anchovy,

   b) Anchovy study. This study focuses on better understanding anchovy populations.

3. Recreational Fishery surveys. These surveys will provide information on population trends of popular recreational fish species.

4. Fish in seagrass. This program will improve our understanding of the fish species using seagrass beds in Port Phillip Bay.

These programs are also complemented by data from other ongoing Fisheries Victoria monitoring, in particular their annual surveys of juvenile snapper and King George whiting.

This report focuses on sub-program 1 – the annual trawl survey of Port Phillip Bay, whose objective is:

- ***To detect interannual changes in the abundance of all common fish in Port Phillip Bay outside of expected variability.***

In addition to this objective, the Annual Trawl sub-program is expected to discuss the overall status of key species in the fishery, highlighting any trends or peculiarities observed in the data, along with comparisons against historical data (i.e. background), environmental conditions (e.g. weather conditions, storms, drought, high river flow events) and any other factor that may have influenced the results.

2. Review Objectives

Fisheries Victoria wishes to review the Port Phillip Bay Annual Trawl program, which has been running for almost 20 years. Dr Ian Knuckey (Fishwell Consulting) and Dr Cathy Dichmont (CSIRO) successfully quoted to conduct the review and were joined by Dr Greg Jenkins (FRB) and Dallas D'Silva (Fisheries Victoria) to form an expert panel to assist in the review.

The objectives of this review are to:

- Review the usefulness, scope and end-use of data from the Port Phillip Bay Trawl Program for Fisheries Victoria and Channel Deepening Bay-wide Monitoring Program purposes, and

- Determine options for future directions for the Port Phillip Bay Trawl Program.

The specific tasks of the review are to:

- Identify limitations of the data and options for enhancing the utility of the data through revised survey methods and analysis for fisheries management;

- Identify additional data needs, linkages to existing databases and associated ecosystem based analyses for purpose of value-adding to the core PPB trawl data;

- To better address the specifications of the CDBMP Detailed Design, determine what additional data is required to analyse the PPB Annual Trawl data as part of a broader ecosystem-based fisheries management approach, including the potential for statistically analysing relationships with:

  a) Ecological datasets e.g. key habitat and environmental parameters, fisheries databases including snapper and King George whiting recruitment and catch and effort;

  b) Potential drivers of changes e.g. long-term climate variation, anthropogenic inputs including water quality; and,

- Identifying opportunities, if any, to leverage CDBMP and FV funds.

Significant differences in the use and requirements of the annual trawl program warrants that comments and recommendations for bay and inlet monitoring and for CDP are often provided separately in this review. Discussions with the FV and the expert panel indicated that the survey protocols to meet the CDP requirements had been previously reviewed and that the current survey design was appropriate to meet the FSR BMP objective (Houtgraaf 2007). Further, it was revealed that the survey had to proceed in its current design at least for the next four years to meet FSR BMP requirements for which funding will be received from the PoMC. Consequently, the priority for the review was the requirement of the trawl program to meet the FV objectives, although potential opportunities for leverage and synergies between CDP and FV remains important.

3. Review

3.1. Review the usefulness, scope and end-use data for FM and CDP

3.1.1. Usefulness of the data

3.1.1.a. Data collected

The data collected during the survey are shown in Table 1. These fall into three broad categories: operational, environmental and biological. The reviewers were not provided with any data relating to the stomach contents of fish collected during the surveys.

Table 1. Data collected during PPB trawl surveys and suggested additional data. * Denotes fields that are not consistently recorded.

Operational	Environmental	Biological
- Date;	- Season	- Species name
- Start / end time;	- Wind speed	- Species code
- Start / end latitude and longitude;	- Wind direction	- No. of individuals of each species;
- Replicate number;	- Wave height*	- Total weight of each species;
- Cruise;	- Actual depth*	- Length-frequency ;
- Station Number;	- Temperature*	- Stomach contents (3 main species);
- Site,	-	- Otoliths from sand flathead;
- Net number;	-	-
- Depth zone;	-	-
- Tow direction	-	-
- Tow speed (water)*	-	-
- Tow speed (ground)	-	-
Suggested additions		
- Door spread	- Current strength	- Sex
- Wing spread	- Current direction	- Otoliths from other common species
- Net height	- Water visibility	- CAAB Code
-	- Water temperature at depth	-

Generally, the data that has been obtained from the trawl surveys since 1990 is sufficient to be considered for use as an index of abundance and appears to be of consistent and high quality (see later section on its precision as an index of abundance). Catch weight data have been collected on a high number of species (>100) captured in a trawl, which means there is potential to investigate long-term changes in abundance of species other than the major fish species or those with high commercial value. However, species code is recorded using a different system to what would be seen as standard - the Codes for Australian Aquatic Biota (CAAB). Some codes in the database (eg. A1, ALGB, ALGR, M7, RA16, SPEO, SPMB, SUID, TX33, TX44, TX55, TX58, Z16, Z31) are not intuitive and have no associated common name and would be most difficult to identify for anyone without corporate knowledge of the trawl data. Use of the CAAB would enable the recording of family codes for species that can not be identified down to species level.

Recommendation 1: It is recommended that a more conventional species coding system is used such as the Codes for Australian Aquatic Biota (CAAB).

Pre-1996, length frequency data was collected only on sand flathead, snapper and King George whiting. Currently, length frequency data is collected on virtually all teleost and chondrichthyan species captured (>90spp). Again, the length frequency data appear to be of consistent and good quality. To ensure consistency in methods over time, a field to record the specific length measurement (eg. total length, length to caudal fork, trunk length etc) would be valuable.

Recommendation 2: A field should be added to the data to record specific length measurement (e.g. total length, length to caudal fork etc.).

Usually, the entire catch of all individuals of a species is used to obtain a length frequency distribution but when >100 individuals of a given species is captured during a trawl, a sub-sample of 100 haphazardly collected individuals is used to gain a length frequency distribution. It is important when using this method to obtain pooled length frequency distributions, that the samples from each shot are catch-adjusted to provide a representative length frequency distribution. Usually this is done using the ratio of the catch weight to the sub-sample weight, but this latter figure has not been recorded. Instead, the catch-adjustment is calculated by using the ratio of the total number of individuals caught to sub-sample number from each shot. While both methods are valid, the current method of counting every fish in the catch (rather than weighing them) is often a less efficient and more time-consuming onboard process, especially when large catches are taken.

Recommendation 3: Consider recording the weight of the length frequency sub-sample to enable a catch-weighted distribution.

3.1.1.b. Relative index of abundance

The most comprehensive recent use of the trawl program data has been by Emphron for the CDP. Two separate sets of analyses were made:

- detection of change points over time; and,
- development of change criteria.

Change Point Analysis was used to detect 'step changes' in biomass and abundance of total fish biomass, combined biomass of the six most abundant obligate benthic feeding fish in the four regions, and the total number of sand flathead in Port Phillip Bay. A detailed description of the change point analysis is given in Appendix 4 of DPI (2008).

In order to develop change criteria, an analysis of the relative index of abundance over time was required. For this purpose, a mixed effects statistical model was developed (Emphron 2007). Change over time (*years*) was represented as a fixed effect term (using a natural spline), and the random effect terms were *site*, *years* within *site*, and *shots* within *years* and *site*. This provided a box and whisker plot of log(biomass) and log(abundance) by fish species within each region. The log(biomass) model was shown to have higher power to detect changes and is recommended for use. These plots of log(Biomass) over time show that many of the species display medium to substantial long term declines in population size (even before channel dredging started). These findings are significant for fisheries management.

For the CDP, the resultant model outputs are used to calculate change criteria by comparing the newly monitored year with the four most recent pre-dredging years. It should be noted that this change criterion is set to be triggered for *major* declines in biomass from a (usually) already low baseline. This is because the power calculations undertaken show good power for reductions of 50% or more, and the test criteria are therefore set up for these order of magnitude declines.

During discussions with Dr Thomas, the author of the Emphron reports, it was highlighted that there have been slight modifications to the methods since the reports were first provided. For this review, he kindly provided the recalculated variance components of the trawl data for the CDP (Appendix 1). The new statistical model remained a mixed effects model with fixed and random effects components. However, the terms in the new model have changed: the fixed effect is *year*, whereas the random effects are *site* and *years* within *site*. The *shot* effect falls within the error term. Previously, the *year* term in the fixed effect model was modelled as a natural spline, but now the analysis recognises that there are multiple sites within region (shallow, intermediate, deep and west). Consequently, a year random effect as a deviation from a smoothing spline is no longer needed. This simplifies the model compared to the previous version and shows that a relatively simple model is needed for the analyses.

These new calculations actually substantially improved the relevant variance components in the model (and therefore the power of the index to detect changes), further strengthening the value of the survey as a relative index of biomass for both the CDP and for fisheries management.

Recommendation 4: The new analysis is used in the CDP and also to create an index of abundance for fisheries management purposes.

3.1.2. Identify limitations to the usefulness of the data

3.1.2.a. Relative vs absolute index of abundance

The value of most ongoing trawl surveys is their use as a *relative* index of abundance rather than an *absolute* index of abundance. Estimating the absolute abundance from a trawl survey requires that the catchability (q) of the fish to the gear be known or estimated to describe how the abundance and size composition of a species differs between the population and the survey catch (Harley and Myers, 2001). In addition to the actual construction of the gear, catchability can be influenced by three components (Edwards, 1968):

- availability to the gear (vertical distribution of the species);
- vulnerability (herding effects, net avoidance, escapement and mesh selectivity); and,
- spatial / seasonal factors (the spatial distribution of the fish in the trawlable and untrawlable regions).

DPI (2008) have assumed parameter estimates of net efficiency, selectivity, escapement and herding to estimate the catchability of the gear for a specific species, presumably in an endeavour to calculate absolute biomass through a trawl swept area method. Such an endeavour is plagued by large uncertainties and assumptions that are often un-testable without significant investment into difficult and expensive trawl research work (eg. Ramm and Xiao 1995). Because of this, one should be extremely cautious about any absolute biomass estimates that are derived from the trawl surveys. To date, however, there appears to have been little or no use of the trawl data as an absolute biomass estimate; the results have generally been used to investigate change in species abundance (Parry *et al.* 2003, Emphron 2008). If this is the case, use of the data as a relative index of abundance is more appropriate and removes the need to derive net efficiency parameters and make uncertain and large assumptions about catchability.

Recommendation 5: The trawl survey data should only be used as a relative index of abundance.

If, on the other hand, absolute biomass estimates are required, there needs to be much greater examination of the assumptions made in DPI (2008) that there is “efficiency of 100% in the path of the net, and 80% between the doors and wings of the net”, and would require more data to be collected during the survey or extra experimental work. Some estimate of escapement and herding has been used in this assumption, but little attention has been given to avoidance by fish due, for example, to them seeing the approaching net (the survey is conducted during the day in shallow and relatively clear water) or hearing the noise of the vessel before the doors begin herding the fish. In response to vessel noise, shallow water demersal fish near the bottom may swim out of the path of the towing vessel (Godø, 1994), demersal fish in the pelagic zone usually swim towards the bottom (Ona, 1988; Ona and Godø, 1990) and pelagic fish often swim perpendicular to the vessel's track (Ona and Torensen, 1988). These effects can increase as depth decreases. Vertical herding (Hjellvik *et al.* 2003) may also be an issue, particularly in relatively shallow trawls. Escapement through the mesh of the trawl should also be considered and varies depending on the size and species of fish (eg. Dremière *et al.* 1999). As with herding, experimental determination of these catchability effects is very difficult and expensive, and can be largely avoided if data is only used as a relative index of abundance.

Recommendation 6: Only if there is sufficient justification for the survey index to be used as an absolute index of abundance, a cost/benefit analysis should be undertaken with explicit quantification of assumptions and uncertainties.

Parry *et al.* (2003) and DPI (2008) assume trawl net dimensions of 47m long, 13 m wing spread, 5 m opening height and 45 m between trawl doors. In reality, it is probably only the first of these measurements that remains static – the other dimensions can vary during each shot. The door spread, wing spread and overall shape of the net opening at the "mouth" of the trawl (and therefore its efficiency) can vary considerably from shot to shot depending on the depth of water, amount of warp released, trawl speed and the angle of attack of the trawl doors. We found no reference to the type of trawl doors used or how they were rigged – this is also critical to maintaining consistent trawl gear characteristics during the survey[1]. Parry *et al.* (2003) also allude to having a Netsonde available, yet details of the door spread, wing spread and headrope height is not recorded for each shot. Measurement of wing spread, door spread and net height are required for accurate swept area calculations even for use as a relative index of abundance. Although the dimensions for these are given, they do not appear to have been measured during trawling. Even without a Netsonde, there are methods of estimating door spread during each shot.

Recommendation 7: Record measurements wing spread, door spread and net height during each shot.

[1] The authors acknowledge that this information is likely to be available, but it should be included in descriptions of the survey gear in at least one of the survey reports – we were unable to find this reference.

Recommendation 8: Details of the entire trawl gear design, construction and deployment information should be published with the survey reports.

The comment that when a Netsonde was used, it "indicated that the net was probably fishing for an additional 2 minutes during its retrieval" is of concern. With much longer trawl durations this would probably only add to the "noise" of the data, but with trawl durations of only five minutes, this is a significant extra fishing period (about 40% more) that presumably would not be consistent with depth. In addition, the extra fishing time during retrieval would have different implications for pelagic and demersal species, because the footrope may leave the seabed during this time.

The strength and direction of the current in Port Phillip Bay relative to the direction of the tow may have an effect on catch rates by altering actual swept volume, changing gear performance and fish escapement. Generally, this effect is expected to be low in Port Philip Bay due to the low tidal currents, but in regions of higher tidal currents (eg. off St Leonards) it may be important to consider. If the survey tows are consistently undertaken from inshore to offshore at each site, they are likely to be perpendicular to the tidal currents which will reduce this effect. The authors were unable to determine specific procedures regarding tow direction from the information provided. We have since been informed, however, that the standard operation procedure is to tow directly into the current. As such, the direction and strength of the current should be recorded, as it could have a direct (albeit small), influence on the swept area calculations, especially for benthic species (as distinct from pelagic). Also, the direction and strength of the current at a particular location may vary from year to year. Presently, the direction of the tow was often recorded in the data, but the direction or strength of the current was not.

Recommendation 9: If tidal currents are expected to be an issue, the water current direction and strength should be recorded for each shot.

Recommendation 10: A standard trawl direction relative to the current should be undertaken and clearly stated in the standard operation procedures, otherwise the direction of the trawl relative to the current should be recorded.

Another small point is that a total of five different nets have been used since 1990. Since the use of the fishing vessel Castella Rosa — which has two net drums — two different nets could be deployed enabling comparison to be made between nets. This appears to have been done well and comparisons of the efficiency of each net allowed for adjustments to catches to be made (DPI 2008). One suggestion is that any new survey nets should be fished for a week or so prior to use in the survey. This allows the net to stretch and "settle in" so it will be more likely to have the same efficiency as nets previously used in the survey without compromising valuable survey shots in the process.

Recommendation 11: New nets should be fished for a week or so prior to being used in the survey.

Overall, it is almost impossible to estimate all of the factors mentioned above and it is unlikely that the necessary experimental work will be conducted for the PPB annual trawl surveys. For this reason, it is more common to base estimates of catchability on stock assessment calculations in which the survey *q* is a composite effect involving all these factors (eg. Harley *et al.* 2001). This is now a standard approach to obtain catchability estimates in modern fisheries management and it makes use of all available data in a single quantitative stock assessment model for the resource. In these models there is a separate value of *q* for the CPUE data and for the survey data. These values are not inputted, rather, they are estimated or calculated analytically within the model (as part of a range of parameters to estimate) such that the overall fit of the model to the data is optimized. To date, there has not been any formal quantitative stock assessments performed for any of the major species sampled in the PPB trawl surveys. The reasons for this are varied and species specific, but given that many of the species have a significant recreational catch (from which catch and effort data are typically hard to obtain), enhances the value of an independent abundance index. The issue of the lack of use of the trawl survey data in formal stock assessments and harvest strategies is discussed later

3.1.2.b. Trawl duration

As eluded to above, the choice of a five minute trawl duration for each survey shot has a number of implications for the use of the data as an index of abundance and for a method of collecting length-frequency data. Understandably, a short shot duration will maximise the number of shots undertaken in a day, thereby minimising the total time and costs of the survey. Short shots also limit the volume of catch taken and therefore the amount of time required to sort, collect and record the data. These reasons for such a short shot duration should be explicitly evaluated against the four potential drawbacks outlined below.

First, the time taken for the gear to set correctly after the drum brakes have been applied and the time for which the net may still fish when the winches have begun retrieving the net (Parry *et al.* 2003) becomes relatively large compared to the actual fishing time. This may cause a greater degree of uncertainty or noise about the catch rate and the derived abundance index that is obtained from a five minute tow. This may not be a problem if this noise is random, but this issue is highly likely to be correlated with depth in which case a basic assumption of the survey has been compromised.

Second, the period of time that fish are capable of swimming in the trawl mouth and hence their vulnerability to capture is dependent on their swimming endurance (Winger *et al.* 2000). Different species have different swimming endurance and swimming strategies adopted by demersal and pelagic fish are often quite different (eg. Main and Sangster, 1981a, 1981b; Piasente *et al.* 2005). Further, their endurance may be effected by towing speed of the trawl and fish length (Main and Sangster 1981b, Wardle 1993), and individual behaviour (eg. Breen *et al.* 2004). Sea temperature is also expected to influence swimming endurance (Claireaux *et al.* 2006; Winger *et al.* 2000). A trawl net captures fish when they tire of swimming in front of the net / sweeps and fall back into the codend, and swimming times before capture may range from a one to six minutes (Main and Sangster, 1981a, 1981b). The very short shot duration used in the PPB surveys (combined with the relatively slow trawl speed of 2.1 – 2.5 knots) means the trawls are less likely to capture fish with good swimming capacity due to either the species type or the size of the individual. The latter will cause selectivity bias against large / old animals by an unknown amount per species and may well apply to a strong swimming species such as snapper. The five-minute shot duration is certainly at the lower end of time it would take for strong swimming fish to tire and be captured in the net.

Third, any fine-scale patchiness of fish / invertebrates distribution at the trawl site may have greater negative impact on the precision of estimates of abundance than would result from a longer trawl duration.

Finally, the data show that the numbers caught per shot for some key species can also be quite low. The statistical power of the survey may be improved through having one longer tow at each site rather than two shorter tows.

Given the above, it would be useful to undertake experiments of the impact (and cost-benefit) of different tow durations on data precision. Of course, if a bias is consistent from one year to the next then the relative index would not be compromised. However, this may not be the case if the size/age structure of different species is changing over time or with different shot depth, as is likely to be the case.

The possibility of changing to a single, but longer tow per site should be investigated. If this was done, there would need to be an interim period when instead of two shot shots being undertaken at a site, one short and one longer tow could be conducted, to allow for comparison between the time series.

Recommendation 12: An analysis of the impact (and cost-benefit) of different tow duration should be undertaken. This should include tests of whether one longer, single tow is an improvement relative to two, short tows. The impact on the statistical model to develop a relative index of abundance should be included in this analysis.

3.1.2.c. Recruitment

To assist in interpreting changes in fish biomass in Port Phillip Bay, DPI (2008) investigated the influence of interannual differences in recruitment patterns on long term changes in fish biomass in the 20 most common species. Recruitment cohorts were identified using the size frequency distributions (DPI 2008, Appendix 5)[2]. Recruitment strength was estimated from length frequencies distribution and trawl catches for seven species known to spawn in Port Phillip Bay. Individuals in the 0+, 1+ (and 2+ for snapper) cohorts in each year were estimated based on their length. These lengths were obtained from published information for two species but otherwise, the size distribution of the smallest size class, was assumed to be the 0+ cohort. To determine whether there was any temporal pattern to the strength of recruitment cohorts of different species that may reflect either an interaction between species or an environmental variable that affects different species similarly, the abundance of cohorts of different species in the same years were correlated.

An issue with this approach is that without any actual ageing data, the authors have assumed that the smallest apparent cohort in the length frequency distribution of each of these species is the 0+ cohort. This may be problematic if some species do not move onto the areas sampled until they are in the 1+ cohort. Being the smallest cohort in the length-frequency distribution they would be labelled 0+ and recruitment strength would then be compared with recruitment of other species or environmental variables from the wrong year. Also, there may be a problem if, as a result of the short tows or the selectivity of the net, the amount of small fish caught is so low that a few animals can completely compromise the index. Another potential issue with this method is that calamari only live for about 1 year, so all animals in

[2] These graphs were not available to the reviewers.

the population are in the 0+ cohort, yet only animals with a mantle length <13cm were included in these analyses. The high interannual variability in spawning times and growth rates of cephalopods present further problems.

There are other current FV research programs that provide recruitment indices and collect otoliths and length frequency samples for some of the species sampled in the PPB trawl surveys (Jenkins pers. comm). Depending on the methods used to sample each species, these programs may provide better, worse, or simply duplicate data collected during the trawl surveys. In this respect, it is difficult to review just the adequacy of the trawl survey alone to collect these data against the FV objectives. It would be more appropriate to review the objectives and sampling programs of the entire suite of Bay and Inlet programs to determine the most robust and cost-effective sampling protocols for all important species. For example, given the sites sampled, the trawl survey is unlikely to provide good information on King George Whiting recruitment or abundance but based on the number and consistency of capture over the years, the survey would be likely to provide valuable information on the abundance of many common endemic species, including sand flathead, flat oyster, scallop, globefish, sparsely spotted stingaree, snapper, spiny gurnard, southern anchovy (although there is now a separate anchovy trawl program), red mullet, barracouta, southern calamari, eastern shovelnose stingaree, sandy sprat, toothbrush leatherjacket, arrow squid, balmain bug, and yank flathead. It also provides potentially valuable information on the relative abundance of a number of introduced species such as the northern pacific seastar, *Sabella spallanzanii*, *Stichopus mollis* and *Pyura stolonifera*, which are important in understanding the health and ecosystem changes in the Bay.

Recommendation 13: Review the method used to estimate recruitment based solely on trawl survey data.

Recommendation 14: Collect otoliths (or vertebrae) from all commonly caught species to enable at least basic verification of age-length relationships.

Recommendation 15: Review the entire suite of Bay and Inlet monitoring programs against the over-arching FV objectives to determine the most scientifically robust and cost-effective sampling protocols for all important species.

3.1.2.d. Relative index of abundance

Clearly for the CDP, the relative abundance index is valuable (and already uses these data). We foresee, however, that a few aspects will need to be taken into consideration. The impacts of dredging on fish species are more likely to be through indirect impacts (e.g. through the foodweb) than direct mortality. This indirect impact on key fish species is important and should not be ignored, but it often means that the impact is much more dampened and difficult to interpret than for direct impacts (e.g. on sessile benthic species and sediment fauna). It is acknowledged that the criteria are applied to species that feed on benthic animals which partially compensates for the above points. However, this issue would still remain true for these species.

Furthermore, the criteria are set such that they are triggered only after large reductions in biomass (from, in some cases, an already low base) (CSIRO and Emphron 2007). Since these are likely to be mostly as a consequence of indirect impacts this may not be seen as adequately precautionary by some sectors.

These relative index data (on their own) would also not be effective in identifying the cause of any major change in relative abundance. This is acknowledged by the CDP framework which adds additional information to the decision framework. The design is not stratified (or post-stratified) by impact, particularly not in terms of dredging. As a result, without further information or a complete stock assessment model (for the potential contribution of the fisheries impact), it would not be easy to identify the source of any decline. See *Spatial analysis* section for further comment.

Recommendation 16: If it is at all possible to (post) stratify the data with respect to dredging impacts this would be most useful for analysis of the effects of dredging.

3.1.2.e. EBFM approach

As a sampling method, trawling is relatively unselective compared to other fishing methods. Whilst a demersal trawl may not, therefore, be the most efficient method to target particular teleost, chondrichthyan or invertebrate species, its “generalist” selectivity ensures it captures a wide range of (mostly) fish species, including many species that would not be easily or cheaply captured by other methods. Importantly, the method does appear to consistently capture some benthic and pelagic invertebrate species in high numbers (eg. *Sabella spalanzanii*, Northern Pacific seastar, blue jellyfish, eleven-armed seastar, *Stichopus mollis*, *Pyura stolonifera*, knobby seasquirt, flat oyster, Balmain bugs, scallops and arrow squid) a number of which are exotic species. This suggests that trawl survey methods may be an adequate method of sampling these species. In the absence of any other long-term monitoring program, the annual trawl survey data probably provides the most valuable abundance index for these species. This may be an advantage when considering ecosystem-based fisheries management (EBFM) or the overall health of the ecosystem in PPB, rather than just the abundance of a few key commercial fish species. On this point, the recent change in the FV objective for the annual survey from "To monitor trends in the abundance and size of ***fish and invertebrates***…" to "To monitor trends in the abundance and size of ***important fish species***…" may be considered inconsistent/myopic given the general direction of moving towards "a broader ecosystem-based fisheries management approach" as stated in the consultancy scoping document.

Recommendation 17: Conduct a quantitative analysis of the capacity of the trawl surveys to adequately monitor the relative abundance of selected important invertebrate species in PPB.

3.1.3. Identify options for enhancing the utility of the data

3.1.3.a. Spatial analyses

The value of spatial information for stock assessment and ecosystem purposes can not be overstated. Spatial management is a legitimate method of reducing fisheries impacts or increasing conservation value. Examples of including spatial information in stock assessments are numerous, but of particular note is that of Booth (2000). A good reference for the use of spatial data in ecosystem models is Walter and Martell (2004).

If variables such as depth and sediment type are added to the data set, then the spatial distribution maps that can be produced would be further enhanced, for example, to investigate spatial impacts of a fishery or environmental variable on migration patterns. In the Gulf of Carpentaria for example, survey, rainfall, water depth and season data \ variables were used to identify spatio-temporal migration patterns of banana prawns (Toscas *et al*. in press). This work was also turned into a time-series movie which was a good communication device to inform stakeholders of temporal and spatial changes in the data. Further examples of using survey data combined with abiotic factors to create spatial distribution maps for stock assessment, impact and conservation management purposes include Pitcher *et al*. (2007a) for the Great Barrier Reef and Pitcher *et al*. (2007b) for Torres Strait. The latter work was subsequently used to evaluate strategies for managing the effects of prawn trawling on benthic biota in Torres Strait (Pantus *et al.* 2007).

However, even without additional information and much further work, the model developed by Dr Thomas (Appendix 1) could be used to look at the spatial distribution of the key fish species.

Recommendation 18: That the model of Dr Thomas be further developed to create spatial distribution maps. Consideration should be made to also add other relevant covariates such as depth.

3.1.3.b. Stock assessment

The value of having such a long time-series of fisheries-independent data on the relative abundance of a large number of important PPB fish species can in no way be understated from a stock assessment and fisheries management point of view. This is especially the case when a large proportion of the catch is taken by recreational fishers – one of the most difficult and expensive sectors from which to obtain reliable catch and effort data. As outlined previously, however, because of the sampling method or the positioning of the sites, the trawl program may not provide suitable information on some important species such as King George whiting or anchovies for example, in which case alternative sampling programs should (and have) been initiated.

Stock assessment models depend on some form of index of abundance (Hilborn and Walters 1992). The most common index of abundance is catch rate – a fishery dependent source of abundance. Since fisheries data is inherently unbalanced and therefore does not sample the whole population randomly or in some designed manner (as is usually the case in a well designed survey), much analysis needs to be undertaken to standardise the data given changes in the fishery. See Bishop (2006) for a discussion of the difficulties with catch rate data. It is now considered best practice in fisheries management worldwide to undertake fishery independent survey of fished stocks. Furthermore, the CSIRO and Emphron (2008) reports and the work of Dr Thomas (Appendix 1) shows that the current PPB annual survey produces reliable indices of abundance for several key species.

Consistent and ongoing collection of fish length-frequency data is also particularly valuable for fisheries stock assessment purposes. It means that different classes of assessment models such as size and/or age based models could be developed. The index of biomass could also be modified to an index of newly-recruited fish into the fishery. However, as mentioned previously, there is some concern about bias in the data away from larger fish given the short duration (5 min) of survey shots. Punt (2003) evaluates the ability of a size-structured stock assessment models to estimate quantities of interest to management. This paper identifies the benefits of this class of model but also the pitfalls. Size-based models tend to have many more estimated parameters than most other classes of stock assessment models. As a result, additional data would probably be required to develop a size-based stock assessment model. For example, a key component to a size-based model is a growth size transition matrix. Usually this is obtained from tagging data (Punt *et al*. 1997) which may also be useful to show migration patterns of the key species.

In the case of recreational fisheries, total catch is often not known. Many agencies endeavour to collect this information. In cases where this is not possible, or credible range of values can not be tested, one can still undertake quantitative analyses that are based on the survey index. Indeed the word stock assessment does not exclude simple measures such as directly using the abundance index.[3] In the case of simple harvest strategies, it is often important to become more precautionary in one's management strategy as the method becomes more uncertain. A good example, is the tier system used within the Commonwealth managed south-east fishery.

If, for some species that are surveyed, the total catch is known but the effort is not accurate or known, then a formal model for of a stock assessment is still possible given that the survey provides an relative index of abundance.

It is interesting that the trawl survey data have not already been fully utilised for fishery management purposes through a formal quantitative stock assessments, particularly given the results presented within the Emphron reports (especially if one considers that the plots showing declines are in the logarithmic scale, therefore under-emphasising the amount of change). Instead, FV "stock assessments" on important teleost species (as distinct from the high quality quantitative assessments of rocklobster and abalone), tend to be informal qualitative reviews of the data by stakeholders. Some justification put forward for this has been then they are recreational species and catch and effort data is poorly known. This being the case, the trawl survey data becomes even more important as an index of abundance for the stock assessment process. In addition, there is no formal harvest strategy for any of the species and no target and limit reference points against which the success (or otherwise) of the fisheries management can be assessed. This is well below established best practice for fisheries management.

Even so, the process of undertaking a quantitative stock assessment is very useful to formalise the need, importance and quality of the various data inputs. We have little doubt that the long time series of fishery-independent trawl survey data would be a critically valuable in this respect. As such, we would suggest that the current assessment process has failed to use the trawl data to its full potential.

[3] In this context, note the discussion of an MSE below, since often one may test simple strategies compared to full stock assessments in assessable species in any case. This method can overtly test the cost and benefit trade-offs inherent in fisheries management.

Recommendation 19: Given the major declines in relative abundance of key teleost species in PPB, it is important to investigate the benefits of developing a quantitative stock assessment model or a harvest strategy based on the survey index to understand the status of the specific stocks and review the veracity of the various data inputs.

Developing a stock assessment model is usually only seen as a first step towards world best fisheries management practice. Fisheries management is most successful in the context of clearly defined harvest strategies (for example, the Australian Commonwealth Policy - Anon, 2007a). A harvest strategy is a fully specified set of rules for determining tactical management regulations, and generally includes specifications for a monitoring system, an assessment procedure, and a decision rule. The management strategy evaluation (MSE) approach allows the trade-offs among the (pre-agreed and pre-specified) management objectives achieved by different management strategies to be evaluated. It takes into account the various sources of uncertainty (e.g. uncertainty in the assessment, implementation error, etc.), and also aims to identify harvest strategies that are robust to uncertainty and achieve desired tradeoffs among the management objectives. MSE has been applied to several single and multispecies fisheries (Punt, 1992; De la Mare, 1996; Butterworth *et al.* 1997; Punt and Smith, 1999; Smith *et al.* 1999; Punt *et al*. 2002; Dichmont *et al*. 2006) and to ecosystems (Sainsbury *et al*. 2000; Fulton *et al*. 2007). The benefit of developing an MSE model for Port Philip Bay is that: a) the operating model could be simply a more detailed stock assessment model, but could extend to using the existing bio-geochemical ecosystem model of the Bay; and, b) an analysis can be made of the benefits of developing a stock assessment model or simply developing harvest strategies from the survey results alone.

Recommendation 20: Investigate the value of developing an MSE for Port Philip Bay (for fisheries or multiple use management). Given the results of the abundance index, we recommend an MSE for fisheries management purposes as a priority.

3.1.3.c. Ecosystem uses

Ecosystem models also would rely very heavily on indices of biomass (both temporally and spatially) and again the PPB trawl data would be very useful in this respect. Most commonly used ecosystem models for fisheries management in Australia are *EcoPath* (Christensen 2000) and *Atlantis* (Fulton 2001). A good overview of ecosystem models as applied to fisheries management (including those mentioned) are given in Plagányi (2007) who give a short description of model parameters, assumptions and data requirements. Also provided are the advantages, disadvantages and limitations of each of the approaches in addressing questions pertaining to EBFM.

Ecosystem models have been developed for Port Phillip Bay – using EcoPath/EcoSim (Fulton and Smith 2002) and Integrated Generic Bay Ecosystem Model (Fulton *et al*. 2004). These models have also been further developed since these publications. A comparison of the usefulness of these different models has also been undertaken (Fulton and Smith 2004). For all these models, the trawl survey data would be a major input both as an index of abundance of several of the species but also for the diet matrix. It is unclear why these data were not made available for this work.

Recommendation 21: The PPB annual trawl data should be made more easily and widely available so that ecosystem model developers are able to include this source of information.

3.1.3.d. Before–After Control-Impact (BACI) experiments?

In the context of the points made in 3.1.2.a "Relative vs absolute index of abundance", some further work should be considered regarding: a) relating the survey better to dredging effects; and, b) undertaking additional sampling on the more direct effects of dredging. Some of the potential effects of dredging on the marine environment include the direct effects of the dredging process (i.e. the removal of substratum from the seafloor) and the process of disposal (Erftemeijer and Robin Lewis III, 2006). Furthermore, dredged material may come into suspension during dredging itself as a result of disturbance of the substratum, but also, amongst others, during disposal of the dredged material (Jensen and Mogensen, 2000). In some cases, adverse impacts of dredging activities are limited to a relatively small area and of relatively short duration (Erftemeijer and Robin Lewis III, 2006), whereas, large scale dredging operations that occur over a long period or a large area can have major adverse environmental impacts (Lewis, 1976). Studies modelling the movement of the suspended fine sediments have been undertaken in other parts of Australia (e.g. Bode *et al.* 1993) and impact of, for example, prawn trawling on the seabed (Pitcher *et al*. 2007) and similar work has been done for Port Philip Bay during the CDP Environmental Effects Study.

The Emphron report stated that they do not recommend an (M)BACI experiment to directly test for benthic impacts. The reason for this is that the author was of the view that it may not be possible to clearly define (comparative) impacted and non-impacted sites. If this assumption is correct, we fully support this recommendation.

However, if it is possible to define impacted and unimpacted sites, it would be worth undertaking a cost-benefit analysis of whether it is a) possible to post-stratify the survey by impact and then investigate the survey power and decision systems associated with this new index, and, b) the potential value of a BACI experiment of benthic species. This would provide more direct dredging impact information on seabed species and also attempt to increase the value of the trawl survey data for the CDP.

Recommendation 22: Examine the potential to identify impacted and unimpacted sites in the current survey design and post-stratify the survey to enable BACI experiments of benthic species to better achieve CDP objectives.

3.2. Determine options for future directions

This review would have benefited from a more encompassing consideration of all of the sub-programs under the Bay and Inlet Fishery Program and the data sets being collected – not just those of the annual trawl survey in Port Philip Bay. Review of the other sub-programs was outside the scope of the current work. The potential overlap with data collected in other Bay and Inlet Subprograms and options to improve the effectiveness and cost-efficiency of the trawl survey as one of a suite of monitoring projects could not be commented on by the reviewers. It would be better if all of the sub-programs related to this Program were reviewed simultaneously, so that an analysis could be undertaken on how sub-programs inter-relate, and recommendations could be made on modifications, improvements and efficiencies in line with the FV objectives.

As mentioned before, environmental data is extremely useful in both temporal and spatial analysis of survey data. There are a large number of environmental data sets available for Port Phillip Bay covering its chemistry, hydrology and ecology. Among others, the following datasets are available for Port Phillip Bay (from Fulton *et al.* 2003):

- Dissolved inorganic nitrogen (DIN), chlorophyll a (chl a) and primary production;
- Zooplankton biomass, production and consumption;
- Biomass of benthos and meiobenthos, and total benthic production and consumption;
- Macrophyte biomass and primary production;
- Total detritus;
- Biomass and primary production of microphytobenthos.

Others could include, seasonal changes in timing of water temperature and salinity to help interpret catches. Bottom/sediment type data could be used to explain spatial distributions. Association between fish communities and benthic infauna and sediment types are discussed in Parry *et al.* 2003 and there are various reports on the diets of fish in PPB (Andrews 1988; Chan 2002; Officer and Parry 1995, 1996; Parry *et al.* 1995). The sediment classifications used are broad scale and more than 40 years old, however, and there may be benefits in re-sampling and analysing the sediment and benthic fauna at each of the 22 trawl survey sites.

Given the changes in climate expected in the longer term, the value of the annual trawl data in terms of climate changes should be investigated. The Port Phillip Bay trawl survey represents one of the longest continuous data sets for PPB biota and long-term data sets are also available for temperature and salinity in the Bay. Analysing the Port Philip Bay trawl data with respect to environmental factors such as temperature and salinity is beyond the scope of this review, however, this analysis would be valuable for climate change studies

Under an EBFM approach, it is unlikely that monitoring of only the "important" fish species[4] will give the best understanding of potential ecosystem-related changes in abundance. Significant changes to the ecosystem and benthic community structure in PPB have related to significant increases in relative abundance of introduced invertebrate species such as northern seastar *Asterias amurensis*, Sabellid worms *Sabella spallanzanii* and *Myxicola infundibulum*, bivalves *Theora lubrica (*cf *T. fragilis)* and *Corbula gibba*, an introduced solitary ascidian, *Styela clava* and the Majid crab *Pyromaia tuberculata*. Some of these species have either become important dietary components of many local fish species (Parry *et al.* 1995), or are unpalatable to fish (Officer and Parry 1997), or have significantly changed the benthic community structure and nutrient cycling of PPB (eg. Longmore *et al.* 1996), and therefore may have direct relevance to fish stock abundance in the Bay. Furthermore, one of the most significant fisheries (and benthic impacts) operating in PPB related to the scallop (*Pecten fumatus* – a non-fish species) and the introduction in 1963 and subsequent banning of scallop dredging in the Bay during 1996. Annual monitoring of scallop abundance in PPB through diver transects (eg. Coleman 1990, 1994) no longer occurs and without any further scallop dredging, the annual trawl program remains a potentially valuable tool (although not optimal) to monitor the location and abundance of what was historically one of the most valuable fishery resources in the bay (Coleman *et al.* 1997) and one which still supports a valued recreational fishery.

[4] It is worth noting that what constituted an "important" fish species was not defined in the background papers for this review and whether it related to commercial/recreational importance or ecosystem importance was not clear, although one would hope it was the latter under an EBFM approach.

Given the above, and that PPB is one of the most invaded marine ecosystems in the Southern Hemisphere (Hewitt *et al.* 2004); rather than reducing the scope of the annual trawl survey to focus just on important fish species, it would be appropriate to consider broadening the sampling tools used during the survey to include, say, Smith-McIntyre grabs or towed/baited underwater cameras that may help elucidate causes/associations of future changes in fish abundance. Importantly, the largest cost of a trawl survey program is usually the hire/operation of the survey vessel and any cost-efficiencies / leverage that can be achieved by better using this research sampling platform as effectively and efficiently as possible should be explored. Generally, the additional costs of deploying another sampling tool or collecting information on all species captured in a trawl rather than on just important fish species is negligible in comparison.

Recommendation 23: A broad analysis of the potential causes of the changes in abundance should be made which includes the environmental data. This study should be tied in with developing an MSE and also investigating climate impact options.

Recommendation 24: Rather than reducing the scope of the annual trawl survey objectives to focus just on important fish species, it would be appropriate to consider broadening the sampling tools used during the survey to monitor the abundance of a greater range of benthic species, which may help elucidate causes/associations of future changes in fish abundance and ecosystem health.

3.2.1. Oportunities to leverage CDBMP and FV funds

The reasonably low level of use of these data is of concern, especially given the strong signals of previous decline of some of the important fish species and evidence of increases in a number of exotic species in PPB. Given the wide range of uses and importance of PPB to the surrounding urban population, it is surprising that these changes have not prompted a call for a greater level of investigation and formal assessment of the causes, implications and potential amelioration. Possible reasons for this are that these data are not publically available, the results have not been published annually and there is no formal mechanism to incorporate/assess the results on a regular (annual) basis. If these issues could be addressed, there would likely be greater use of the data and more appreciation of the true value of this data as a time-series of abundance indices on PPB fish stocks and ecosystem health. It is also possible that negative publicity, potentially associated with some of the results, has had unpalatable political implications. If this is the case, it is even more necessary to develop a formal mechanism of assessment and evaluation.

The opportunity provided to FV by the CDP is that funding is now available, not only to conduct the trawl surveys over a number of years, but also to develop a formal system of annual reporting and evaluation of the results of annual trawl surveys. With limited extra costs, the assessment requirement of the CDP could be augmented with formal stock assessment of the important PPB fish species and the development of harvest strategies. In addition, given the targeted work that is being done to meet CDP requirements, FV (and the broader DPI) has a unique opportunity to value-add all of the current PPB research and monitoring projects and the data that is derived from them in an effort to achieve EBFM of the marine fishery resources of PPB and a more rigorous reporting system of the ecosystem health of the Bay. An example of such a system is the "Report Card" published as part of the Ecosystem Health Monitoring Program for Moreton Bay (See Appendix 2).

Recommendation 25: That the annual PPB trawl data (in a summarised) form be made more widely available to all stakeholders on an annual bases – in annual written reports and on a web site or something similar.

Recommendation 26: Development of a formal reporting system similar to the Report Card used in the Ecosystem Health Monitoring Program for Moreton Bay. This report card should include the trawl survey data.

4. Conclusions

The trawl survey data is a valuable time series of information on the relative abundance of numerous teleost, chondrichthyan and invertebrate species in Port Philip Bay – both endemic and introduced. The design of the monitoring program and quality and consistency of the data appears statistically robust enough to support analysis of annual changes in abundance of a number of commonly caught species or species groups. There are, however, a number of improvements that could be made to both the survey design and the data collected, which would enhance its value to both FV and/or CDP objectives. It is essential, however, that if any changes are made to the design of the survey, the impact of these changes on the data series are known and can be accommodated in the analyses so as to preserve the integrity of the data series. Notwithstanding the need for improvements, the annual frequency of the trawl survey appears appropriate to the objectives of both FV and the CDP.

Broadening of the scope of data collected during the trawl surveys and incorporation of additional data would add value to both agencies. The recent narrowing of the FV objectives for the survey to just monitoring trends in abundance of important fish species appears to be a retrograde step that undermines the potential value of the survey data to move towards the FV goal of ecosystem-based fishery management. For the CDP objectives, the value of the survey would be greatly improved if it is possible to post-stratify impacted and un-impacted sites for use in BACI analyses.

To date, the potential value of the trawl survey data to FV has not been fully realised. This appears to be due to a number of reasons, but primarily, we believe it is because there has been no formal quantitative stock assessment process or development of stock reference points and/or harvest strategies for any of the major species in Port Philip Bay. This is well below established best practice for fisheries management. As such, significant declines in the relative abundance of important fish species have occurred with no structured management response. Similarly, the increase in abundance of a number of exotic invertebrate species in the Bay has been demonstrated through the survey results without a formal management framework to guide a response.

Not unrelated to the above is the fact that there has been no annual reporting of the results of the survey and that the data/results have been virtually unavailable for use outside the trawl survey program. This appears partly to be due to funding issues, but also could be attributed to a belief that because the data can show long term changes in abundance, short-term (annual) reporting is of limited value. In fact, the data reveal that there can be very rapid changes in abundance of some species as well as long term trends, and lack of annual reporting has prevented (or at least not promoted) a timely management response. It is also possible that the political implications and potential negative publicity associated with the release of some of the trawl survey results may have influenced how the trawl survey was valued.

Regardless of the past value and use (or otherwise) of the annual trawl survey data, it has an increasing value in the future with each additional year of data. The guaranteed funding and improved reporting framework that has been enabled through the CDP process over the next few years should be value-added by FV to ensure that a more rigorous and structured assessment and management process is applied in a move towards its EBFM objectives - not just for Port Philip Bay, but for the entire Bay and Inlet Program.

5. Recommendations

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8. Figures

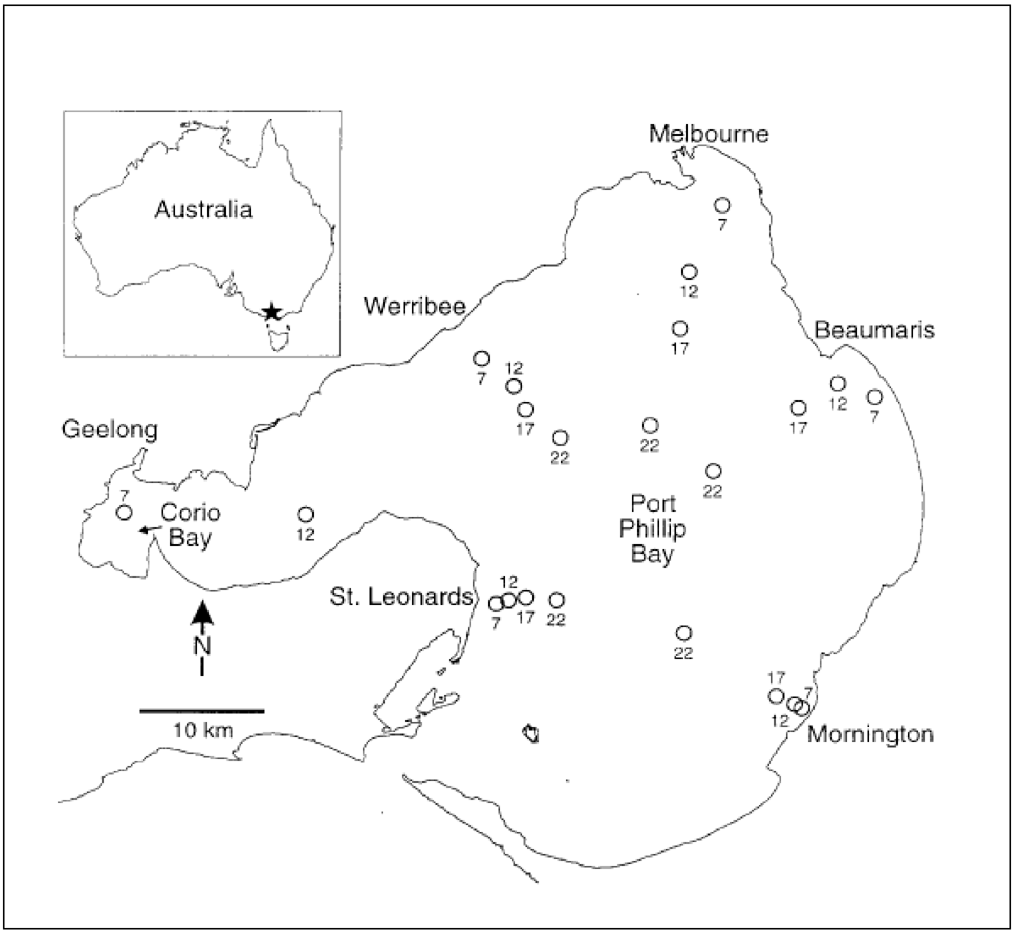

Figure 1. Sites sampled during the Port Phillip Bay Trawl survey.

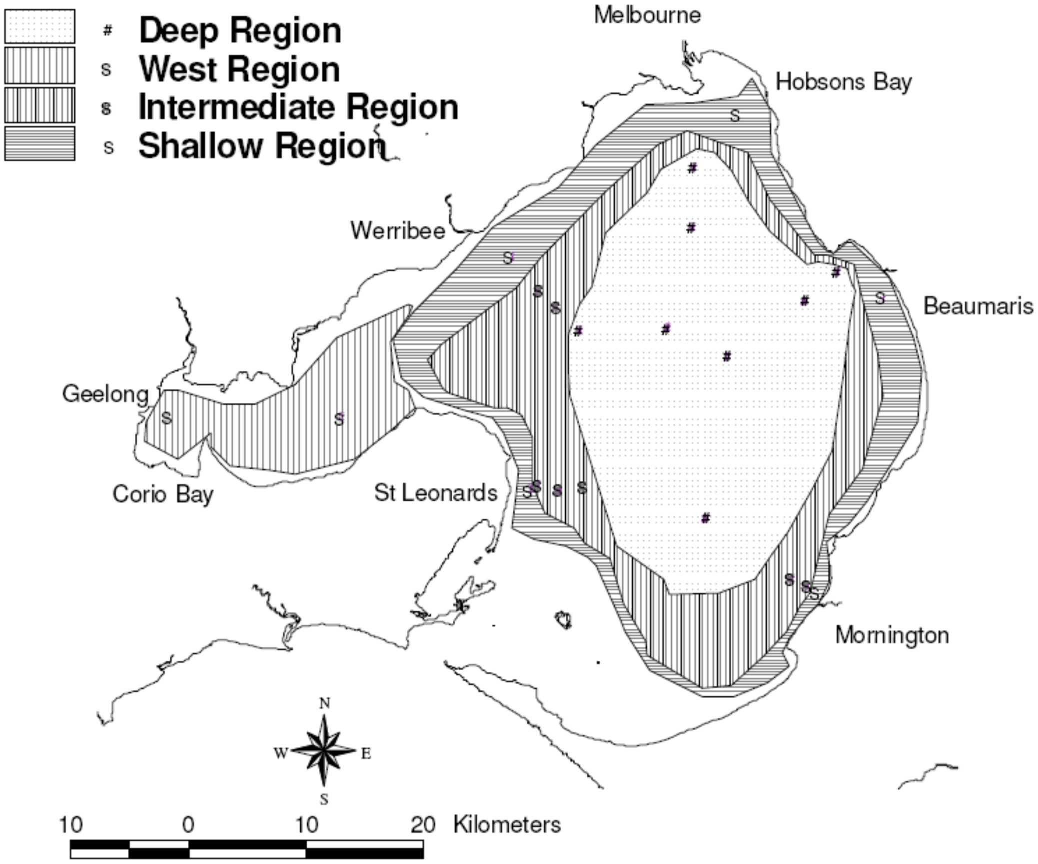

Figure 2. The four designated regions of PPB: 'shallow', 'intermediate', 'deep' and 'west', as determined by Parry *et al*. (2003).

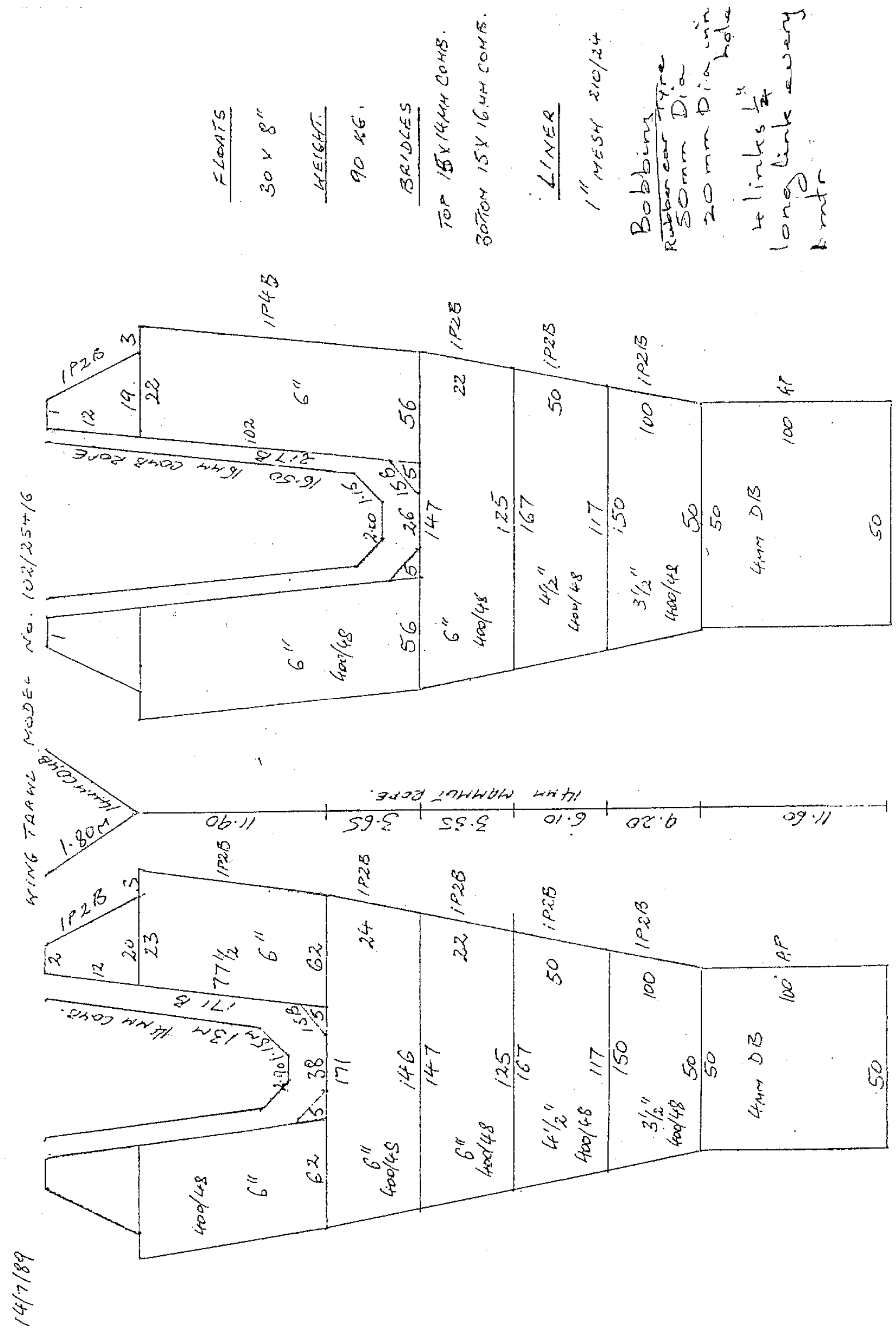

Figure 3. Design of the PPB Trawl survey net.

9. Appendix 1

9.1. Recalculated variance components and power calculations of the trawl data for the CDP

Variance Component Estimates for log CPUE based on Biomass Tabulated by Species and Location

		Cov Parm		
		Residual	scode	year(scode)
Species	Location	Estimate	Estimate	Estimate
Eastern shovelnose stingaree	ashallow	0.439219	0.168351	0.147722
	inter	0.442663	0.153910	0.190218
	sdeep	0.450451	0.140486	0.112323
	west	0.424063	0.155045	0.091897
Globefish	ashallow	0.307980	0.353548	0.236641
	inter	0.399365	0.002472	0.288503
	sdeep	0.170452	0.139235	0.211796
	west	0.464749	0.000000	0.000000
Sand flathead	ashallow	0.171831	0.214788	0.239969
	inter	0.111634	0.180336	0.273288
	sdeep	0.088463	0.018696	0.121082
	west	0.105719	0.166589	0.201585
Sparsely spotted stingaree	ashallow	0.171610	0.095525	0.296194
	inter	0.209739	0.093425	0.260948
	sdeep	0.138025	0.011410	0.286163
	west	0.402681	0.154658	0.151420
Spiny gurnard	ashallow	0.009867	0.004789	0.007730
	inter	0.039816	0.010160	0.041080
	sdeep	0.021316	0.007285	0.025347
	west	0.007141	0.004741	0.015564

Variance Component Estimates for log CPUE based on Numbers Tabulated by Species and Location

		Cov Parm		
		Residual	scode	year(scode)
Species	Location	Estimate	Estimate	Estimate
Eastern shovelnose stingaree	ashallow	0.418257	0.184046	0.218686
	inter	0.342090	0.179727	0.349233
	sdeep	0.279575	0.158366	0.062708
	west	0.265908	0.099634	0.136015
Globefish	ashallow	0.385303	0.425511	0.184278
	inter	0.493515	0.015187	0.553911
	sdeep	0.320471	0.361229	0.477295
	west	0.689664	0.009649	0.010683
Sand flathead	ashallow	0.484465	0.704852	0.477815
	inter	0.168572	0.358813	0.389235
	sdeep	0.113482	0.026789	0.137427
	west	0.275564	0.401106	0.326016
Sparsely spotted stingaree	ashallow	0.324501	0.050572	0.285077
	inter	0.332603	0.145900	0.409618
	sdeep	0.226636	0.042977	0.408749
	west	0.493433	0.205163	0.373766
Spiny gurnard	ashallow	0.350141	0.272337	0.314721
	inter	0.314300	0.125627	0.360486
	sdeep	0.213666	0.046109	0.236530
	west	0.435609	0.209974	0.322243

10. APPENDIX 2

10.1. About the Moreton Bay Ecosystem Health Monitoring Program

(EHMP - http://www.ehmp.org/about_ehmp.html)

The EHMP uses rigorous science to measure waterway health using a broad range of biological, physical and chemical indicators of ecosystem health. These indicators were chosen because they provide essential information about the condition of SEQ's waterways. Currently, 135 freshwater sites are monitored twice a year (in spring and autumn), and 254 estuarine and marine sites are monitored on a monthly basis. The results provide an assessment of the responses of aquatic ecosystems to human activities, such as catchment alterations and point source discharges (e.g. wastewater treatment plants (WWTPs)), and also take into account natural processes such as rainfall.

The information collected in the EHMP is used to advise councils and land managers on areas of declining health, report on the effects of different land uses, and evaluate the effectiveness of management actions aimed at improving and protecting aquatic ecosystems. SEQ's local governments have invested significant sums to repair damage to our waterways, including upgrades to WWTPs, stormwater management, and restoration of riparian areas. The EHMP helps evaluate the effectiveness of these and other investments and management strategies, and also helps to identify emerging issues that may require intervention. To achieve this, the program is embedded into the Partnership's adaptive management framework, which links monitoring to management. The regional scale approach and ecosystem-based objectives ensure that effective management strategies are implemented throughout SEQ.

Why do we need an EHMP?

South East Queensland has important aquatic ecosystem assets. The waterways of the region provide a number of important ecosystem values, wildlife habitat, visual and recreational amenities. SEQ's waterways also play a role in providing commercial resources, for example for drinking water, commercial fishing, aquaculture, agriculture and industrial use. Local councils, CEOs, etc. identified that they want to protect these important assets through an integrated regional ecosystem health assessment program to ensure these assets/values are not compromised. They also expressed a need for an evaluation tool of the various on-ground actions implemented. For example, local governments in recent years have invested $300 million on sewage treatment plant upgrades alone, and during 2002/03, $2.5 million has been invested by local governments on the restoration of riparian areas in SEQ. As a response to the above, the EHMP was devised to provide an audit mechanism for the management actions undertaken to protect SEQ's catchments and Moreton Bay.