Assessing the outcomes of Victoria's existing marine protected areas for biodiversity and ecological processes – a critical review of contemporary relevant scientific approaches and literature.

Part 2: Review of existing scientific assessments of ecological outcomes from marine protected areas

Report for the Victorian Environmental Assessment Council

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Executive summary

This critical review has focussed upon the 24 Victorian Marine Protected Areas (MPAs) declared in 2002 with reference to the purposes for which they were established. The review has two parts. This report is the second part of the review. It builds on, and should be read together with, part one.

In the first part (Part 1) of the review (Fairweather 2012), I outlined some of the current ecological thinking about the performance of MPAs with reference to relevant literature concerning a variety of potentially-useful attributes and indicators that could be monitored in Victorian MPAs. The key to negotiating this plethora of options is relating field measures to assessing outcomes, especially regarding the two divergent expectations about the intentions for establishing MPAs. That is, whether an MPA has been established to ensure we have intact biodiversity or for the purpose of fixing some perceived problem has important ramifications for our predictions of performance and also how we could do the monitoring to assess that. Such conceptual and theoretical underpinnings are sometimes obscured by vexing issues of limiting data availability or uncertain likelihood of successful implementation of any monitoring schemes within any managerial framework. The latter concerns are also important to take into account but perhaps secondary to knowing what you are monitoring for in the first place.

In this part (Part 2) of the review, I go on to consider what existing scientific assessments of outcomes from MPAs can tell us about how they perform, emphasising comparable environments and aims so that we can critically evaluate the relevance of the many possible case studies to the Victorian situation. Focussing upon a handful of reviews that have assembled such evidence on a global basis, I have laid out the types, spatial and temporal scales of expected outcomes.

I also draw some overall conclusions relevant to the Victorian setting to assist VEAC with the assessment report for its Marine Investigation. I consider what is really required to report upon the five purposes for which the MPAs were declared (but especially #1 to do with protecting biodiversity and ecological processes), what steps forward are possible from here, and where the greatest bang for the available buck may lie. In particular, I note the progress made by Parks Victoria in assessing MPA performance via the Subtidal Reefs Monitoring Program (SRMP) and suggest ways of extending the lessons from the SRMP to other habitats that occur within the 24 Victorian MPAS and thus are worthy of attention.

Section 1. Background and scope of this project

As defined by the Project Specification (see Appendix 1), the purpose of this project was to provide expert scientific advice to inform the Victorian Environmental Assessment Council (VEAC) in conducting its current Marine Investigation. A more specific purpose is to inform VEAC's examination of the outcomes from Victoria's existing marine protected areas (hereafter MPA) so far and thus its assessment of the performance of the MPAs in meeting the purposes for which the protected areas were established. These existing marine protected areas are the 13 Marine National Parks and 11 Marine Sanctuaries in Victoria that were declared in November 2002 and since have operated as 'no-take' areas (Power and Boxshall 2007) rather than the 6 pre-existing Marine Reserves or Marine and Coastal Parks. The purposes for which the marine national parks and marine sanctuaries were established were provided to me by VEAC and are derived from stated Government intent, establishing legislation, and formal commitments. In summary, they are:

- Protection of biodiversity and ecological processes
- Public enjoyment, appreciation, education and understanding
- Contribution to national system by protecting representative examples of Victoria's marine environments
- Protection of features of geological, geomorphological ecological, scenic, archaeological, historic or other scientific interest
- Scientific study relating to the natural environment.

Within this scope, this report (parts 1 and 2) focuses specifically on that subset of the purposes that relate to biodiversity and ecological processes, except those that relate more to the concepts of comprehensiveness, adequacy and representativeness. Some passing reference is made to the other four purposes to illustrate some desirable linkages across data sets that could result in efficient uses of the data.

Assessing the outcomes of these MPAs necessarily focuses upon the contemporary science of biodiversity and ecological processes as it relates to marine conservation. Many scientific concepts have been invoked in this context in the past but the level of debate has not necessarily involved much critical thought. Suffice to say that not all scientific approaches to these questions are always relevant and, in a relatively specific review such as this, it is appropriate to narrow down the array of possible scientific approaches and literature to those most applicable.

As a case in point, many MPAs around the world have been established with the intention of bolstering fisheries yields, especially in areas that have been previously overfished or poorly managed. Such a reason for establishing MPAs does not apply to the Victorian situation, where their program of establishment and management has always had a focus upon marine conservation. Even in such clear-cut situations, there is often a mis-use of information about fisheries-related effects of MPAs to present a public justification of their existence. Such a mis-use is unfortunate because it creates a false impression amongst the public and may raise expectations about performance that are bound to be dashed. This report acknowledges the body of work relating to potential biological or ecological benefits to marine areas surrounding MPAs (e.g. spillover via movement of adult fishes or export of propagules or genetic material) but will provide no detailed assessment of such effects.

The approach I have taken to this project has been based upon my expert opinion, which is in turn, informed by: extensive experience working (i.e. research, teaching and advice) on marine conservation issues in NSW (1985-1997), Victoria (1997-2001) and South Australia (since 2001); access to a voluminous database of more than 1000 publications on MPAs from around the world that vary in relevance to Victoria; targeted searches of bibliographic databases; numerous discussions with many workers in these fields both in Australia and overseas; and, since 2008, working closely with the state environmental department of South Australia in planning for their marine parks network. In considering case studies that are relevant to the Victorian Marine Investigation, I paid most attention to studies from temperate, first-world countries that, like Australia, practise effective fisheries and environmental management as well as being active in the conservation of marine biodiversity. Most attention was paid to studies that have been published in the international scientific literature, and so have undergone thorough peer-review processes. I also used unpublished documents that were more directly relevant to Victoria but only when no peer-reviewed alternative was available. Extensive use was made of the *Technical Series* of publications by Parks Victoria. In all cases, citations are made here wherever relevant and an extensive list of references appears toward the end of this document, so that readers can make up their own minds about the evidence, if they should so wish.

Section 2. Existing scientific assessments of outcomes from MPAs

The reserve effect as seen in various biological measures

The studies done have typically examined the response of fishes, especially species that are of recreational interest for angling or of commercial interest for harvest, especially those species that can grow to great lengths (e.g. > 40 to 70 cm). Thus fished species of fishes, decapod crustaceans like lobsters or crabs, large molluscs such as abalone, oysters or clams, or other targeted species (e.g. sea cucumbers in the tropics) have the most extensive databases. Non-targeted smaller species are much less-commonly studied despite their obvious potential importance in contributing to overall biodiversity.

Four measures are typically made on those fish (Table 2), *viz*. their:

1. abundance, usually as a density, e.g. the number seen along a transect or in a quadrat area, numbers seen per unit time, or catch per unit effort (CPUE);
2. sizes, usually divided into adult versus juvenile or large versus small size classes, sometimes in terms of their weights but more commonly lengths;
3. biomass, often derived from multiplying the abundance and size estimates together (esp. after converting lengths to weights for that or similar species). Only rarely is biomass directly measured, e.g. from weighing fish catches; and
4. measures of diversity, such as species richness (e.g. number of species seen in an area, which can be derived for the same data as abundance estimates, across multiple species).

Typically species richness has the smallest range of values (e.g. from zero to a few 100s at most) whereas biomass has the biggest range (e.g. from zero to 1000's of kg).

Table 2. Summary of the main findings from Lester *et al*. (2009) based on reserve effects seen in 124 studies of fish from around the world. Numbers shown are the increase in % terms seen inside a no-take marine reserve compared within outside. Thus any number above zero is an increase and numbers below zero are decreases in terms of the effects of protection within the MPA; so the percentage of cases that showed a relative decrease is also highlighted as the column '% cases < zero'. *n* = number of cases included in each analysis

Biological measure	Mean effect (% increase)	Median effect (% increase)	Range (decrease to increase, %)	% cases < zero	Sample size *n*
Abundance as density	166	61	-77 to 2206	13	118
Biomass	446	194	-34 to 2800	6	55
Organism size	28	17	-7 to 153	8	51
Species richness	22	15	- 37 to 143	23	39

The average effects seen in Table 2 therefore suggest increases in each of these measures although to different extents (i.e. larger effects on biomass or abundance) and all of the measures are quite variable, with some cases (6 to 23%) always resulting in declines within the no-take MPA.

It is much less common to have direct measurement of non-target species, features of the habitat (e.g. bivalve reefs or seagrass beds), or species lower down the food chain (e.g. algae, microbes or small invertebrates). The survey work from Tasmania, where rocky reefs within several reserves have been followed over some decades since their declaration (Edgar and Barrett 1997, 1999; Barrett *et al*. 2007, 2009) and the methodology now exported to examine rocky reefs in existing reserves of various ages around the Australian continent, including Victoria (Edgar and Stuart-Smith 2009; Edgar *et al.* 2009), is a notable exception here. Their diver-based surveys have gone beyond targeting catchable fishes and invertebrates to assess the condition of algae, small invertebrates, more cryptic species of small fish, and habitat features. That thoroughness is matched by some work in New Zealand (e.g. Shears and Babcock 2003).

Not all species prosper in MPAs but that is to be expected from what we know of ecological theory. For example, due to trophic cascades or other interactions amongst species, some species get consumed by the protected taxa (otherwise exploited or affected by humans) and so their abundance, biomass, etc. is going to be less within MPAs. Such changes are mostly interpreted as being inherent to ecological processes in nature and show that effects of human activities often permeate natural communities well beyond just the targeted species. Notice how decreases are most prevalent in species richness measures (see Table 2); as mentioned earlier, this is manifest in the trophic cascades and keystone predator effects well-known within ecological theory (Stolzenburg 2008; Eisenberg 2010; Terborgh and Estes 2010; Estes *et al.* 2011). For example, if protected lobsters prosper in numbers, then eat many mussels, abalone or urchins and so clear reefs of much of those important habitat-forming or –shaping organisms, then the overall diversity of the system may decline for entirely natural reasons.

Other patterns seen within the reserve effect of MPAs

Studies of recruitment of marine organisms into MPAs are not common due to the difficulties of studying the small larval forms of most marine species (i.e. these studies are even rare for fished species). But some recent studies of exploited molluscs in Chile (Manriquez and Castilla 2000) or clown fishes in Papua New Guinea (Planes *et al*. 2009) are quite persuasive in showing that spillover from MPAs can be driven by settlement of larvae and their subsequent recruitment as juveniles into distant populations. Thus predictions based on theories of spillover via increased larval production within MPAs are borne out by these few studies. Genetic methods (as used by Planes *et al*. 2009; Harrison et al. 2012) are likely to be the way this is measured in the future.

Another sceptical view of the efficacy of MPAs contends that global comparisons like Lester *et al.* (2009) are biased by including many cases that are irrelevant to the situation that occurs in Victoria or Australia more generally. This might occur where: MPAs are placed (and thence studied) in countries that allow illegal, unethical or destructive fishing practices like using dynamite or poison; rampant overfishing is rife and fisheries management is either non-existent or compromised in method or effect; or many tropical examples are included where populations behave differently or human societies rely upon subsistence fishing that is largely unregulated. To test this possibility, Lester *et al*. (2009) made explicit a temperate versus tropical comparison and found that reserve effects in temperate cases were at least as strong as the tropical ones. Furthermore, I (in an appendix to Fairweather *et al*. 2009) examined that subset of the Lester *et al*. (2009) database that came from countries with efficient fisheries management of a kind like that in Victoria (e.g. New Zealand, Canada, Australian temperate cases) and found some even stronger (but still variable) effects than for the global trend in

Lester *et al*. (2009), see Figure 2 below. It is notable that the means in Figure 2 are larger than those in the full data set (see Table 2 and Lester *et al*. 2009) for both biomass and density but only slightly lower for size and richness. The spreads of the data points are very comparable. Notably almost none of these few cases showed decreases in any variable due to protection inside a no-take marine reserve (Figure 2). From this re-plotting, I previously concluded (see Fairweather *et al*. 2009, Appendix 3) that the effects seen in the full data set were not just due to the location or management regime, and that the global results are still relevant to temperate Australia.

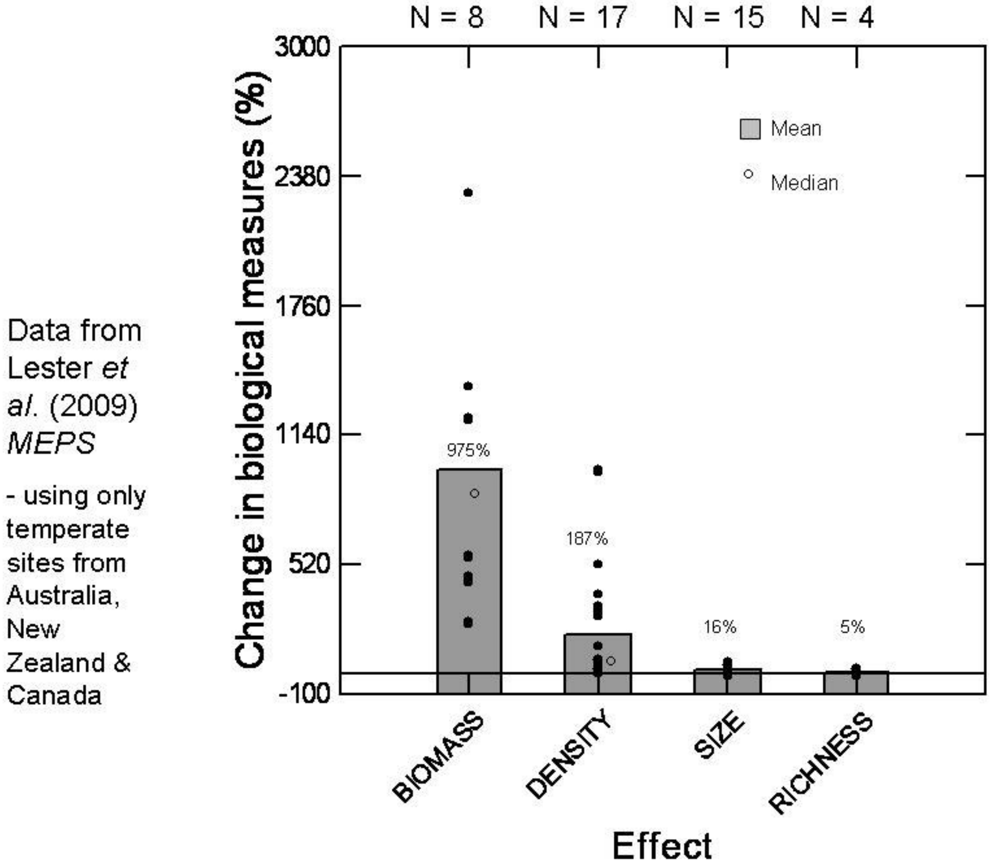

Figure 2. Re-plotted raw data from Table S1 in Lester *et al.* (2009) including only case studies from temperate sites in Australia, New Zealand and Canada. Percentages refer to the means (grey bars), medians (where they differ substantially from the means) are shown as open circles, and individual values from the case studies included are shown as filled dots. N is the sample size for each subset of data. Any value above zero is an increase inside a reserve relative to outside and any value below zero is a decrease. Source: Figure A3 in Fairweather *et al*. (2009).

Awareness of protection, compliance by the public with no-take regulations, and the level of enforcement are all important to the reserve effect seen for any MPA and its eventual success as a management tool for biodiversity conservation. For example, an Italian study of multiple reserves (Guidetti *et al.* 2008) showed a strong reserve effect where enforcement was rated as high or even intermediate but *In = Out* where enforcement was non-existent. There illegal activities like poaching probably wiped out any benefit of protection from MPAs where enforcement was lacking. Unfortunately most studies pay no attention to enforcement levels nor to fishing effort or the public's usage of the MPA for other human activities and where they are concentrated, e.g. recreational angling just outside park boundaries known as "fishing along the line" (Halpern *et al*. 2010). Interpretation of any effects seen in Victoria would be greatly aided by data on enforcement and usage for various human activities being collected (as in Porter and Wescott 2010) alongside measurements of biological conditions. In this context, it is notable that that one study (Currie and Sorokin 2009) of a no-take Aquatic Reserve (AR) present in South Australia found no differences inside versus outside the AR, implying that the level of compliance on Eyre Peninsula (SA) is perhaps too low to show any reserve effect that would be expected (although other competing explanations also exist). Thus having data on usage of MPAs (including non-compliance) is crucial to interpreting their performance.

Effects of the age of reserves are more complex, and some changes do seem to take decades to reveal themselves. Early reviews (e.g. Halpern and Warner 2002) found few differences between "young" and "older" reserves with the reserve effect becoming apparent after only 1-3 years of protection but these comparisons were probably limited by incomplete databases, short timeframes and uneven enforcement regimes. More recent reviews (e.g. Claudet *et al*. 2008 in the Mediterranean; Edgar and Stuart-Smith 2009 and Edgar *et al*. 2009 from around southern Australia) have shown more strong signals from the age of reserves within the overall reserve effect. Typically some effects do occur quickly (within 3 years), e.g. for heavily-exploited fish species or for ones that are mobile and so can move into protected areas and thus behaviourally respond to protection. Early responders also tend to be smaller, faster-reproducing species whereas ones that are slow-growing, large in their maximal sizes, not very fecund, or have some combinations of these traits (e.g. elasmobranchs), can take many years to decades to respond demographically. This was quite clear in the case of an Australia-wide comparison (Edgar and Stuart-Smith 2009), where the age effect was extremely strong: the biomass ratio of *In/Out* more than twice as large on reefs that had been protected for 20 years than ones for only 2-5 years (Edgar *et al*. 2009). It is notable that in Edgar *et al*. (2009) Aldinga Reef Aquatic Reserve in South Australia was the oldest reserve included, at 38 years of protection (at that time), and also had the largest positive *In-Out* difference for fishes bigger than 45 cm length and a near-to-largest biomass ratio of fish in the analysis of 14 no-take MPAs from around temperate Australia.

These age effects are quite important in two ways. First, they serve to sculpt out expectations of what changes we might expect to see in MPAs over different timeframes, so that we are more realistic about we expect to see happen. Second, we can use such trends and associated biology of the responding species to predict which species should benefit from protection more quickly than others, and hence it is possible to make explicit predictions to be tested in monitoring. This is especially so when the range of life histories shown by individual species is taken into account (Begg *et al*. 2005).

There is also a likelihood that indirect effects of protection, if they occur (i.e. under the insurance role for MPAS), would take longer to be evident than direct effects upon species targeted by fishing and other activities that are eradicated within no-take reserves. This was most clearly seen in an analysis by Babcock *et al.* (2010) that detailed several case studies in temperate or tropical setting where many elements of the biota (both targeted and not) were sampled often over more than a decade. They deliberately did not use the metrics comparing Inside versus Outside the MPA detailed earlier and instead plotted trajectories over time of the abundances of species across a range of trophic levels for these reserves. Direct effects of increased abundances (targeted species) occurred after a mean of just over 5 years whereas indirect effects (non-target species) became significant after about 13 years on average (Babcock *et al.* 2010). This contrast was quite different from the similar timing seen in an analysis by Menge (1997) but that that earlier review dealt only with small-scale scientific experiments in rocky intertidal settings, where a host of indirect effects emerged with similar timing to the direct effects of the experimental manipulations. If the delay of indirect effects of MPAs occurs generally, then it is important that performance monitoring of MPAs be continued long enough for any indirect effects to emerge before any judgement is made of their ultimate effects. Thus sampling is needed to be done regularly over many years to decades to allow such a thorough assessment to materialise.

The size of MPAs has also received some attention but a definitive review of size influences on the reserve effect is currently lacking. MPAs in Victoria span several orders of magnitude in size with Marine National Parks being larger than Marine Sanctuaries (Figure 3). This size range is important because it determines the range of habitats within each MPA (with larger ones having generally more habitats) as well as providing logistical challenges regarding compliance. The effect of reserve size on the reserve effect has been studied in several reviews with some early assessments suggesting that even small-sized reserves can have important effects on biotic assemblages within them. For example, Halpern (2003) reviewed 89 studies and was surprised to find that many aspects of the reserve effect were independent of reserve size. Larger reserves did accumulate larger populations of protected species. A review of 19 European marine reserves by Claudet *et al.* (2008) concluded that larger reserves have bigger effects upon the fished species of fishes within them. In a Tasmanian study of four reserves, Edgar and Barrett (1999) found that the largest one, with a 7 km coastal extent, protected targeted species better than ones as small as 1 km of coastline. Victoria's MPAs span these ranges of size (see Figure 3) where effects were seen, so we would expect that they are large enough, although the effect of reserve size still lacks a definitive perspective.

Other jurisdictions have MPAs that have multiple-use zoning, i.e. zones other than just 'no-take' protection. These zones variously include regulations providing for the notional protection of habitats, or more general uses within overall environmental protection, or limited access (i.e. areas that are 'no go', hence limiting effects from the public even more than 'no take' does). These zones constitute different levels of protection, with general usage or habitat protection considered by some to be only partial protection but no-go zones actually convey greater restriction of human influences than the no-take zoning used in Victoria. Most of the published studies worldwide have been done on no-take reserves but the only analysis (Lester and Halpern 2008) of multiple studies involving comparisons of partial protection (i.e. equivalent to the other zone types) with no take concluded that rather less dramatic changes were seen and hence greater benefits came from increased level of protection. Their comparison used the measures shown in Table 2 and Figure 2 above.

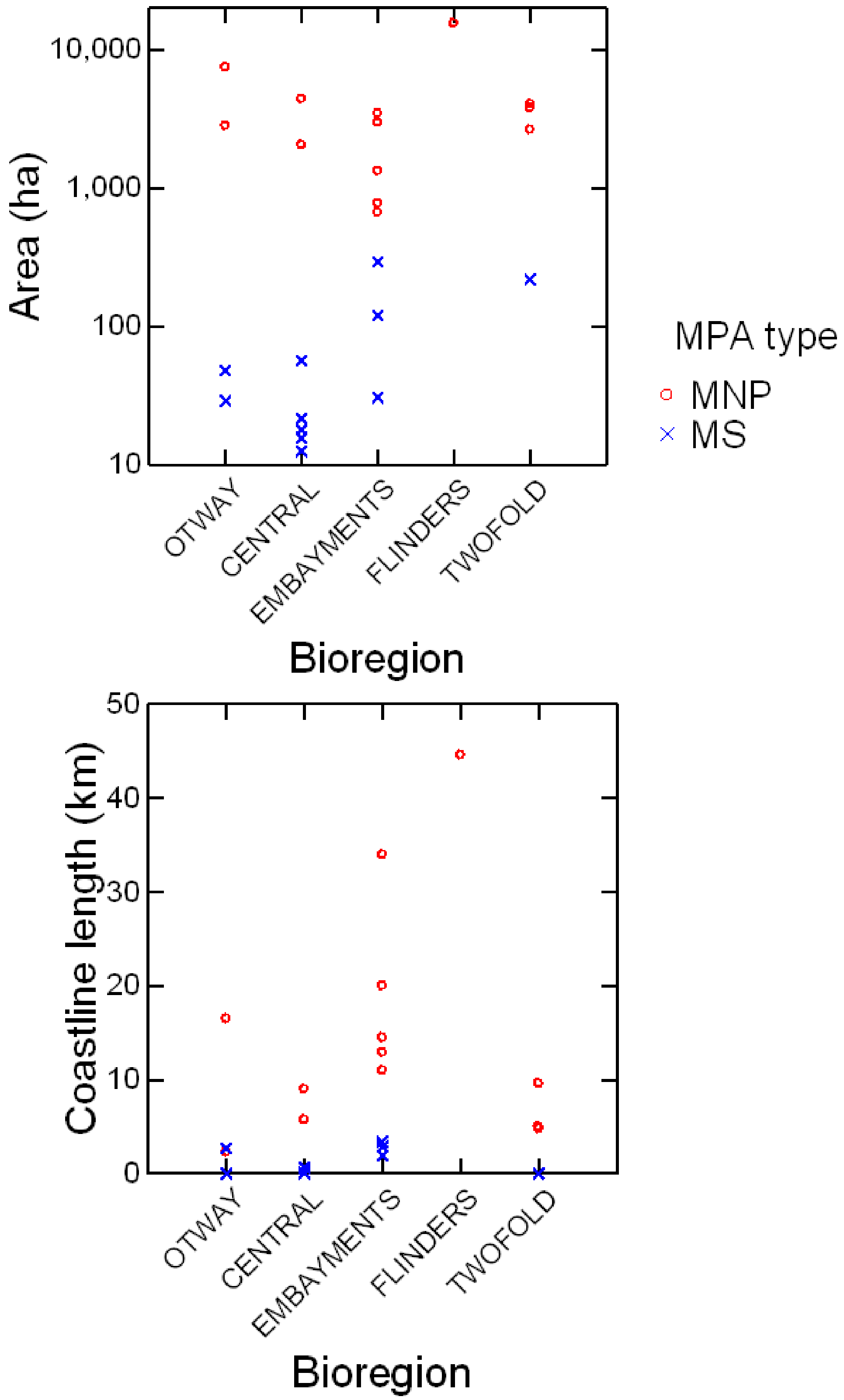

Figure 3. Sizes of Victorian MPAs as shown by a) log area and b) coastline length plotted for each marine National Park or Marine Sanctuary in their Bioregion. Note that not all Victorian MPAs have coastlines.

Pertinence of the MPA literature to Victoria

As mentioned before, many studies of MPAs around the world seem to have set out to test them as tools for augmenting or supplanting more traditional fisheries management. Studies are also common in many tropical regions where numerous no-take MPAs have been implemented to protect coral reefs and, to a lesser extent, mangrove forests. There are many fewer studies of MPAs done in cool temperate areas of the world. To illustrate this point, I did a literature search using the global database of *Web of Knowledge: ISI Current Contents Connect* (Table 3). There were returned very few papers once the keywords "temperate" were added to more general ones defining MPAs (Table 3). This relative paucity of case studies that can be applied directly to the situation of Victoria suggests that we should cautiously apply lessons learned from elsewhere. Note that, where data for temperate case studies have been compared to tropical studies, the general message for responses of fishes to MPA protection do seem to be borne out (see above). Generally I have tried to make appropriate comparisons with the Victorian situation throughout this report (see Introduction).

Table 2. Results of a computer-based bibliographic search of terms relevant to this project. The search was done at the end of June 2012 using the Agriculture, Biology and Environmental Sciences database covering 1998-2012 of Thomsen Reuters *Web of Knowledge: Currents Contents Connect*. All search terms were used in both singular and plural forms, where appropriate.

Search terms used			**# papers returned**
primary	**secondary**	**tertiary**	
Marine reserve OR marine protected area OR marine park			2986
	temperate		195
		reef	142
		intertidal	13
		seagrass	11
		saltmarsh OR salt marsh	2
		mangrove OR mangal	2
		supratidal	nil
	protection		546
	assessment		61
	performance		12
	impact		142
	change		130
	effect		315
	Victoria		2

Section 3. Overall conclusions relevant to the VEAC Marine Investigation

MPAs in Victoria have been studied since their inception, and often before establishment in some cases. This clearly fulfils purpose # 5 (Section 1). It is very commendable that more than 60 reports on various aspects of their monitoring are publically available in Parks Victoria's *Technical Series*, which contributes to achieving purpose # 2 *re* education and understanding (Section 1, see also Plummer *et al.* 2003). The best-developed monitoring has been in the Subtidal Reef Monitoring Program (SRMP) and so there have been some excellent reviews of past performance in this program using the data available up to each review date (Keough *et al*. 2007; Keough and Carnell 2009). This level of scrutiny has resulted in a clear plan for monitoring (Power and Boxshall 2007), some rationalisation of future sampling effort, adoption of novel ways of portraying data (such as using multivariate control charts, see Anderson and Thompson 2004; Burgman *et al*. 2012), and use in 'state of the parks' type reporting. Victoria should continue this desirable trend of sensible evolution via use of independent peer review by the scientific community to ensure application of world's best practice for this monitoring.

It is important that monitoring of the MPAs in Victoria continues to be a self-aware and deliberate activity that is aimed at providing the most useful information needed for now and in the near future. The shift of emphasis from Step 1 to 2 in Table 3 is a key progression in monitoring MPAs, *viz*. it was a major recommendation of the review of science behind the NSW MPA network (Fairweather *et al*. 2009) to shift from the necessary but preliminary stage of making inventory of the park system to doing mainly performance assessment, as a re-focussing of effort during the second 5-year plan for monitoring in NSW. Victoria should also move consciously and deliberately through the steps in Table 3.

That monitoring in Victorian MPAs has so far been mainly focussed upon subtidal reefs is understandable. Reefs have a high public profile as focal points for diving and underwater photography, they are a very common habitat (e.g. a major subtidal habitat in 19 of the 24 MPAs), tend to be discrete habitats for which we have a well-developed sampling methodology (i.e. the Edgar-Barrett method originally from Tasmania). VEAC should assess the costs and benefits arising from the latest monitoring done for Parks Victoria under the SRMP.

The SRMP to date has largely dealt with describing the assemblages found on subtidal reefs in a subset of Victorian MPAs. This is a necessary first step in assessing their performance but is not sufficient by itself to provide a thorough assessment regime. I understand that a number of approaches focussing more on how the MPAs are performing over time have been begun by Parks Victoria and look forward to the public dissemination of those findings and assessments. This transition often requires a subtle shift in thinking along the lines outlined in Fairweather *et al*. (2009). For example, more sophisticated predictions of the trajectories that different species would be expected to take over time within the MPAs should be possible by taking into account the particular suites of life-history and other biological characteristics of the species of interest within each MPA (Begg *et al*. 2005; Edgar *et al*. 2009). More clever predictions about how Victoria's MPAs should perform are possible and desirable as part of performance monitoring.

The extension of the SRMP to intertidal reefs as the Intertidal Reef Monitoring Program (IRMP) is also desirable, in that this seashore habitat is even more accessible for the public and also constitutes areas under risk from various recreational uses and wider threats. Intertidal reefs suffer from a larger range of impacts and probably at higher intensities (i.e. more users) than do subtidal reefs, e.g. trampling occurs from people just walking around rock platforms, and collecting of biota for food or bait is accessible by the public without any of the specialised gear needed for subtidal recreation. There exist clear Standard Operating Protocols for both subtidal and intertidal reefs (Edmunds and Hart 2003; Hart and Edmunds 2005), which are open to public scrutiny. The recent summaries (see Stewart *et al.* 2007; Pritchard *et al.* 2011) of the IRMP would also now provide a thorough basis for a critical review of the IRMP sampling efficiency, power of statistical designs, and future refinements. Such a review (similar to but extending those done so far for Parks Victoria of the SRMP, see Keough *et al*. 2007; Keough and Carnell 2009) would be very useful to several of the purposes of Victorian MPAs, if commissioned.

Plans have been made for the monitoring expanding to cover other habitats and features of the MPAs (Power and Boxshall 2007) but it is less clear how much progress has been made to date in this regard, especially in quite different ecosystems like mangroves or saltmarshes. Likewise, the commitment to monitoring other habitats like intertidal or subtidal soft sediments

Table 3. Progression of the monitoring cycle for MPA performance.

No.	Step	Details of considerations within this step
1	Describe assets of MPAs	Inventory of features, habitat mapping (esp. for extent, e.g. Holmes *et al.* 2007), species lists
2	Assess their condition	Baseline establishment, historical reconstruction if necessary (e.g. Connell *et al*. 2008), assess present condition
3	Predict effects from protection	Integrate conceptual models (Pocklington *et al*. 2012), likely threats, regulation of human activities and any other complementary management actions, consider SMART indicators to test predictions
4	Document change(s) over time	Repeated measurement to provide trajectories *re* predictions (timing specific rather than just regular)
5	Ascribe causality	Contrast in *vs* out of MPAs *re* predictions (for selected metrics and indicators rather than measure everything, Keough *et al*. 2007; Keough and Carnell 2009)
6	Interpret effects	Logical in relation to predictions, ongoing management plans and observed compliance levels?
7	Integrate *re* purposes of MPA establishment	Synthesis *re* benefits in relation to predictions, including economic valuation, cost-benefit analysis of any proposed actions
8	Re-assess understanding	Where appropriate (necessary), re-work conceptual models and theoretical knowledge of marine ecosystems
9	Re-evaluate priorities for future monitoring	Reconsider relevant theories and desired conditions from that time onward, plan for next monitoring phase(s)

(considered for Western Port in Butler and Bird 2010) is not clear. Indeed monitoring of seagrass beds, often acknowledged as another discrete but important focal habitat (i.e. like reefs), seems to be being left to community groups in Victoria. All habitats and features should be brought into the fold of more routine monitoring by planning for their inclusion as part of a regular agreed schedule (but not necessarily being monitored in every place at every time). This will also assist in fulfilling purposes # 3 and 4 (see Section 1). In the near future, monitoring efforts should be focussed upon providing a catch-up regarding the habitats other than reefs (especially in seagrasses, mangroves, saltmarshes, mudflats, sandy beaches; noting that these are all historically under-studied in Australia when compared to all other habitats; see Fairweather 1990; Fairweather and Quinn 1995). This re-focus would benefit from some fruitful interaction with other agencies responsible for managing and monitoring estuarine habitats in Victoria (Victorian Saltmarsh Study 2011).

Regarding biodiversity, the monitoring of Victorian MPAs could more directly address diversity at the species/population level by compiling species list for each MPA. Data to be analysed more formally in assessing MPA performance could then include the incidence of species occurrences. Hayek and Buzas (1997) make the argument that tallies of occurrences are more useful than many ecologists think because they are strongly related to density, easier to collect than abundance data, but undervalued as a data source. Analysing patterns of occurrences fits more with describing reserves effects as an estimation exercise (for example, Possingham 2011 argues that we know that MPAs will have some effects, so monitoring to test that possibility is rather mindless – instead we should estimating the effect sizes that come from protection) and also fits with the so-called "new statistics" that do not emphasise the testing of null hypotheses (see Cumming 2012). Likewise the genetic level of biodiversity is opening up with many new approaches available (e.g. Gotelii et al. 2012) and exploration of those can probably be done in partnerships with specialists in these newer approaches. Future reviews of this monitoring should consider focussing upon effect sizes from MPA protection (Cumming 2012) and consider ways in which novel but cost-effective data sources like occurrence of species (yielding species lists) or modern molecular techniques can be taken advantage of.

Regarding ecological processes, there needs to be much more attention paid to those occurring within MPAs, building upon conceptual models (Pocklington *et al*. 2012) but moving to making effective measurements of the rates of some of these important processes (Ross 2011). Consideration of ecoassays (Fairweather 1999) is warranted here, which may also (like compiling biodiversity profiles) require a rethink of monitoring priorities within Victorian MPAs. In the meantime, more focus upon food webs via classifying the species encountered during monitoring into functional feeding groups should be a very doable re-focal point. Some serious planning should be put into expanding the monitoring protocols to include more overt consideration of trophic interactions and of making rate-based measures of ecological processes within selected MPAs in Victoria.

Section 4. Acknowledgements

This project was very ably facilitated in a logistical sense by Joan Phillips, Jo Klemke and Megan Liddicoat of the Victorian Environmental Assessment Council and Daniela Tyson of Flinders Partners. I also thank the many people that I have interacted with over the last 27 years in NSW, Victoria and South Australia regarding issues to do the science of MPAs, especially my fellow members of the Scientific Working Group for Marine Planning and Marine Parks (for the Minister for Sustainability, Environment and Conservation and the Department of Environment, Water and Natural Resources, SA) and the Scientific Advisory Group for the Marine Investigation of VEAC. Regardless, the views expressed within this critical review are solely my own as a professional scientist working in marine ecology.

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Appendix 1. Project specification

Assessing the outcomes of Victoria's existing marine protected areas for biodiversity and ecological processes – a critical review of contemporary relevant scientific approaches and literature

1. Scope

The purpose of this project is to provide expert scientific advice to inform the Victorian Environmental Assessment Council (VEAC) in conducting its marine investigation. Its more specific purpose is to inform VEAC's examination and assessment of the performance of Victoria's existing marine protected areas in meeting the purposes for which the protected areas were established.

- Within this scope, the project will focus specifically and solely on the subset of: *purposes* that relate to *biodiversity and ecological processes*, except those that relate to comprehensiveness, adequacy and representativeness. An analysis of these purposes, and their specific definitions in relevant legislation and policy, will be provided by VEAC as an input to the project.
- *existing marine protected areas* that are Marine National Parks and Marine Sanctuaries

The objective of the project, within the above scope, is to provide an expert scientific analysis of:

1. Current ecological thinking and literature on appropriate <u>attributes</u> and <u>indicators</u> (or measures) for assessing the *outcomes* of Victoria's existing marine protected areas in meeting their defined purposes relating to biodiversity and ecological processes, taking into account:

    - the conceptual ecological basis for such attributes and indicators;
    - the likelihood that they could be practically applied given the availability of relevant data

2. Existing scientific assessments of the outcomes of marine protected areas, in comparable environments, in meeting comparable purposes – using the above, or other measures – taking into account:

    - the temporal and spatial scale over which it would be reasonable to anticipate ecological outcomes for such assessments

The project should acknowledge, but not provide a detailed assessment of, scientific work that relates to biological and ecological <u>benefits t</u>o surrounding marine areas.

The project will draw on, and build on, relevant discussions that occurred at Meeting 1 of the VEAC Marine Investigation Scientific Advisory Committee, which was held on 26 April 2012.

<u>Information inputs and sources</u>
VEAC will provide the following inputs to the project:

- an analysis of the defined purposes of Victoria's existing marine protected areas, including the priority among the various relevant information sources.
- a summary of relevant discussions the occurred at Meeting 1 of the VEAC Marine Investigation Scientific Advisory Committee.

<u>Key project outputs</u>

The project output will be a report divided into sections that clearly address each of the above objectives. The report is to target a relatively technical audience, but contain an executive summary that will be interpretable more broadly. It is critical that the report includes a bibliography of all scientific references cited within it.

The final report will be guided by a draft report which is to be provided to VEAC for comment (see section 3 below).

1. Background

VEAC Marine Investigation

The Minister for Environment and Climate Change has requested VEAC to carry out an investigation into the outcomes of the establishment of Victoria's existing marine protected areas. The terms of reference for the investigation are:

Pursuant to section 15 of the Victorian Environmental Assessment Council Act 2001, the Minister for Environment and Climate Change requests the Council to carry out an investigation into the outcomes of the establishment of Victoria's existing marine protected areas[1]*.*

The purpose of the marine investigation is to examine and provide assessment of:

- *(b) the performance and management of existing marine protected areas in meeting the purposes for which they were established, particularly the protection of the natural environment, indigenous flora and fauna and other natural and historic values; and*
- *(c) any ongoing threats or challenges to the effective management of existing marine protected areas, particularly in relation to the biodiversity and ecological outcomes.*

In addition to the considerations in section 18 of the Victorian Environmental Assessment Council Act 2001, the Council must take into account the following matters:

- *(i) all relevant State Government policies and strategies, Ministerial statements and reports by the Victorian Auditor-General;*
- *(ii) all relevant national and international agreements, policies and strategies, including ecosystem-based management approaches; and*
- *(iii) relevant regional programs, strategies and plans.*

Three public submission periods are to be held and a discussion paper and a draft proposals paper are to be prepared. The Council must report on the completed investigation by February 2014.

[1] *For this investigation, marine protected areas means the 13 marine national parks, 11 marine sanctuaries, and 6 marine parks, marine reserves or marine and coastal parks established under schedules seven, eight and four respectively of the* National Parks Act 1975.

The specific role of this project is to inform VEAC's assessment of the 13 marine national parks and 11 marine sanctuaries for term of reference (a) of the investigation

Project approach

Assessments of protected area management effectiveness often conclude a number of elements (eg: IUCN-WCPA framework for assessing management effectiveness of protected areas). The scope of this project aligns with the 'outcomes' element of such assessment frameworks.

The project objective, as defined in section 1 above, is to provide an expert scientific analysis of:

1. Current ecological thinking and literature on appropriate attributes and indicators (or measures) for assessing the *outcomes* of Victoria's existing marine protected areas in meeting their defined purposes relating to biodiversity and ecological processes, taking into account:

- the conceptual ecological basis for such attributes and indicators;
- the likelihood that they could be practically applied given the availability of relevant data

2. Existing scientific assessments of the outcomes of marine protected areas, in comparable environments, in meeting comparable purposes – using the above, or other measures – taking into account:

- the temporal and spatial scale over which it would be reasonable to anticipate ecological outcomes for such assessments

The project should acknowledge, but not provide a detailed assessment of, scientific work that relates to biological and ecological benefits to surrounding marine areas.

In addressing these objectives:

The analysis provided for component 1 should -

- outline the conceptual ecological framework surrounding the range of potential attributes and indicators / measures described, and define whether the indicators / measures are included due to their potential to act as *surrogates* or because they *represent symptoms* of the impact of a particular threat category.

- include a range of potential attributes and indicators / measures, but highlight those that are most ecologically appropriate and practically feasible – from a scientific perspective – for VEAC's purposes

The analysis provided for component 2 should –

- give most attention to literature for assessment within project resources based on its (1) compatibility with the specific scope defined in section 1 of this brief, and comparability with Victoria's marine environment and (2) scientific rigour

- provide a clear assessment of the quality the scientific studies assessed and the defensibility of their conclusions.

Where possible, in addition to text discussion, the analysis provided should also be summarised in tables, or any other format that makes it as easy as possible for multiple audiences to interpret.