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SETTING WATER QUALITY CRITERIA: BE A TORTOISE

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ABSTRACT

In general, water quality guidelines provide only narrative criteria for biostimulants, leaving regulators and managers in the position of having to set their own requirements, often based on a paucity of local data. Fortunately, numerical values for such materials and their effects can be sensibly established, and are generally quite widely applicable. Environmental values and associated criteria have been set for the Marmion Marine Park, an oligotrophic coastal area north of Perth, Western Australia, that receives treated wastewater from an ocean outlet. The criteria that have been established include traditional physical and chemical parameters, as well as a suite of biological parameters. Reference to these by regular measurement as well as simple ecosystem modelling and process studies, will form the basis of a regional water quality monitoring programme to be implemented by the Water Authority of Western Australia. The criteria themselves, as well as the process used in their development, have wide geographic applicability.

KEY WORDS

Water quality, criteria, nutrients, monitoring.

1 INTRODUCTION

The evaluation of water quality is presently a major task for resource managers worldwide. Conventionally, water quality is most easily assessed relative to a set of numerical and/or narrative criteria. However there is wide debate on the use of criteria expressed in such a manner for 2 main reasons. The first is the view that not all water bodies function in the same way, and the second is that for certain materials, especially biostimulants, the most appropriate management approach is not through the use of set numerical values on static concentrations, but on an understanding of overall environmental condition.

Both of these arguments have validity. However the consequence of the lack of desire to subscribe to specific criteria is that Water Quality Guidelines tend to skirt the issue of setting numerical criteria for materials such as biostimulants, and offer no more than the recommendation that these be evaluated relative to "variable local conditions", to be examined on a case by case basis. Further, to resolve acceptable receiving water conditions, the implementation of complex environmental studies and the development of ecosystem models are frequently offered as the panacea for grappling with "acceptable loading", with the overly optimistic view (authors' opinion) that the appropriate management strategies will fall out of the model. It is our experience in the coastal zone, and particularly in areas of relatively minor perturbation, that this approach alone is insufficient. Ecosystem models are not able to realise this level of discrimination between cause and effect. As a result, management of water bodies must be undertaken with a healthy blend of observation, monitoring, empirical comparison, and some ecosystem modelling.

Decisions must be made on criteria that are chosen to reflect selected environmental values, and these criteria must be set using best available information, accepting that these criteria can only but be improved as sound data continues to be obtained. Such an approach is mindful of the tortoise, whose motto in life is: "Stick your neck out, and proceed cautiously".

2 PERTH COASTAL WATERS STUDY

The Perth Coastal Waters Study (PCWS) which has been supported by the Water Authority of Western Australia (WAWA) has as one of its objectives to define acceptable environmental values and associated criteria in the vicinity of the discharges of its 3 ocean outlets. One of its outlets (discharge from Beenyup WWTP that enters the sea off Ocean Reef) discharges into the Marmion Marine Park thereby demanding a high standard of environmental management.

3 MARMION MARINE PARK

3.1 Defining Environmental Values (Or Beneficial Uses)

Management of the Marmion Marine Park is vested with the National Parks and Nature Conservation Authority (NPNCA), with advice from the management agency, the Department of Conservation and Land Management (CALM). The general uses of this Marine Park have already been defined through extensive public discussion, the management planning process, and approval by the Minister. (CALM, 1991). These uses are conservation, recreation, and education. The area is also used extensively for marine research.

The attributes of conservation are difficult to define in terms of environmental value or beneficial use. Rather, it is simpler to define conservation by utilising the three aims of the World Conservation Strategy (which have been adopted by Federal and State governments). These are to:

- Maintain essential ecological processes and life support systems.
- Preserve genetic diversity.
- Ensure sustainable utilisation of species and ecosystems.

The following beneficial uses were identified for the area, and are intended to incorporate these principles, as well as to protect recreational and other uses. These uses include a further subdivision of five principal environmental values proposed by ANZECC. (ANZECC, 1992).

Conservation of flora and fauna (over the entire Marine Park)
- Protection of aquatic ecosystems.
- Maintenance of ecological function.
- Maintenance of biodiversity.

Contact recreation over the entire Marine Park (but noting that the most significant activities are swimming and surfing in the nearshore region and SCUBA diving and snorkelling on the reefs).

Fishing
- Collection of benthic organisms such as abalone, lobsters, and filter feeders such as mussels.
- Line fishing for pelagic species, including mullet, whiting and squid.
- Spearfishing for larger fish and lobsters, which is allowed in about half the marine park area, but not within about 2.5 km of the shore.

Aesthetic/landscape values
- Avoidance of visual contamination of the area as viewed from either the shore or boats.
- The need to cater for the expanding importance of a tourism industry, including catering for observational diving and whale watching in the area.

The philosophy was adopted that the presence of a known 'perturbation' should not be allowed to exclude the selection of a desired beneficial use for an area. Therefore in defining the above beneficial uses, existing or potential perturbations have been ignored: only those uses that are desired have been considered. Where 'perturbations' already exist or may occur in the future, these can be managed; for example by reducing the perturbation or considering exclusion zones. Such decisions are a matter for the appropriate management authority in consultation with all relevant parties.

3.2 Defining Acceptable Environmental Conditions, Or Criteria

The frame of reference for defining acceptable environmental conditions to protect each of these beneficial uses is an 8-level system that was prepared to describe various grades of environmental condition that could occur (Table 1). The NPNCA has indicated that for the Marmion Marine Park level 3 would be acceptable, and that level 4 could be acceptable with appropriate support.

The beneficial uses of Contact Recreation, Fishing and Aesthetic/Landscape Values have been broadly grouped under the heading of 'Sustainable use of species and ecosystems'. (ANZECC, 1992). To achieve these beneficial uses obviously requires meeting the criteria for the level of protection for Conservation, but because they are entirely concerned with human uses and perceptions, additional criteria are required for the levels of contaminants in water used for contact recreation, the levels of contaminants in aquatic organisms harvested for human consumption, and the aesthetic standards demanded of a marine park. Unlike criteria for Conservation they are not graded: they are either considered acceptable or unacceptable.

4 ESTABLISHING CRITERIA

A series of criteria have been established for the Marmion Marine Park that incorporate this 8-level system, and that include both the more traditional physico-chemical criteria, as well as biological criteria. These criteria are shown in Tables 2, 3 and 4. Clearly incorporating biological criteria represents a more integrated mechanism of measuring water quality, and therefore provides a sounder procedure for the preservation of ecological function. However, biological assessment of water quality is traditionally more difficult, due to:

- Natural variability inherent in ecosystems, and therefore the difficulty of detecting small changes.
- Need for the selection of the correct component of ecosystem to be measured.
- High level of costs and expertise required for sound ecological monitoring.

The criteria were developed from information from a number of different sources, including the detailed field and laboratory measurements that have been made as part of the PCWS, historical information collected along this part of the coast, as well as from published information for similar or comparable conditions.

The biological criteria are relevant mainly to the impacts of nutrient enrichment. Further, these biological criteria have been biased in a conservative manner, accepting that any reduction of nutrient loads to nearshore regions that may be required could take 5 years or more after perturbations have been observed. Biological parameters are also classified according to habitat type (sand, reef, seagrass) and include the use of artificial substrata at selected monitoring sites.

5 USE OF CRITERIA - MONITORING

The criteria that have been established have a far wider geographic application than the local WA coast. These criteria will form a major reference for the 5 year Ocean Outfall Performance Monitoring Programme (1996-2001) proposed to be undertaken by WAWA, which will include regular monitoring, continued development of the COASEC ecological model developed for the area, and selected process studies.

Further, the interpretation of a suite of criteria will require further definition. For example, additional nutrient effects could cause one, some of, or all of, an increase in periphyton, an increase in algae, change in algal community structure, increase in water column chlorophyll a, an increase in light attenuation, and increases in sediment nutrient recycling. Combined index procedures are being considered to interpret the overall effect on a variety of different attributes in an ecosystem.

6 CONCLUSION

In many, if not most of our coastal environments, there is information that can be used for developing and establishing sets of criteria that enable environmental value to be assessed. Further, this information is more widely applicable than a single geographic area and we should not be nervous about using numerical criteria for evaluating nutrient effects. Managing coastal systems exposed to nutrients will certainly require more than just looking at results from monitoring programmes though, and will be most successful when undertaken using a blend that contains monitoring, systems modelling, process studies, along with a large slice of realism.

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Table 1 Levels of environmental impact and associated changes in Marmion Marine Park

LEVEL	ENVIRONMENTAL CHANGE
1. Return to a pristine condition	Current levels of use, as well as accepted management objectives of the Park (including recreational use and fishing) mean that restriction to this level of impact cannot be achieved. It is also difficult to determine what constitutes a pristine system.
2. No detectable changes in water quality or ecology compared to the present status of the Park.	Documenting the present status of the Park will require a thorough description of the current environment and appropriate, regular monitoring of the water quality and floral and faunal diversity and community structure. Changes in recreational use and its influence on ecological conditions will need regular assessment.
3. Detectable changes in water quality outside of the initial mixing zone that do not exceed the beneficial uses criteria, with no detectable changes in either species abundance or diversity, and no loss of ecological function.	The assumption is made that alterations in species diversity, species abundance or ecosystem processes would not occur before detectable changes in water and sediment quality. This level of change would permit changes in water quality in the area of discharge from the outlet that do not exceed the beneficial use criteria for the area. This would require consistently very high water quality. Regular monitoring of the environment would be required to confirm that no statistically significant changes occur in either water quality or community structure and diversity with time.
4. Detectable changes in water quality outside of the initial mixing zone that exceed the beneficial uses criteria, but no detectable changes in either species abundance or diversity, and no loss of ecological function.	This level of change would permit excedance of water quality if that did not entail a loss of ecological function, species diversity or species abundance. The level of water quality variation would therefore need to be within the range of natural variation in the system. To ensure this level of change is not exceeded would require both monitoring of water quality and comprehensive community modelling.
5. Detectable changes in water quality outside of the initial mixing zone, and detectable environmental impact confined to the mixing zone only involving changes in species abundance but not species diversity.	Changes in water quality would be permitted to the point that some loss of species abundance in the mixing zone occurred. A decrease in abundance of those species in the remainder of the Park would not be acceptable. Monitoring would need to be capable of determining the changes in water quality, the changes in species abundance and the spatial extent of the change. It would also need to be capable of demonstrating no loss of ecological function.
6. Detectable environmental degradation on a broader scale (ie outside the mixing zone) and impacting on a significant proportion of the Park, but again confined to changes in species abundance and not diversity, and with no detectable loss of ecological function.	Changes in water quality would occur beyond the mixing zone but some loss of species abundance in the mixing zone only would be permitted. The total absence of any species present elsewhere in the Park would not be acceptable. Monitoring would again need to be capable of determining the changes in water quality and the changes in species abundance and the spatial extent of that change. It would also need to be capable of demonstrating no loss of key ecological function.
7. Detectable deterioration in species abundance and diversity, but maintenance of the KEY ecological processes.	It may be that a loss of some species diversity and abundance can occur without compromising the KEY ecological processes. For example the loss of a minor species of red alga may not affect the overall ecological function of the reef macroalgal community. The level of change must be confined to species level rather than community level and must not affect the overall function of he community to which that (or those) species belongs.
8. Detectable deterioration in species abundance and diversity, and a loss of some KEY ecological processes. This constitutes UNACCEPTABLE environmental change.	Changes in water quality leading to a loss of species abundance and/or species diversity to the extent that this results in a loss of key ecological functions. This requires a clear definition of what the key ecological processes are, and appropriate monitoring of water quality, biotic assemblages and the ecological processes of concern.

Table 2 Proposed water quality criteria for the Marmion Marine Park: physico-chemical parameters. Water column values are expressed for the important summer period only. All values relate to median concentration and 90th percentile. All data in μgL1 unless stated otherwise. Data from chifflings 1979, Hillman 1986, Hillman et al 1994 (a) and 1994(b)

Parameter	'Background' NPNCA Levels 1/2	'Healthy' ecosystem NPNCA Level 3	'Healthy' ecosystem NPNCA Level 4	Mildly degraded ecosystem NPNCA Levels 5/6	Moderately degraded ecosystem NPNCA Level 7	Grossly degraded ecosystem NPNCA Level 8
WATER						
Toxic and bioaccumulated chemicals	Limited data available	ANZECC (1992)	ANZECC (1992)	x2 ANZECC values	x5 ANZECC values	x10 ANZECC values
Dissolved inorganic nitrogen (DIN):	13, 23	15, 30	15, 30	20, 40	30, 60	40, 100
Total kjeldahl nitrogen (TKN):	260, 300	280, 320	280, 320	300, 450	350, 600	400, 800
Soluble reactive phosphorus (SRP):	3, 5	5, 10	5, 10	8, 15	12, 15	15, 25
Total phosphorus (TP):	12, 17	15, 25	15, 25	20, 40	30, 60	40, 80
Chlorophyll a:	0.4, 1.2	0.6, 1.5	0.6, 1.5	1.0, 2.5	1.5, 4.0	2.0, 5.0
Light attenuation (m^{-1})	0.20	< 0.22	< 0.22	0.22-0.24	0.24-0.26	>0.26
SEDIMENTS						
Toxic and bioaccumulated chemicals	'Background' median values (BM) to be determined	Median <75th percentile of background values	Median <75th percentile of background values	Median >75th percentile of 'background' values. Proceed to Tier 1 of sediment assess. (see text)	-	-
Sediment characteristics, including Particle size distribution, TOC, TKN, TP, FRP, interstitial waters, eH, nutrient release rates, sediment oxygen demand	'Background' median values (BM) to be determined for all parameters	Median <75th percentile of background values for all parameters	Median <75th percentile of background values for all parameters	2 x BM values for all parameters	2-5 x BM values for all parameters	> 5 x BM values for all parameters

Table 3 Water quality criteria: biological parameters for Marmion Marine Park. Data from Kinhill (1994) and Walker et al (1993)

Habitat and parameter	'Background' NPNCA LEVELS 1/2	'Healthy' ecosystem NPNCA LEVEL 3	'Healthy' ecosystem NPNCA LEVEL 4	Mildly degraded ecosystem NPNCA LEVELS 5/6	Moderately degraded ecosystem NPNCA LEVEL 7	Grossly degraded ecosystem NPNCA LEVEL 8
PERIPHYTON COLLECTORS						
• Periphyton load (g dw/ unit substrate)	control site mean (CM)	0-200% of CM	0-200% of CM	>200% of CM	>200% of CM	>200% of CM
• Periphyton carbonate content (% of periphyton dry weight)	22-40%	22-40%	22-40%	15-20%	10-15%	<10%
SEAGRASS MEADOWS						
• Seagrass shoot density	control site mean (CM)	75-100% of CM	75-100% of CM	50-75% of CM	25-50% of CM	<25% of CM
• Epiphyte load (g dw/unit seagrass)	control site mean (CMn)	0-200% of CMn	0-200% of CMn	>200% of CMn	>200% of CMn	>200% of CMn
• Epiphyte carbonate content (% of epiphyte dry weight)	22-42%	20-40%	20-40%	15-20%	10-15%	<10%
• Invertebrate community structure.	Non available as yet.	-	-	-	-	-
SAND						
Use periphyton collectors						
MACROALGAL STANDS						
• 'Nuisance' algal biomass as % of total algal biomass: reef kelp	0-2%	0-4%	0-4%	5-10%	10-50%	> 50%
- reef assemblage	0-15%	0-15%	0-15%	15-25%	25-75%	> 75%
- pavement assemblage	0-15%	0-15%	0-15%	15-25%	25-75%	> 75%
- coastal platform kelp	0-2%	0-4%	0-4%	5-10%	10-50%	> 50%
• Invertebrate community structure	Non available as yet					

Table 4 Criteria for sustaninable utilia\sation of species and ecosystems. AFSC = Australian Food Standards Code, 1992, and WAHFR = Western Australian health Food Regulations, 1987

PARAMETER	GUIDELINE VALUES
Microorganisms in water	
Primary contact:	ANZECC (1992) values.
Secondary contact:	ANZECC (1992) values.
Toxicants in Water	
Primary contact:	NPNCA Level 3 values (see Table 2).
For the harvesting of seafood for human consumption:	ANZECC (1992) values.
Microorganisms in filter feeders:	AFSC and/or WAHFR.
Microorganisms in finfish:	No criteria exist.
Metal concentrations in filter feeders:	AFSC and/or WAHFR.
Metal concentrations in finfish:	AFSC and/or WAHFR.
Aesthetic parameters	ANZECC (1992) values