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 1: Attributes and indicators for assessing the ecological outcomes from Victoria's 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. This review has two parts. This part of the review (Part 1) outlines 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.

Part 2 of this critical review then goes 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.

Lastly, some overall conclusions relevant to the Victorian setting are drawn to assist VEAC with 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 New South Wales (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. Current ecological thinking about the performance of MPAs

Summary of the effects of marine protected areas seen around the world

There have been many studies of the effects of no-take marine reserves done around the world in the last 40 years (e.g. a quantitative review by Lester *et al*. 2009 could use data from 124 studies of effects on fish). Many of these are not necessarily very relevant to the Victorian situation, e.g. they might deal with reserves set up solely for fisheries enhancement purposes or come from tropical parts of the world where both the biota and how people interact with it are very different from Victoria. Here I have sought to give a feel for this extensive literature but draw the lessons we can learn from those parts of the world (and their case studies) where the biology, physical setting and management regimes are broadly comparable to Victoria. So the points I make are drawn from considering a subset of those many studies.

Nevertheless It is surprising how narrow is the database in terms of which marine organisms have been examined in relation to how MPAs have affected them. Most studies are concerned only with fish that can be caught and eaten. These investigations take the form of both individual case studies of a single reserve or, less commonly, several within a locality. There are several quantitative reviews of multiple case studies, culminating in a global compendium of the so-called "reserve effect" (Lester *et al.* 2009) using standardised data on just four measures of fish performance. Such broad-brush reviews rely on taking results from many different small-scale studies, combining them into one large meta-analysis and then drawing lessons from them that can be generalised further. In some cases, the database is large enough to also examine issues that might influence the reserve effect, e.g. temperate versus tropical studies, or whether MPAs have a greater effect in areas with intense fishing. It would be nice if all such reviews (or at least the largest of these) had critically examined all such relevant ideas (e.g. covariates like reserve size and shape, initial reserve condition, which biota or habitats are there, whether fishing is the main threat to the ecosystem, whether regulations are enforced, etc.). But the individual case studies that go into these reviews don't necessarily provide such information and in some cases it might not be relevant anyway. The power of large reviews comes from including many cases that differ in lots of specific ways, so that the lessons drawn are truly general.

So the individual studies tend to be more detailed, locally relevant to the point of being parochial, and often cover a wider range of features of biodiversity than the reviews do. Such in-depth case studies are, however, the raw material of these reviews and without them no overall view of the reserve effect would be possible. Many individual studies have focussed upon any promised fisheries benefits of having parks within a region rather than just their role in biodiversity conservation. There also exist books (e.g. Sobel and Dahlgren 2004; Roff and Zacharias 2011) and textbook chapters (e.g. Roberts 2005; Edgar *et al.* 2007) about marine reserves. This section summarises those findings and highlights their implications for Victoria by addressing the following broad questions: what trends over time and other changes have been seen after the implementation of no-take marine protected areas in places that are broadly comparable to Victoria? What aspects of the marine ecosystems have been studied for such changes and how? Do covariates like time since protection, reserve size, the effective degree of protection or enforcement play a part in what effects are seen?

Direct versus indirect effects of no-take protection

Many different aspects of marine ecology can be affected by well-managed and effective protection on a spatial basis by marine protected areas (i.e. within their boundaries). We know from ecological theory that protection can directly affect the abundance (i.e. numbers, density) of marine organisms, their individual sizes, overall biomass (i.e. total amount of living creatures, usually as a weight), and their diversity. The overall experience highlighted in the review literature is that the reserve effect increases these measures on average although there is considerable variation observed in such effects. These direct effects tend to be strongest on the species that are targeted by the human activities are being regulated in the no-take reserve (e.g. fishing).

There are also less direct effects of protection that flow through marine populations and assemblages of multiple species because of demographic changes and/or interactions amongst the species inside the MPA being rather more natural and so are allowed to take their course without any human interference. Thus these shifts may only become apparent over time and include increases in the fecundity of populations (both through increases in individual size of fishes but also increased densities), the potential for "spillover" of larvae and/or adult fishes into unprotected areas beyond the boundaries of the MPA, and changed abundances of non-target species occurring via trophic cascades and other interactions between sets of multiple species. These various effects will be highlighted below.

It is important to note that we would never expect every species to increase in density or size in any MPA. Apart from differing greatly in details of their biology (and hence speed to respond to protection), the reality of the situation is that protection may favour some species that are large and hence targeted by, say, fishers. These large species increase in number after protection and their own activities then interact with the rest of the environment. For example, one predator that is protected may then feed voraciously upon other species that would not benefit from protection. These ecological interactions between different species are a main point of study in ecology, very well known and expected to occur in any ecosystem that is undergoing its normal dynamics. Thus this “Nature red in tooth and claw” view is quite natural for many ecosystems, including marine ones (Stolzenburg 2008; Eisenberg 2010; Terborgh and Estes 2010; Estes *et al.* 2011) but we may not be seeing this so often in ecosystems affected by human activities (Estes *et al*. 2011) – so this more natural range of behaviours is one of the anticipated outcomes from MPAs. There is emerging evidence (e.g. from Tasmania, see Ling and Johnson 2012) that more natural interactions in MPAs allow for more resilience in ecosystem responses to threats from exotic invaders (directly) and climate change (indirectly).

One way to deal with different public expectations of what MPAs will do is to develop and use conceptual models of ecosystems (as Parks Victoria has done, see Pocklington *et al*. 2012) and to make clear predictions about expected changes (those then feed into the monitoring in ways that enhance that activity too, see discussion about the specificity of aims in Keough *et al.* 2007).

How the reserve effect is usually studied

The basic comparison made is usually to contrast conditions inside versus outside the reserves. The magnitude of differences seen in, say, fish populations is then a measure of how large the realised reserve effect is. Most studies compare inside versus outside no-take marine protected areas. This comparison is expressed either as a ratio of values for *In/Out* (with values often logged to improve mathematical behaviour when analysed) or as a difference of *In minus Out* values.

Relatively few studies have been able to set up a study design that encompasses sampling both before and after protection in multiple areas that cover both protected versus not protected status (i.e. impacted versus control sites). Such a design is called a BACI because it covers Before-After-Control-Impact aspects and that is desirable for determining exactly what is going on regarding potential impacts and why any changes that are seen have occurred. This is the basic design used in many studies of environmental impacts of human activities (e.g. see Downes *et al*. 2002 for a thorough review of these concepts).

Indeed most reserve-effect studies start some time after protection has been declared, thus being reduced to an After study of Impact (inside MPA) versus Control (outside) areas. Not all the differences seen in such cases can then be unambiguously concluded as being due to protection of the MPA. For example, sceptics of MPAs often claim that many MPAs are put in the "best" places for fish populations or biodiversity more generally. In that case the *In/Out* differences seen are actually pre-existing before establishment and thus have nothing to do with ongoing protection *per se* by the MPA. Some reviews (Halpern 2003; Lester *et al*. 2009) have attempted to test that proposition by using the minority (<20%) of studies that do have some Before data (i.e. they fit a BACI statistical design). In those subsets, there was little evidence that any differences were solely pre-existing; in nearly all cases, relative changes occurred between Control and Impact areas After protection compared with Before. In Victoria, some MPAs were sampled well before they were declared and that Before data, where available, has been used to good advantage in the statistical designs used to evaluate performance (e.g. of some Victorian MPAs including reefs, see Keough *et al*. 2007; Keough and Carnell 2009). Not all of the 24 MPAs, however, have such Before data and so a different design is needed in those cases (i.e. documenting trajectories over time that may not relate so well to any effect of protection *per se*).

Two functional roles for MPAS

As pointed out by Fairweather (2010), it is sometimes not widely recognised that MPAs can fulfil at least two different roles in biodiversity protection. These modes of operation differ depending upon the relative magnitude of human impacts in the area when the protection via an MPA is first provided. The first mode can be called the **insurance role** for MPAs, whereby protection is provided now for future benefits by reserving areas that are currently in good condition, essentially to try to keep them as pristine as possible. Thus conditions would be the same, or as good, In versus Out at the time of declaration but then we expect them to diverge later because Outside areas decline over time (see Figure 1a). This insurance role emphasises that the biota and interactions seen within MPAs are likely to be more natural than in areas where some species are heavily exploited.

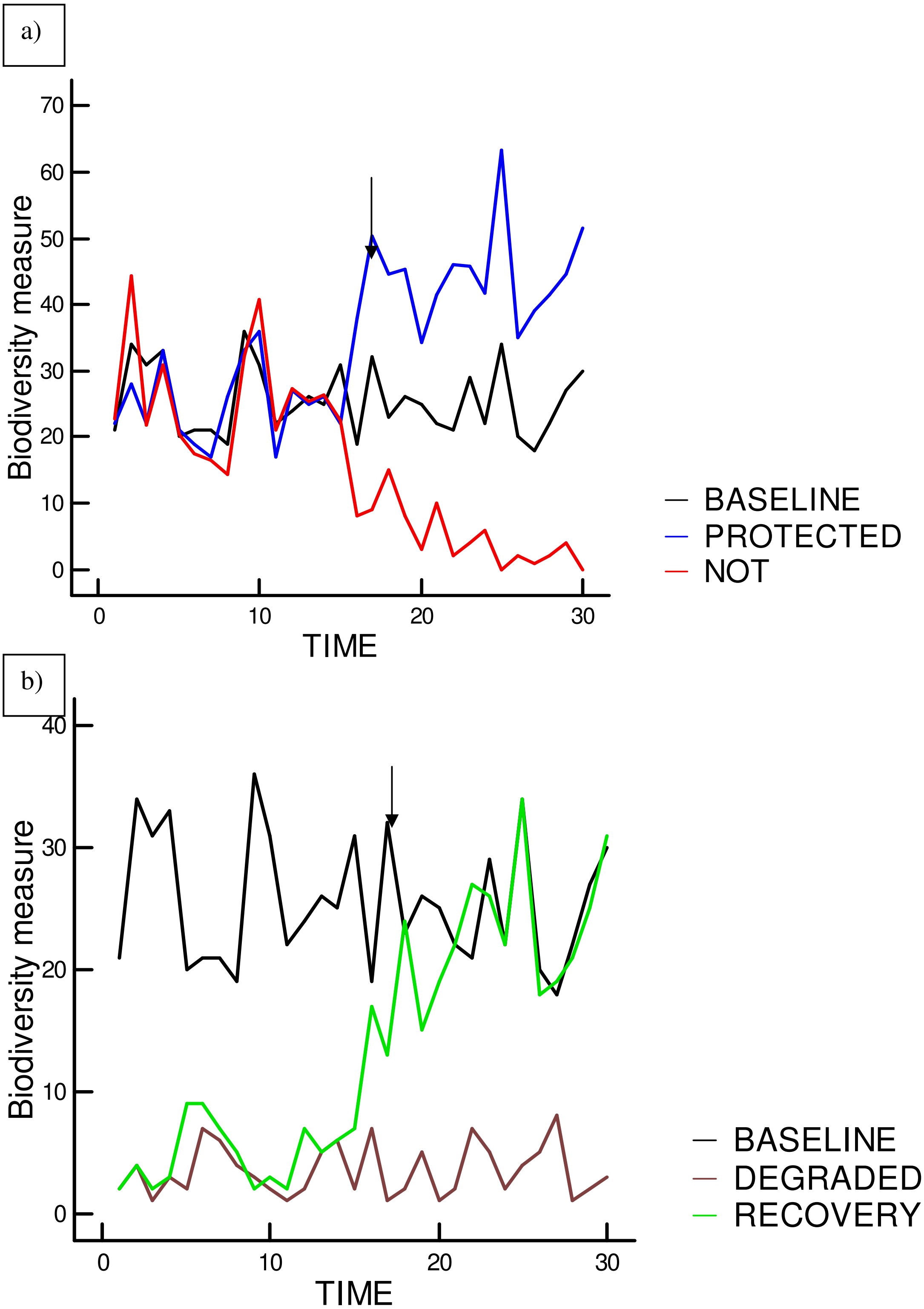

Figure 1. The two contrasting modes of operation of marine protected areas that differ in relation to our expectations of what changes should be seen and hence their purposes. a) the **insurance** purpose, where no further declines (Not, red line) in ongoing condition from the historical baseline (black line) are achieved by protecting areas from any further harm, thus they increase in terms of biodiversity (protected, blue line). b) the **remedial** purpose, where via protection, the condition of an MPA (Protected, green line) improves above the Degraded present state (brown line) and moves towards a reference condition (Baseline, black line) constituting recovery. In each graph, the time steps along the x-axis are likely to be either months, years or decades and the measure of biodiversity on the y-axis could include those discussed in the text (e.g. abundance, size, biomass, species richness or another biological variable). The arrows indicate when effective protection begins. The variable trajectories shown are hypothetical but based in ecological theory. Modified after Fairweather (2010).

The second mode can be called the **remedial role** for MPAs, whereby they are used to allow some areas to recover from a degraded state by protection now and into the future removing past problems from human activities (e.g. intense fishing, mining, recreational impacts). Thus these past and current threats are arrested under protection and so areas inside the MPA then improve over time from being in a more poor, or the same, condition as the outside areas (see Figure 1b). It should be obvious that declaration of a no-take MPA does not, in itself, mean that all possible threats to a site are arrested (i.e. in Victoria it's mostly fishing that is affected). Of more import to this project, the sorts of changes we expect to see after protection within MPA boundaries differ greatly across these two roles. Direct changes to ecological conditions within the boundaries of the MPA are expected under the remedial perspective whereas the main changes would occur outside the MPA boundary under the insurance hypothesis. MPAs set up to conserve biodiversity tend more toward ensuring the insurance role, and this fits with pleas (e.g. Possingham 2008) to focus future actions bent upon preventing biodiversity loss rather than just curing poor outcomes from past usage.

Studies that just show that conditions inside MPAs do not equal areas outside of them now (i.e. After) may be examples of either mode because typically no Before data have been collected, esp. where declaration of the MPA occurred years to decades before the study. This is a widespread problem where no monitoring scheme is put in place around the time of declaration, e.g. only 3 out of 20 studies included in a review by Micheli *et al*. (2004) had any Before data to compare the changes over time. It is notable, however, that the sort of evidence that might be viewed as being more consistent with the insurance role was not strong in the analyses done by Lester *et al*. (2009).

We would also predict, after considering the starting points for each of these two functional roles, that the balance of direct and indirect changes seen within MPA boundaries compared with outside would differ greatly between the roles. Under the insurance view, we would expect that abundances of different species are closer to natural levels and so any natural interactions amongst them (e.g. across trophic levels) would already be operating. In contrast, under the remedial role, the absolute and relative abundances across species would at the start differ from natural levels and so there would be few or unnatural indirect effects operating. Babcock *et al*. (2010) thus made the point in passing that we would only expect to see indirect effects of protection emerging in addition to direct differences between *In versus Out* comparisons under the remedial role.

Thus the different expectations associated with each of these two perspectives are important in terms of how a monitoring scheme would be designed and what it would report upon. These issues were touched upon by the discussion in Keough *et al*. (2007). The first meeting of Scientific Advisory Group for VEAC's Marine Investigation also affirmed that the remedial perspective did not apply because restoration or enhancement was not one of the purposes of these MPAs (see Section 1).

Most of the studies included in reviews like Lester *et al*. (2009) are looking for any changes going on inside the MPA and therefore tend to have a remedial perspective (as defined above). Similarly, the public often call for MPAs to be used to "fix" environmental problems (often to do with overfishing or pollution), especially those located close to urbanised areas, which would fit MPAs into the discipline of restoration ecology. In contrast, very few studies seem to be coming from the insurance perspective (as defined above), even though that might fit better with biological conservation and the legislation under which many Australian MPAs (including those in Victoria) were established.

As stated earlier, most studies have examined fishes as the organisms of interest (Lester *et al*. 2009; Molloy *et al*. 2009), but some include other edible species (e.g. invertebrate shellfish), maybe some of the habitat-forming sessile organisms (like seagrass, corals or macroalgae) but rarely do they study more than one or a few taxonomic groups. The Tasmanian studies of Edgar and Barrett (1997, 1999) and Barrett *et al*. (2009) included macroalgae, invertebrates and some cryptic organisms along with schooling demersal fish but some of their later papers, including meta-analyses, of reserve effects have tended to focus much more upon the fishes (e.g. Barrett *et al.* 2007; Edgar and Stuart-Smith 2009; Edgar *et al*. 2009). This may be a case of the public interest in fish channelling scientific attention away from other taxa. It should be noted that the monitoring done for Parks Victoria on subtidal reefs in Victoria also follows the Edgar-Barrett method for describing reefal communities (Edmunds and Hart 2003).

Thus even studies of MPAs that do include multiple species are mostly quite constrained in terms of taxonomy (e.g. deal with a taxocene rather than whole community of organisms) as well as using only one to three techniques of sampling. All of these decisions about what to study and how within an MPA result in selectivity of sampling and hence limit the data returned to coming from only a subset of organisms. Thus, biodiversity *per se* rarely ever gets considered, even in terms of species diversity (as opposed to the additional genetic and ecosystemic levels of biodiversity, Roff and Zacharias 2011). This is curious whenever the enabling legislative under which a MPA has been established emphasises that the maintenance of biodiversity is a main consideration (as is the case in Victoria, see purposes identified in Section 1). Certainly I am aware of no published study of an MPA or network of them anywhere including a full inventory of the biodiversity found within the MPA because of the logistical difficulty in directly measuring marine biodiversity (although some such might be forthcoming in publications from the Census of Marine Life).

Thus we need to consider what possible attributes and potential indicators are available to represent biodiversity at the species, genetic, and ecosystemic levels. Many different measures have been used in past studies covering many different situations (e.g. see Pomeroy *et al.* 2004 for discussion in the global context of IUCN) but often these have only local application or lack much justification for their adoption more widely. The scientific literature suggests that many different attributes and potential indicators can be derived that might apply to biodiversity or ecological processes within MPAs (Table 1). A number of the variables mentioned in Table 1 are components in themselves of biodiversity but some approaches also adopt them as surrogates (*sensu* Rodrigues and Brooks 2007) for the totality of biodiversity. This latter step may be common but is rarely founded upon a demonstration that measuring one component also covers many other unmeasured and much more problematical aspects (including the search for the so-called “umbrella species”). I think that it is safer to measure some different components of clear interest for a given habitat (and not just targeted species) and treat each separately on its own merits.

We have already seen that the treatment of species focuses upon only a subset of organisms (especially fishes) and so it would seem to be apposite to extend this to cover other taxonomic groups, especially those with more fundamental functional roles in their marine habitat (see below). There are, however, limitations upon taxonomic expertise across many groups of algae, invertebrates, microbes and fungi, which mean that real impediments are in the way of this inclusive approach.

Table 1. List of ecological attributes and potential indicators of them that might be relevant to monitoring the performance of MPAs. * = widely used (including in PV programs), # = potential goes beyond mere description to beginning to explore functional aspects, ~ can represent threats and pressures within the MPA, @ = also bridges to next level of biodiversity (e.g. up to the ecosystemic or down to species)

Type of information	Attribute	Potential Indicator	References
Biodiversity			Zacharias and Roff 2000
- **species/ population level**	Taxonomic variety	Species lists across selected taxonomic groups and habitats	
	Population features of selected species *	Abundances, sizes, life stages ~	
	Community structure @ (esp. taxonomic composition and relative abundances)	Analyses of assemblages * – species diversity, multivariate descriptions #	Clarke and Warwick 2001
	Species with particular traits, e.g. endemic, habitat-forming, exotic, common, rare, exploited, charismatic, iconic, important (keystone)	Presence/absence or abundances of various groupings of species *	
	Species turnover (across sites and habitats)	Beta diversity estimates	Anderson *et al*. 2006, 2011
- **genetic level**	Genomic variety	Molecular measures of genetic connectedness of selected species	Teske *et al.* 2010; Harrison *et al*. 2012
	Metagenomics	Environmental samples of water or sediments screened for metabolism or C utilisation #	Barton 2006 Dinsdale *et al.* 2008 Burke *et al*. 2011 Gotelli *et al.* 2012
- **ecosystemic/ landscape level**	Ecosystem variety	Habitat presence/absence and extent *, possibly condition #	
	Community structure *	(as above for species level)	

Type of information	Attribute	Potential Indicator	References
	Juxtaposition of ecosystems	Landscape ecology measures of patch dynamics	
	Surrogates of overall biodiversity @	Analyses of types of habitats – presence/absence, extent	
Ecological Processes			Fairweather 1999; Lester *et al.* 2011
	Primary production	1° producers or functional groupings of them - presence/absence, % contribution to biomass, photosynthetic rates, growth of plant biomass	
	Recruitment	% of new recruits in selected populations, size frequency analysis * ~	
	Trophic cascades and other feeding effects	Food web analysis, apex predator presence/ absence or abundances, feeding intensity	
	Competition, mutualism, facilitation or other interspecific interactions	Measures of evidence of interactions – species associations	
	Decomposition and nutrient cycling ~	Rates of organic matter breakdown in litterbags, measures of standing stocks and fluxes of nutrients	
	Bioaccumulation rate ~	Enrichment ratios of toxic or other chemical pollutants within organisms	
	Degree of invasiveness ~	Arrival and % contribution of invasive species over time	

The genetic level of biodiversity has also rarely been tackled in relation to MPAs although studies of how some taxa are connected across MPA boundaries are becoming more common due to the focus now of much ecology upon using molecular tools (e.g. Teske *et al*. 2010; Harrison *et al*. 2012). There would appear to be several new approaches opening up at present, involving the examination of multiple samples of environmental media (e.g. water or sediments) in an attempt to understand diversity at genetic and finer levels (e.g. see Dinsdale *et al*. 2008; Burke *et al*. 2011; Gotelli *et al*. 2012) but none of these have been applied to assessing outcomes from MPAs as yet.

In some ways the level of biodiversity that has been most strongly linked to MPA assessment has been that of ecosystems, habitats and landscapes, i.e. at the largest scale. This is because the presence of different ecosystems, the extent of cognate habitats, and their spatial arrangements have all been used as surrogates (Rodrigues and Brooks 2007) for biodiversity *per se* within the systematic design of reserve networks for some time. Hence most jurisdictions with MPAs have invested heavily in sophisticated habitat mapping at reasonably fine scales and Victoria is no exception (e.g. Holmes *et al*. 2007).

Most of the monitoring done of, say, subtidal reefs in Victorian MPAs has adopted the quite common approach of measuring the populations of species and assemblages of communities for a few key organisms, often taxonomically restricted via the methods employed. Patterns of taxonomic composition and relative abundances of multiple species are revealed by multivariate analysis of the data (Clarke and Warwick 2001) coming from a few methodologies involving sampling transects and quadrats. In this way mobile demersal fishes, macroalgae and the larger invertebrates are used as surrogates for other organisms found on reefs. This species set corresponds to the many of key players in ecological theory about how reefs operate but the approach also omits any information specific to some important players (e.g. larval or other early life-history stages of these species, all microbes including many pathogens, smaller cryptic taxa that are often food for the fishes, etc.) and so may not tell us much about the other levels of biodiversity *per se*. Nevertheless this sampling is covering a broader range of biodiversity at the species/population level than just fishes.

The other part of purpose #1, the maintenance of ecological processes (see Section 1), has received much less attention but there are potential ways forward in that regard as well. It is notable that each section on threats in the multiple Marine Natural Values Study reports on MPAs (Parks Victoria in prep., updating Plummer *et al*. 2003) lists “limited ecological knowledge of important processes” as a key threat to the persistence and ongoing management of each MPA. So the challenge of getting a better understanding of processes is important as well as real. Studying ecological function is generally much harder than making structural measurements, and so is done less often in ecology. Studies designed to capture data about the structure of an ecosystem do not easily lend themselves to studies of ecological processes, different things have to be measured (Ross 2011) and it requires a distinct approach to make indicators out of ecological processes (Lester *et al*. 2011). In fact, many ecological processes often require experimental evidence to gain a full understanding of them. Fairweather (1999) proposed that applied ecologists need to do different sorts of studies to really capture the dynamism of ecological processes in their monitoring. He named the rate-based indicators he sought to develop “ecoassays” (in analogy to lab-based bioassays) but they typically do require at least two visits to a site (to deploy and then collect the ecoassay installations, Fairweather

1999), so there are additional logistical costs to the normal study that visits a site only once to measure what is there (whereas ecoassays measure what it is doing).

Probably the most widespread set of ecological interactions, which are studied more routinely than are others, concern the feeding of animals and hence the trophic interactions within a food web. Information about the trophic level at which organisms are obtaining their nutrition is an excellent surrogate for the ecological interactions of predation and herbivory, leading to concerns that where apex predators at the top of a natural food web disappear the resultant community may operate very differently (Estes *et al*. 2011). Likewise, the related idea of "fishing down food webs" (Pauly *et al*. 1998) has been put forward as an explanation for a trend seen in many fisheries where the species in the catch change over time, viz. the overall trophic level of the catch declines. So, it is not unusual to see monitoring data about species populations and community assemblages to be broken down into functional feeding groups as a way of interpreting what the trophic interactions are doing.

Some of the ecological processes that might lend themselves to ecoassay-type indicators of rates given in Table 1 might actually give more information about threats in the environment, e.g. bioaccumulation ratios *re* pollutants and invasiveness regarding exotic species. In this regard they relate to processes involving the organisms themselves but just measuring the density of an organism won't tell you about what is happening here without some further work (e.g. chemical body burden measurements for bioaccumulation or weighing up exotic versus native species for invasiveness). These are examples of how different styles of measurement and different ways of interpreting the information are both needed to get useful information from them.

In addition to indicators of ecological processes or ones that link across different levels of biodiversity, Table 1 also suggests that some may best indicate localised evidence of threats to biodiversity or pressures upon ecological processes. For example, the impact of human activities unbalancing some aspect of a natural system might be seen in unusual size frequency distributions (e.g. the truncation of age classes of fishes, see Stewart 2011) or other phenomena that are routinely measurable. The easiest to utilise of these indicators of unnatural process would have strong causal understanding of how they arise and what the risks are. Some examples could include the indicators in Table 1 linked to bioaccumulation of pollutants, rates of marine pest infestation, and evidence of eutrophication or other disruption of nutrient cycling. The raw data for compiling such indicator sets may well be collected already by the EPA or other state government agencies charged with regulating the impacts of interest, so their use for MPA performance assessment may even be more cost effective than collecting new data. In other cases, the causal links may be untested for Victorian waters and so an R and D exercise would be needed before adoption for use in monitoring these MPAs. Those research questions might be fruitful areas for ARC Linkage Grant applications in the future to fund such an evaluative exercise.

Section 3. Acknowledgements

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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.