



**Cooperative Research Centre for Coastal Zone, Estuary & Waterway Management**

# **USERS' GUIDE TO ESTUARINE, COASTAL AND MARINE INDICATORS FOR REGIONAL NRM MONITORING**



**Report to DEH, MEWG, ICAG.  
Revised version, December 2004**

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This report was commissioned by the Australian Government Department of Environment and  
Heritage (DEH)  
For the Monitoring and Evaluation Working Group (MEWG) and  
Intergovernmental Coastal Advisory Group (ICAG).

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**Important:** The advice in this document is provided to the Monitoring and Evaluation Working Group for their consideration. It does not represent guidance that has been agreed to by the Monitoring and Evaluation Working Group. For agreed advice, please refer to the Australian Government's 'Natural Resource Management Monitoring and Evaluation and Standards and Targets' website ([www.deh.gov.au/nrm/monitoring](http://www.deh.gov.au/nrm/monitoring)).

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## SECTION 1 ESTUARINE, COASTAL AND MARINE INDICATORS FOR REGIONAL NRM MONITORING

The development and use of estuarine, coastal and marine indicators for regional NRM monitoring is directed by two national documents. Please refer to Appendix A and these documents for more information:

- National Framework for Natural Resource Management – Standards and Targets (2003) (<http://www.deh.gov.au/nrm/monitoring/standards/pubs/standards.pdf>)
- National Natural Resource Management Monitoring and Evaluation Framework (2003) (<http://www.deh.gov.au/nrm/monitoring/evaluation/index.html>)

The following document also provides some guidance on monitoring for natural resource management:

- Draft Users' Guide (Preamble) Monitoring and Reporting on Natural Resource Management (2003) (<http://www.deh.gov.au/nrm/monitoring/reporting/index.html#download>)

'Estuarine, coastal and marine habitat integrity' has been identified through the 'National Framework for Natural Resource Management – Standards and Targets' (2003) as one of ten matters for targets to be addressed by regional NRM groups. This matter is not defined in any greater detail in the national documents. For the purposes of identifying appropriate indicators for monitoring, we have considered this matter to encompass any natural resource management issue within estuarine, coastal and marine ecosystems. This geographic region is further defined in Section 2.

Two indicator headings are identified in the Monitoring and Evaluation Framework relating to this matter for target:

- (1) Estuarine, coastal and marine habitat condition; and
- (2) Estuarine, coastal and marine habitat extent and distribution.

This document serves to further specify indicators under these headings.

### Why is the natural resource condition of estuarine, coastal and marine ecosystems to be monitored?

Two major components of the National Monitoring and Evaluation Framework require the monitoring of natural resource condition, but for different reporting needs.

The purpose of monitoring the indicators identified in this document is to assess the performance of programs, strategies and policies in terms of their achievements towards improved natural resource condition (see right hand side of Figure 1.1). Specifically, these indicators will: "be used to monitor changes in resource condition associated with each program, strategy or policy" (*National Natural Resource Management Monitoring and Evaluation Framework, 2003*)

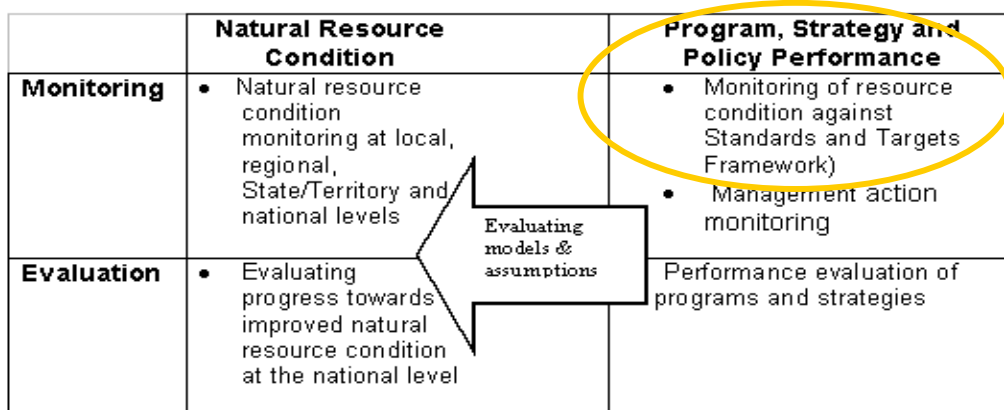


Figure 1.1. Monitoring and Evaluation Framework (*National Natural Resource Management Monitoring and Evaluation Framework, 2003*; <http://www.deh.gov.au/nrm/monitoring/evaluation/index.html>). The indicators described in this report have been developed to address the highlighted section.

The left hand side of the framework 'Natural Resource Condition' also requires the monitoring of natural resource condition, but at scales from local to national, and monitoring that is not necessarily targeted at assessing the effectiveness of regional-scale management actions. This is to be used to assess, on a national scale, the state of Australia's natural resources and the effectiveness of national strategies. The data and indicators used for this assessment may be the same as those used for regional-scale reporting and assessment of regional NRM programs. That is, the activity of collecting data on indicators of natural resource condition may actually be one-and-the-same for both parts of the framework (collected only once), but the data may be used and reported differently.

The indicators in this document are not necessarily designed for the other elements of the framework:

- Management action monitoring;
- Performance evaluation of programs and strategies;
- Natural resource condition monitoring at local, regional, State/Territory and national levels (although some indicators identified herein may also be useful for this type of condition monitoring); and
- Evaluating progress towards improved natural resource condition at the national level.

### **Purpose and structure of this document**

The estuarine, coastal and marine indicators package is designed to assist in the identification and selection of indicators that are relevant to a specific NRM region to meet the monitoring needs specified under NHT2 (Natural Heritage Trust) and NAP (National Action Plan for Salinity and Water Quality).

The matter to be addressed through these indicators is: 'Estuarine, Coastal and Marine Habitat Integrity'. We consider this to refer to the ecosystems (habitats and communities) within the estuarine, coastal and marine biomes.

The purpose of these indicators is to monitor the impact of specific regional management actions on natural resource condition within the estuarine, coastal and marine ecosystems. It is intended they will be used by regional NRM bodies (and other groups) to assess the performance of their management actions.

The Monitoring and Evaluation Working Group (MEWG) has specified that these indicators directly assess the condition of natural resources, rather than the pressures upon them. Please refer to Section 3 for a discussion on pressure indicators.

This document intends to build upon the significant work already undertaken in developing indicators. It does not seek to invent new indicators, but rather bring together relevant indicators and other information about estuarine, coastal and marine ecosystems to meet the monitoring needs for regional NRM monitoring as specified by the MEWG.

Whilst this document does intend to provide users (primarily regional NRM groups) with advice on appropriate indicators for assessing the impact of actions on natural resource conditions, including advice concerning methodologies for using the indicators, we recommend users take advantage of expert advice regarding monitoring of natural resources available to them through the relevant State/Territory agencies. These agencies may provide additional information about the use of indicators in specific regional contexts.

This document does not address the process of how regional groups should identify which NRM issues are important in their region. See below for further discussion.

The use of this document for setting regional natural resource condition targets is also discussed on the following page.

## **Regional variability**

To meet the objective of monitoring changes in natural resource condition in response to management actions, it is anticipated that different coastal NRM regions will have different monitoring needs because:

- (1) NRM issues, and therefore the management actions implemented to address them, will vary between coastal NRM regions; and
- (2) Habitats and communities that exist within the estuarine, coastal and marine continuum will vary between coastal NRM regions.

At the same time, a key objective of the monitoring and evaluation framework is that specific indicators that are used in multiple NRM regions should be nationally consistent to allow for comparisons and maximise efficiency of effort.

To allow for the regional variability in ecosystem types as well as NRM issues, we have developed a framework for selecting indicators, which are accompanied by guidelines for their use. This framework allows users the flexibility to monitor NRM outcomes by using indicators that are relevant to their regional ecosystems and NRM issues, while using consistent monitoring approaches.

The framework for the selection of estuarine, coastal and marine ecosystem extent and condition indicators is based on coastal NRM issues, so that regional NRM groups monitor only indicators relevant to their issues and corresponding management actions. The framework also considers the range of ecosystem types present (and that appropriate indicators may differ in different ecosystem types).

Because NRM issues can be identified at a range of spatial and temporal scales, rather than attempting to identify all of these issues, we have used a defined number of 'stressors' in the framework. Section 3 provides more information on stressors.

The framework does not identify indicators in relation to specific community held values, but rather identifies indicators for specific stressors in the environment. These stressors will be the targets of management actions, which are in turn influenced by community values. It is assumed that regional NRM groups will use appropriate methods to identify management actions, including identifying community held values for the use of regional natural resources.

## **Identifying NRM issues relevant to a region**

The selection of indicators using the guidance provided in this document requires users to have already identified the NRM issues important to their region and to be addressed through their NRM plan. These NRM issues should have been/are being identified during the development of the regional NRM plans. This document does not provide guidance on how to identify which NRM issues are important for a region. However, Section 3 provides lists of NRM issues that may exist. These may assist NRM regions in identifying potential NRM issues for further investigation.

Advice and data on whether a NRM issue is important in a particular region can be obtained from a range of sources – some of these data and information sources are listed here.

State/Territory Government Departments – see 'References' section for details.  
Local/Regional community groups/activities (e.g. Waterwatch). Most regional NRM groups will have contact details for the community-based groups in their region.  
OzEstuaries website ([www.ozestuaries.org](http://www.ozestuaries.org))  
National Pollutant Inventory ([www.npi.gov.au](http://www.npi.gov.au))  
National Land and Water Resources Audit (NLWRA) ([www.nlwra.gov.au](http://www.nlwra.gov.au))  
Australian Coastal Atlas ([www.deh.gov.au/coasts/atlas](http://www.deh.gov.au/coasts/atlas))  
Australian Natural Resources Atlas (<http://audit.deh.gov.au/ANRA>)  
Oceans Portal, National Oceans Office ([www.oceans.gov.au](http://www.oceans.gov.au))  
Data Centre at CSIRO Marine Research ([www.marine.csiro.au/datacentre/](http://www.marine.csiro.au/datacentre/))  
Australian Spatial Data Directory (ASDD) (<http://asdd.ga.gov.au/asdd/>)



## Setting regional natural resource condition targets

The Australian Government provides guidance on setting regional natural resource condition targets in several documents (see above) and from their website (<http://www.deh.gov.au/nrm/monitoring/>).

“Setting targets requires the identification of a baseline - the level against which progress will be measured. Regional bodies will need to draw together baseline data for those matters for targets they have identified as relevant to their region. Ideally, baselines should be quantified as fully as possible, and should relate to trends going back over several years rather than a single point-in-time measurement.” (*Using the National Standards and Targets Framework and the National Monitoring and Evaluation Framework*, Natural Resource Management Ministerial Council, 2002, [www.deh.gov.au/nrm/monitoring/reporting/index.html#different](http://www.deh.gov.au/nrm/monitoring/reporting/index.html#different))

This advice suggests that any guidance provided on indicators for natural resource condition may be useful for setting targets. This document identifies indicators of natural resource condition that are expected to change in response to targeted management actions. It is these aspects of the environment that should be the focus of regional targets of natural resource condition. The information provided here will also provide guidance on setting quantitative values against the targets – either by referring to existing guidelines or by recommending baseline monitoring to establish changes over time.

## Links to other matters for target

The Matter for Targets addressed here, ‘Estuarine, coastal and marine habitat integrity’ has links with some of the other Matters for Targets either because:

- they are adjacent habitats and therefore impacts to one may affect the other; or
- they recommend common or related indicators.

Appendix A provides the complete list of Matters for Targets and the indicators identified to date.

The table below identifies which of the Matters for Targets have links with the ‘Estuarine, coastal and marine habitat integrity’ Matter for Target. Refer to the Australian Government website for more information about these other Matters for Targets (<http://www.deh.gov.au/nrm/monitoring/>).

Matter for Targets	Links to ‘Estuarine, coastal and marine habitat integrity’ Matter for Target
Land Salinity	
Soil condition	
Native vegetation	Yes
Inland aquatic ecosystems integrity	
Estuarine, coastal and marine habitat integrity	-
Nutrients in aquatic environments	Yes
Turbidity/suspended particulate matter in aquatic environments	Yes
Surface water salinity in freshwater aquatic environments	
Significant native species and ecological communities	Yes
Ecologically significant invasive species	Yes

## Where to start with this document?

The key steps to using this document to assist in identifying indicators of changed natural resource condition in response to management actions are listed below and summarised in Figure 1.2.

1. Familiarise yourself with the nature of the estuarine, coastal and marine ecosystems in your NRM region. Each coastal NRM region will have different habitats and communities present. Section 2 provides some basic information about the types of habitats and communities present in estuarine, coastal and marine ecosystems around Australia.
2. Use the NRM issues identified in your regional NRM plan, (i.e. important NRM issues to be addressed through management actions over coming years), to identify which of the 15 stressors listed in Section 3 are important or relevant to your NRM region of interest.
3. Using Section 3, for each selected stressor, identify the possible indicators under the three indicator categories (Physical-Chemical condition, Biological condition and Habitat extent). For some stressors, more than one indicator may be recommended. In this case, use the 'Indicator profiles' information provided in Section 4 to choose the most appropriate indicator for your situation.
4. Refer to the 'Indicator profiles' information provided in Section 4 to obtain information which will help identify which of the possible indicators may be most applicable, based upon the resources available, the complexity of the indicator (in terms of data collection, and data interpretation and analysis) and whether other organisations may already collect data for this indicator. These profile sheets will also provide guidance on standard methodologies for using the indicator.

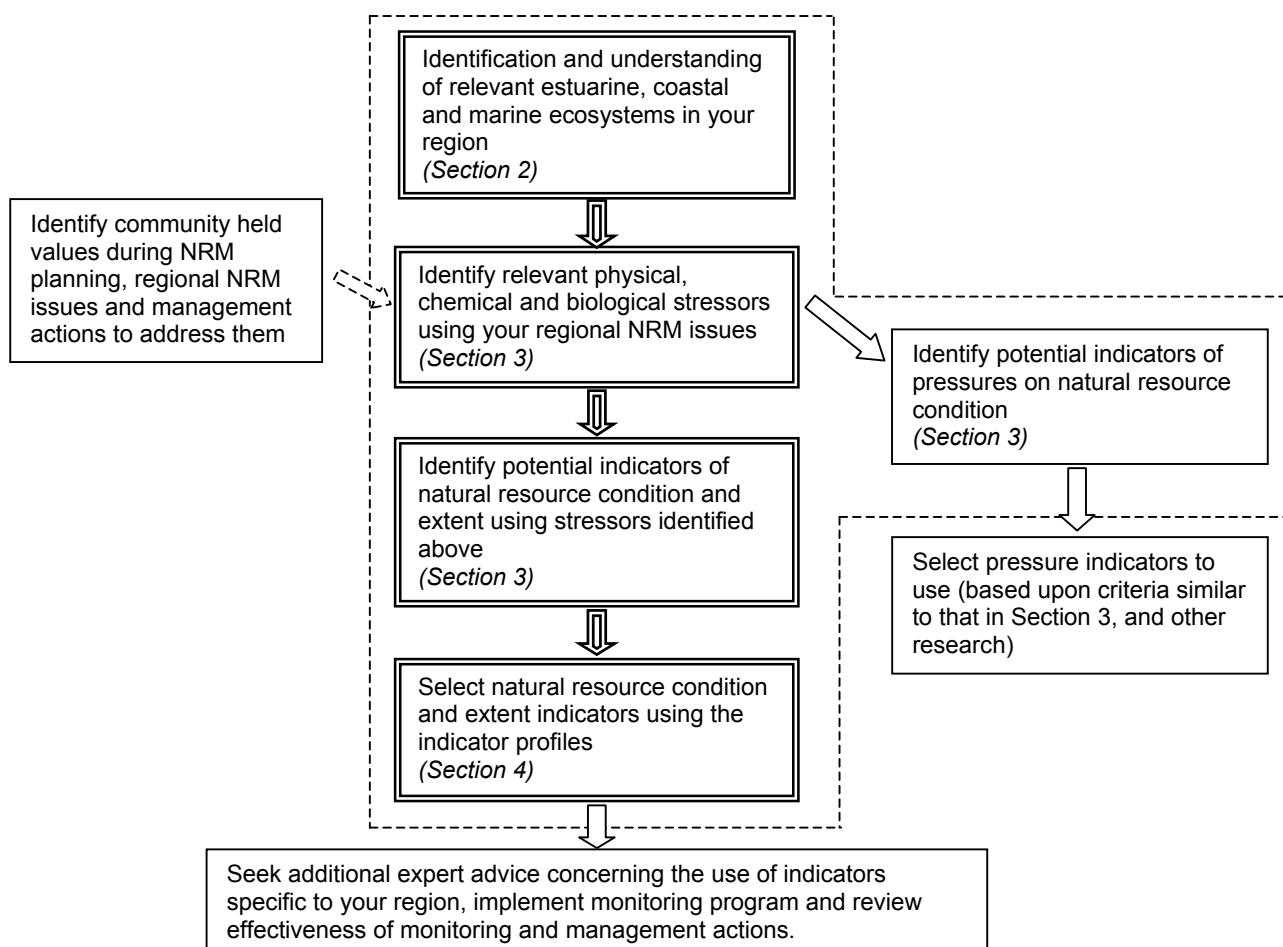


Figure 1.2. Overview of process for selecting estuarine, coastal and marine indicators for regional NRM monitoring. This document addresses the actions within the dashed box.



## SECTION 2 ESTUARINE, COASTAL AND MARINE ECOSYSTEMS

Estuarine, coastal and marine ecosystems form a continuum comprising a diversity of habitats and communities, extending from the landward influence of saltwater out to the oceans. The importance of these ecosystems and the types of communities and habitats that exist within estuarine, coastal and marine ecosystems have been described in the State of the Environment Report (2001) and excerpts are included below.

With respect to the seaward extent of estuarine, coastal and marine ecosystems, NRM regions will define their own geographical area of interest. For the purposes of this project, we consider NRM regions may extend to three nautical miles off the coastline, therefore potentially including marine ecosystems but excluding ecosystems beyond the continental shelf (i.e. deep water marine ecosystems).

*Excerpts from State of the Environment, 2001, Coasts and Oceans Theme Report*  
(<http://www.deh.gov.au/soe/2001/coasts/index.html#download>):

Australia's very diverse marine and estuarine habitats range from small estuaries to the extended continental shelf, and from the tropics to the Antarctic and to the island ecosystems of Australia's external territories. The familiar coastal habitats of beaches, dunes, rocky shores, seagrass beds, algae-covered reefs and even mangrove swamps occur in most of the mainland states. These habitats are the home of a wealth of fauna and flora, most of which is found only in Australia. For example, Australia has:

- the world's largest areas and highest species diversity of tropical and temperate seagrasses,
- one of the largest areas of coral reefs,
- the highest mangrove species diversity, and
- the highest levels of biodiversity for a number of types of marine invertebrates.

Indigenous peoples have been custodians and users of Australia's marine environments for thousands of years, and cultural associations remain strong. From an Indigenous perspective, the sea is not additional to but part of their traditional territory. With some 150 groups whose country abuts the coast and includes the sea, the cultural associations of coasts and oceans are thus of very high significance to Indigenous Australians.

In many respects Australia is established around the coastal rim of the continent, and the coastal and marine environment is important to the culture and lifestyle of Australians and visitors. In 1996 around four out of five Australians lived within 50 kilometres of the coast, in cities and towns on the coastal fringe. The coastal zone is used for activities such as settlement, industry, agriculture and mariculture. The ocean environment supports a number of activities, including petroleum mining and commercial fishing.

Some Australians appreciate where this environment is fragile and where it is resistant to human influence, but relatively few know of the importance to our economy of the shipping and port industries, and of the economic value added to Australia by marine tourism and the seafood industry.

Marine resources have considerable economic value and contribute to Australia's economy. The gross value of fisheries production in 1999-2000 was \$2.3 billion (ABARE, 2001). The size of economic activity of the major marine industries is estimated to be more than \$30 billion annually (Greiner *et al.*, 1997). Marine tourism and recreation is estimated to contribute 50% to the economic activity; oil, gas and engineering 27%; shipping, transport and ship building 13%; and commercial fishing and aquaculture 5%.

Our marine environment also has an important role in the provision of ecosystem services. The concept of ecosystem services is a way of describing the functions (or

services) that come from the ecosystems that sustain or fulfil human life and that cannot be replicated in any other way. Some examples of ecosystem services are purification of air and water, biological breakdown of wastes, and recycling of wastes.

Interest in valuing ecosystems services has increased following a global study that estimated the economic value of 17 ecosystem services across 16 biological zones to be between US\$16-54 trillion per year ( $10^{12}$ ), with an average of US\$33 trillion per year (Costanza *et al.*, 1997). This valuation was in turn used to estimate an average value in 1997 for Australian marine ecosystems of US\$640 billion per year (Jones and Pittock, 1997).

Australia's marine and coastal systems depend on and influence global climatic and other systems. Changes in global systems like sea temperature or the major global ocean currents may have potentially unwelcome effects.

The marine environment differs in some crucial aspects from our terrestrial environment, in that most of the marine environment can be regarded as a common resource, to be used and enjoyed by people who do not possess an exclusive right to own or use the resource. This aspect of a common heritage is reflected in one of the principles for ecologically sustainable ocean use in Australia's Oceans Policy (Commonwealth of Australia, 1998a):

'the benefits from the use of Australia's common ocean resources, and the responsibilities, for their continuing health and productivity should be shared by all Australians'.

### **The coastline and beyond**

The shores include open coasts with rocky headlands, cliffs and sandy beaches, and sheltered coasts, bays and estuaries with muddy and sandy tidal flats. The predominant substrates around the coastline are sand, mud and rock. Dunes and sandy beaches feature most commonly, with tidal mudflats more evident in the tropical north. Rocky shorelines are limited, but are common along the southern margins of the continent. The coastline encompasses some 61,700 kilometres (including nearby islands) with variable physical characteristics around the country.

Australia's marine and estuarine habitats are diverse in nature, vary greatly in scale, and are interconnected in a variety of ways. Coastal and estuarine habitats are closely linked with upstream catchments and the associated land uses, all of which have an effect on the condition of these habitats. The concept of a land water continuum is also well established in the Indigenous worldview.

Some of the common communities and habitats that exist within the estuarine, coastal and marine continuum (to 3 nm offshore) are represented graphically in Figure 2.1 and described in the following text. It is important to recognise that not all coastal regions will have all communities and habitats described below, and some may have other less common habitats or communities which are not listed here.

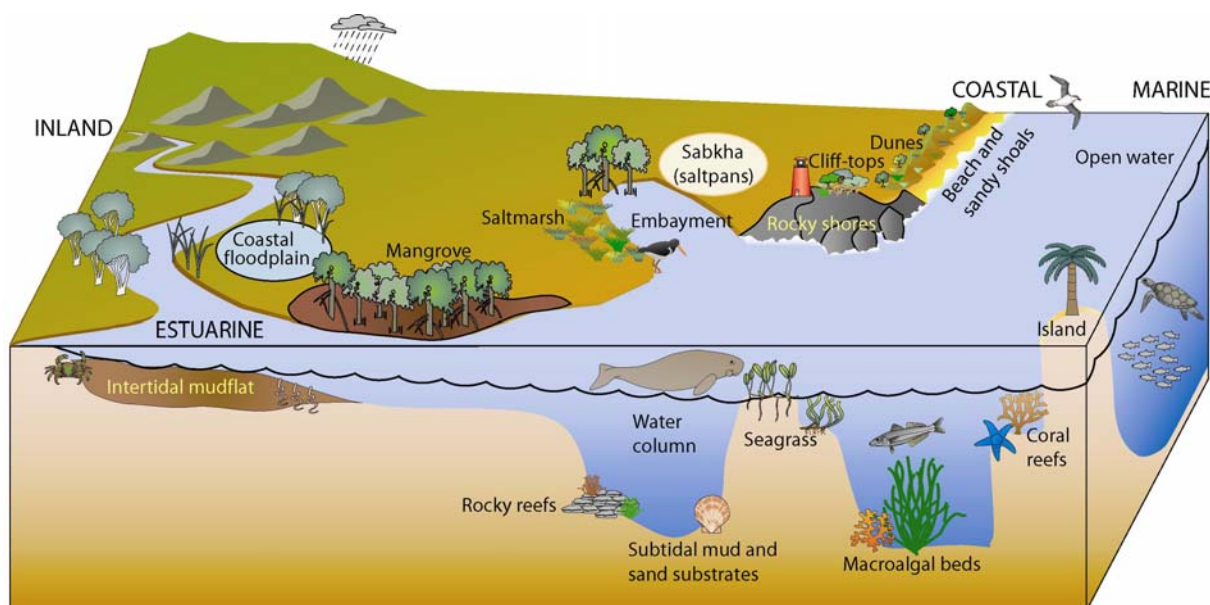


Figure 2.1. Common communities and habitats present within estuarine, coastal and marine ecosystems.

The following descriptions of estuarine, coastal and marine ecosystems are primarily modified from 'Where River Meets Sea: Exploring Australia's Estuaries' (Turner *et al.*, 2004). Other sources are referred to in the text below or in the 'References' section.

#### Seagrasses

Seagrasses are flowering plants (angiosperms) that grow rooted in soft sediments of marine and estuarine environments. They form a productive, widespread and ecologically important component of nearshore environments. Australia's coastline contains the largest and most diverse seagrass assemblages in the world. Seagrasses in Australia can be divided into those with temperate and those with tropical distributions, with the most diverse assemblages occurring where these zones overlap, e.g. Shark Bay in Western Australia. Seagrass areas are highly productive, meaning that they produce a lot of new plant material that supports large populations of animals. Nevertheless, only a few types of animals eat living seagrass. Dugongs and turtles graze certain tropical species, and seagrass is also eaten by sea urchins and other invertebrates (e.g. amphipods, snails), some fish species (e.g. garfish, luderick and leatherjackets) and birds (black swans, ducks and geese). The majority of organic matter and nutrients that supports seagrass food webs originates as detritus. The decomposition of seagrass litter is undertaken by vast populations of bacteria and fungi, which in turn are eaten by the small organisms that form the base of the predatory food web. Intact seagrass beds help to stabilise the sea floor, slow currents and reduce water turbulence, thereby facilitating the deposition of suspended sediments, limiting erosion and providing a safe haven for fauna. Seagrass stems and leaves provide hard surfaces in areas of soft sediment that are colonised by numerous organisms, such as algae, bryozoans and hydroids. Seagrass beds support a great variety of invertebrates such as sponges, anemones, bivalves, polychaete worms, starfish, sea cucumbers and crustaceans, including crabs, shrimps and yabbies. Cuttlefish, squid and a large number of fish species are predators in seagrass beds. By providing protection and food for juvenile fish and crustaceans, seagrass beds are vital for a variety of coastal fisheries around Australia. Some fish live in seagrass beds for their entire life cycle, some species spend their juvenile stage here and others come and go with the tides.

#### Mangroves

Mangroves are trees and shrubs that usually grow in soft sediments in the intertidal zone. They are specialised in a number of ways to cope with waterlogged soils deprived of oxygen and nutrients, and high levels of salt in the water. Extensive, though shallow, root systems help anchor the plant, and many mangroves have aerial roots (pneumatophores) that enable them to 'breathe'. The seeds of many mangrove species germinate while still on the parent tree which enables them to establish

rapidly without being washed away by the tide. Mangrove diversity reaches its peak in the tropics, which have some 37 species, and falls away rapidly to the south. The versatile grey mangrove (*Avicennia marina*) is the dominant species in temperate Australia and is the main species found in southern Western Australia, South Australia and Victoria. There are no mangroves in Tasmania. Mangroves provide physical protection of the coastal fringe from erosion, and trap sediments from overland run-off. Mangrove forests are highly productive ecosystems, producing a considerable amount of litter (leaves, twigs, bark, fruit and flowers) that provides nutrients and organic material to the mangrove food web. Some is eaten by crabs, but most is decomposed by bacteria and fungi. Larger particles are consumed by fish and prawns, while smaller particles are taken up by molluscs and small crustaceans. A considerable amount of detritus is also exported and provides an important source of food in many nearshore areas. Mangrove forests provide habitat for numerous terrestrial and marine animals, and important feeding areas for others. Polychaete worms and small crustaceans are common in the mud; bivalves, tubeworms and barnacles grow attached to wood; snails and crabs move about over the mud and in the trees, and fish move in with the tides to feed. The food and shelter provided by mangroves are vital for different life stages of many, perhaps most, commercially caught fish species in northern Australia. Because of their structural complexity and productivity, mangrove forests often support greater densities of fish than adjacent habitats.

### Saltmarshes

Saltmarshes are communities of low-growing herbs, shrubs and grasses tolerant of high salinity and poorly aerated soils that occur in areas where tidal inundation is regular but infrequent. They often form a mosaic of vegetated, low-lying mounds bordering shallow pools or hypersaline salt pans and are sometimes drained by small creeks. Most saltmarsh plants belong to a few widespread families, including the grasses, saltbushes and their allies, rushes and sedges. In contrast to mangroves, many more saltmarsh species are found in southern Australia than in tropical Australia, although individual estuaries are usually dominated by only a few species. The plant communities of saltmarshes often occur in distinctive zones and smaller scale patches, determined by a range of interacting physical and biological factors. Saltmarshes help maintain estuarine water quality by filtering sediment from land-based run-off. They provide organic matter to estuarine food chains, but are not as productive as seagrass or mangrove areas; nor are the animal communities in saltmarshes as diverse as those of adjacent habitats. However, they provide important habitat for some fish and aquatic invertebrates and a range of terrestrial species including insects and their larvae, spiders and lizards. These attract waterbirds such as herons, bitterns and egrets, waders and some bush birds. Saltmarshes are frequently covered by high tides and may support dense mats of algae that provide an additional food source for many fish and invertebrates. Shallow pools topped up intermittently by rain provide transitory feeding habitats for larval and juvenile fishes including several of importance to fisheries.

### Coastal floodplains

Coastal floodplains are areas associated with the lower reaches of rivers that are partially inundated by floodwaters and/or tides up to several metres above the high water mark. In regions with low relief such as the Gulf of Carpentaria, the coastal floodplain can be very extensive. Large areas of low-lying floodplain are inundated in periodic floods, less extensive areas are inundated with king tides and a smaller proportion are inundated with regular tidal events. Nutrients and sediments transported by rivers are deposited onto floodplains during inundation events. Algae that are present in soils become active when soils are hydrated and may contribute to the productivity of the floodplain food web, e.g. through nitrogen fixation. Evaporation following inundation events results in the formation of swamps and lagoons, including shallow marshes and deeper ponds and billabongs. These wetlands may be permanent, or may flood only on an intermittent basis and disappear entirely during dry periods. Salinity often increases from freshwater to brackish or saline throughout the year. Floodplain wetlands are important as breeding areas, dry season refuge and migration stopover points for many bird species. Vegetation includes grasses and sedges, *Melaleuca* species, waterlilies and other aquatic herbs. Floodplain communities are often bordered by eucalypt forests or woodlands, and saltmarsh or mangrove vegetation. Coastal floodplains are the most poorly understood ecologically of the coastal ecosystems.

### Sabkha (saltflats, salt scalds, salt pans)

(Modified from 'A Global Representative System of Marine Protected Areas', Chiffings, 1995)

Sabkhas is an Arabic name for saltflats. They are very saline, flat areas of sand and silt lying just above the hypersaline water table. It is a widespread inter- and supra-tidal habitat, measuring many kilometres across in places. It forms flat plains, with crusts of sodium chloride and gypsum, with

important algal mats a few centimetres thick, beneath which is a black reducing layer. The mats are complex associations of cyanophytes, bacteria and diatoms. Pools are a special feature of sabkha. The close proximity to the water table keeps the sand damp and thus limits wind erosion. They are found in arid South Australia and generally occur below high tide but are protected from inundation by sand barriers. Occasional small sand dunes, with vegetation growing on interstitial rainwater, occur on the saltpan. This is an extremely unfavourable habitat where evaporation exceeds rainfall, flooding via the sea or heavy rains/floods is rare and soil temperatures are high (may exceed 40°C). Species diversity is low. With increasing isolation from the sea, diversity falls and the persistent microbial biota then forms a typical mat. These are highly productive and fix nitrogen. When desiccated in summer, mats become dry and crisp, breaking into characteristic polygons.

#### Subtidal mud and sand substrates

Unvegetated, or 'bare' sand or mud beds occupy the greatest subtidal area of many estuaries, but these areas are by no means uniform. Variation in the type of sediment (e.g. from marine sand to mud), salinity, water depth, water movement and position in relation to other habitat types all strongly influence the biota of these areas. Subtidal sandy bottoms occur in more exposed areas, particularly in larger embayments. Muddy basins are associated with the sheltered conditions of many estuaries. Where light penetration is sufficient and the sediments sufficiently stable, a range of microscopic algae occupy the sediment surface. Many of these algae migrate up and down within the sediments to photosynthesise during the day and escape predation at night. Scavengers and organisms that feed on surface deposits dominate in unvegetated areas. Common invertebrates living in unvegetated muddy areas include prawns, bivalve molluscs, polychaete worms and small crustaceans. Prawns are opportunistic feeders that ingest bacteria, algae and tiny animal species during their juvenile stages. As they mature, small molluscs, crustaceans and polychaete worms also form part of their diet. Prawns and other invertebrates are also preyed upon by estuarine fish that live and feed in unvegetated areas. Juvenile fish also inhabit these areas, and may escape predation through schooling behaviour and camouflage, or because turbid conditions obscure them from predators. A different range of invertebrates is found in sandy areas. These include hydroids, seapens, bryozoans, sponges and molluscs such as scallops, as well as polychaetes and crustaceans. Fish such as flounder, flathead, whiting and sharks are also found on sandy bottoms.

#### Intertidal mud and sand substrates

Intertidal mudflats are formed by long-term deposition of fine silt and clay particles eroded from catchments. Gradual accumulation of particles in sheltered areas results in an almost flat, muddy shore extending some distance seaward from the high water level. Mudflats are more common and extensive in tropical Australia, where greater river flows carry large amounts of fine sediments and organic material to the coast. Mudflats have very poor drainage, and remain saturated with water at low tide. Bacterial decomposition of organic material depletes oxygen from all but the top few centimetres of sediment, below which the mud is black and sulphur-smelling due to anaerobic bacteria. Few animals are able to survive in these anoxic conditions and as a result most of the fauna of intertidal mudflats is found in the top few centimetres of sediment where oxygen is available. In this layer, a diverse range of tiny, mostly microscopic, animals inhabit the spaces between the sediments. The surface of the mud is also occupied by high densities of microscopic single celled and filamentous algae, which can help bind and stabilise the surface sediments. Larger invertebrates that construct and live in burrows and tubes, such as ghost shrimps (yabbies), soldier crabs and tubeworms, are able to live much deeper in the mud as these burrows are more readily flushed with oxygen-rich seawater. The larger animals living in mudflats are dominated by polychaete worms, small crustaceans, and snails, which feed mostly on detritus, algae and micro-organisms in the sediment. Intertidal mudflats are important feeding areas for birds, especially waders. Fish also move in to feed at high tide, but mudflats are not as important as mangrove and seagrass areas as nursery areas. People also use mudflats as a source of food and bait.

#### Rocky shore and reef ecosystems

Rocky shores and reefs are common in temperate Australia and are associated with a number of estuaries, particularly drowned river valleys and embayments. Subtidal rocky reefs are characteristically colonised by macroalgae (seaweeds) such as kelps. Unlike mangroves and seagrasses, these plants attach with simple holdfast structures, which are unsuitable for anchoring in soft sediments. Macroalgae are dominant in the temperate regions of Australia. Well over a thousand species occur along Australia's southern coastline, roughly three times as many as are found in the tropics. Rocky shores and reefs provide habitat for a diverse flora and fauna. Well-lit subtidal and

lower intertidal areas are dominated by algae, especially kelps. Where light levels are lower such as beneath kelp canopies, or at greater depths, red algae are more common. Shaded areas are dominated by sessile animals such as sponges, bryozoans, anemones and hydroids, ascidians (sea squirts) and barnacles. Many motile invertebrates are also common including molluscs, echinoderms (starfish, sea urchins, sea cucumbers), various polychaete worms and crustaceans. The abundance and variety of food, and physical diversity of rocky reefs enable an abundant and diverse fish fauna to inhabit these areas including larger juveniles of many species. Rocky shores are a much less favourable habitat. Exposure at low tide to desiccation, high temperatures and bright sunlight makes survival difficult. Moving up the shore, algae become smaller with only encrusting species present at the top of the tide. Many animals have adapted to inhabit rocky shores, such as crabs, predatory and grazing snails, flattened grazing molluscs (limpets, chitons), oysters and barnacles. Various birds feed on exposed rocky shores at low tide.

#### Coral reefs

Corals are not normally associated with estuaries. In general they are intolerant of freshwater, sensitive to turbidity and sedimentation and need a hard substrate to colonise. Corals are tropical organisms, patchily distributed along temperate coastlines and almost entirely absent from Australia's southern coast. Most tropical estuaries present extremely unfavourable conditions for coral establishment and growth. Nevertheless, corals can be found in several estuarine bays such as Moreton Bay and Hervey Bay. Nearshore corals reefs along much of the Great Barrier Reef are also subjected to 'estuarine' conditions when rivers are in flood and carry freshwater, nutrients and sediments some distance offshore. Coral reefs support unique and diverse fish and invertebrate communities, and are sensitive to environmental disturbance, particularly increased sediment and nutrient concentrations in the water.

#### Beaches and dunes

Dunes are generally characterised by *Spinifex* grasses, pig face (*Aizoaceae*) and *Casuarina*, *Banksia* and/or *Acacia* trees growing on a relatively infertile sandy substrate. Survival is hard in these areas due to the high amount of wind and salt spray, sand remobilisation and the low water holding capacity of the sandy soils. Dunes often form important habitat for sea turtle and wader/shorebird nesting sites. They act as barriers to erosive on-shore wind and wave action and their vegetation helps to stabilise windblown sand. However, due to these high winds and loose sandy soils, dunes are particularly vulnerable to erosion, particularly if vegetation is removed. Physical disturbance and construction on and around dunes will have serious impacts on the success on turtle/bird nesting.

Sandy shoals and beaches are characteristically found near estuary mouths where coastal wave energy is high and there is a sufficient supply of sandy sediment from terrestrial or marine sources. They are much more common in temperate than tropical Australian estuaries. Sand particles vary from predominantly river-derived quartz grains in eastern Australia, to carbonate sands of marine origin in the south and west. Because the size of sediment particles is related to the speed of water movement over the bottom, sandy shoals and beaches are much more dynamic habitats than muddy bottom areas. Within sandy areas, particle size varies, affecting the tiny animals and plants that live amongst the sand in two main ways. Larger particles are associated with larger spaces between adjacent particles, which provide habitat for many small species. Coarse sediments are also better flushed and oxygenated and animals are able to live deeper in the sediments. Sandy shoals and beaches tend to contain fewer (and different) invertebrates than mudflats. They are inhabited by microscopic plants that live on or near the surface of the sediment or migrate between the water column and the sand. Bacteria and fungi actively decompose organic material within the sand. A diverse range of tiny, streamlined animals live between the sand particles. Larger invertebrates burrow into the sand, predominantly molluscs, polychaete worms and crustaceans. These animals are adapted to an ever-changing environment and are able to reburrow rapidly following disturbance, e.g. during storms. Extensive intertidal and shallow subtidal sandy shoals are also used by a variety of fishes such as flathead and sand whiting.

#### Water column and open water

The majority of life inhabiting the open waters of estuaries goes completely unnoticed by the casual observer. In fact, estuarine waters are teeming with life, but most of it is too small to be seen with the naked eye. The millions and millions of tiny organisms that inhabit estuarine waters are collectively known as plankton. These include microscopic bacteria, plants and animals, and a range of single celled organisms (protists) that are often something in between an animal and a plant. The



phytoplankton (plant plankton), which includes cyanobacteria and photosynthetic protists, use light energy and simple chemicals in the water to grow and multiply. These are then eaten by a range of tiny animals and protists (the zooplankton), which provide food for larger zooplankton and so on up the food chain. In this way, the phytoplankton form the basis for the productivity of estuarine waters. The zooplankton includes larval forms of many familiar animals including sea urchins, snails, crabs, lobsters and fish, as well as many species that spend their entire life in the plankton. The open waters of estuaries serve as feeding grounds for pelagic fish such as tailor, fish-eating birds such as sea eagles, terns, gulls and cormorants, and mammals such as dolphins and even whales.

#### Cliffs and cliff-top communities

(UK Biodiversity Group Tranche 2 Action Plans - Volume V: Maritime species and habitats, October 1999)

Coastal cliffs and slopes comprise sloping to vertical faces on the coastline where a break in slope is formed by slippage and/or coastal erosion. There appears to be no generally accepted definition of the minimum height or angle of slope which constitutes a cliff, but the zone defined as cliff-top should extend landward to at least the limit of coastal influence (i.e. limit of salt spray deposition), which in some exposed situations may continue for up to 500 m inland. Cliff profiles vary with the nature of the rocks forming them and with the geomorphology of the adjoining land. While most coastal cliffs have been formed by coastal erosion, steep slopes falling to the sea in mountainous districts may have been formed long before the sea level reached its present position; in such cases only the lower part of the slope will have been steepened by the sea.

Coastal cliffs can broadly be classified as 'hard cliffs' or 'soft cliffs', though in practice there are a number of intermediate types. Hard cliffs are vertical or steeply sloping; they are inclined to support few higher plants other than on ledges and in crevices or where a break in slope allows soil to accumulate. They tend to be formed of rocks resistant to weathering, such as granite, sandstone and limestone, but can be formed of softer rocks, such as chalk, which erode to a vertical profile. Soft cliffs are formed in less resistant rocks such as shales or in unconsolidated materials such as boulder clay; being unstable they often form less steep slopes and are therefore more easily colonised by vegetation. Soft cliffs are subject to frequent slumping and landslips, particularly where water percolates into the rock and reduces its effective shear strength.

The vegetation of coastal cliff and cliff-tops varies according to several factors: the extent of exposure to wind and salt spray, the chemistry of the underlying rock, the water content and stability of the substrate and, on soft cliffs, the time elapsed since the last movement event. Cliff-top habitats can also be transformed by soil erosion processes. In areas where cliffs occur adjacent to sand dunes, sufficient wind blown sand can accumulate on the cliff-tops to allow cliff-top dune vegetation to develop (perched dunes). On exposed hard cliffs giving little foothold to higher plants, lichens are often the predominant vegetation. On cliffs and slopes which are more sheltered from the prevailing winds and salt spray, the communities are more similar to those found inland, and are increasingly influenced by the chemistry of the substrate.

### SECTION 3 IDENTIFYING INDICATORS BASED ON NRM ISSUES AND ENVIRONMENTAL STRESSORS

The indicators framework is designed to encourage the selection of indicators based upon regional situations, including the problems or issues relevant to a region. However, stakeholders do not all use the same language when describing issues, or problems. The way in which NRM issues are defined can vary on temporal and spatial scales (e.g. elevated chlorophyll concentrations versus climate change). They may also be defined as causes of natural resource problems, or symptoms of natural resource problems (e.g. inappropriate land clearing versus turbid water). Or they can be defined as a change in the state of a naturally occurring component of the environment (e.g. changed freshwater flows or elevated nutrients). Therefore, it is not possible to compile a comprehensive list of NRM issues and specific indicators for each.

To provide a common starting point in the process of selecting indicators, the key environmental stressors important to estuarine, coastal and marine ecosystems are used rather than specific NRM issues. Figure 3.1 shows the relationship between environmental stressors and the causes and symptoms of natural resource 'problems' – all are commonly used to describe NRM 'issues'.

Also included is the influence of community-held values. These values influence current land management practices and activities in the region, and management actions to be undertaken. Values are not listed in the indicators framework, as they are not directly associated with the selection of indicators. However, community-held values do influence the choice of indicators through the causes (management actions) and stressors to be addressed by management actions.

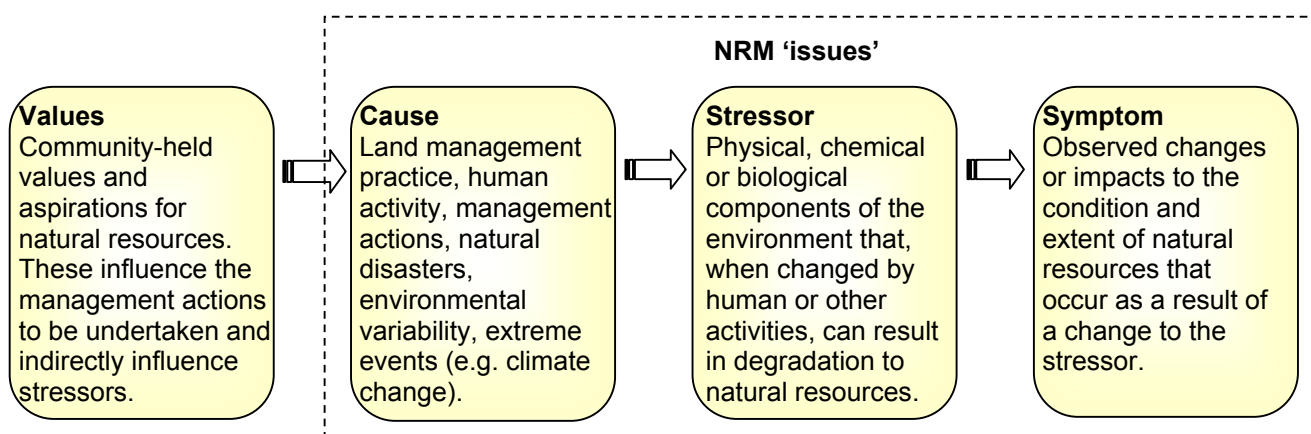


Figure 3.1. Relationship between values, causes, stressors and symptoms.

Physical, chemical and biological stressors are major components of the environment that, when changed by human or other activities, can result in degradation to natural resources. Stressors can be:

- a component of the environment that transfers the impact of a pressure (e.g. human activity) to other parts of the environment by being changed from its natural state, e.g. nutrient concentrations changed from natural, habitat coverage less than natural, excess salt. These components of the environment are usually present in natural (healthy) ecosystems and are only considered stressors when they are different from natural; and
- a component of the environment that, when present, causes stress on the ecosystems, e.g. litter, pest species. These components of the environment are not usually present in natural (healthy) ecosystems and are considered potential stressors when they are present in any amount.

Appendix B provides a greater discussion on stressors and provides a description on the relationship between stressors and the Pressure-State-Response model commonly used for environmental reporting.

For this project, the following components of the environment have been identified as major stressors important in estuarine, coastal and marine ecosystems. These were identified through reviews of literature and technical advice provided by experts.

Stressors (physical, chemical and biological) used in the indicators framework:

- Aquatic sediments (changed from natural)
- Bacteria/pathogens
- Biota removal/disturbance
- Excess Freshwater (hyposalinity)
- Excess Salt (hypersalinity)
- Freshwater flow regime (changed from natural)
- Habitat removal/disturbance
- Hydrodynamics (changed from natural)
- Litter
- Nutrients (changed from natural)
- Organic matter (changed from natural)
- Pest (plant, animal) species
- pH (changed from natural)
- Toxicants
- Water temperature (changed from natural)

**Identifying indicators of natural resource condition relevant to a NRM region**

The following pages represent a framework for selecting indicators relevant to significant NRM issues (i.e. those identified in regional NRM plans to be addressed by specific management actions).

Each page of the framework is focused on one stressor and has the following information:

- (1) A brief description of the **stressor**.
- (2) **NRM issues** associated with the stressor, listed as either potential causes or potential symptoms of a change to the stressor.

Users should read through the NRM issues listed and mark those that have been identified through the regional NRM plan as being important and to be addressed with actions.

To allow as many users to identify stressors using language familiar to them, a range of scales (time and space) of causes and symptoms are identified using as many different terms as possible. The causes and symptoms listed are not listed in any order of importance. Note: some symptoms are more likely to eventuate than others, and some will only result if there are changes to multiple stressors at the same time. Likewise, some causes are more likely to impact stressors than others.

Users should also note that other NRM issues not listed in the following pages might be relevant to the stressors listed. Users may identify other NRM issues relevant to any stressor and should include this stressor and the indicators relevant to it.

- (3) The recommended **potential indicators** to monitor for changes in natural resource condition related to a change in the stressor. The indicators are listed under three categories:
  - o Estuarine, coastal and marine habitat condition – Physical-chemical condition;
  - o Estuarine, coastal and marine habitat condition – Biological condition; and
  - o Estuarine, coastal and marine habitat extent and distribution.

For use in this framework:

- o **condition** is defined as the state or health of individual animals or plants, communities or ecosystems. These indicators can be physical-chemical or biological and represent the condition of the ecosystem.

- extent is defined as the area/distribution (usually hectares or km<sup>2</sup>) covered by a particular habitat type (e.g. seagrass). The 'extent/distribution of key habitat types' indicator profile (Section 4) provides a list of some key habitats (see also Section 2).

Some guidance on identifying indicators:

- To allow the best possible understanding of indicator data, when possible, indicators should be included from all three indicator categories listed, i.e. one from each of; physical-chemical condition, biological condition and habitat extent. The use of multiple indicators for each stressor will improve the users' ability to relate observed changes in condition to changes in the stressor caused by management actions.
- For a particular stressor, more than one indicator may be listed for each of the three indicator categories (e.g. two separate biological condition indicators (animal kills, occurrence of imposex) are listed for the stressor toxicants). This is because there is more than one useful and appropriate indicator. When more than one indicator is listed, they usually cover a range of complexities, costs, etc. A minimum of only one of these needs to be monitored. The indicator profiles (Section 4) provide additional information about these indicators to allow users to determine which indicator will be most suitable for their situation.
- For some stressors, there may be no recommended indicators listed for a particular indicator category (e.g. no biological condition indicators are listed for the stressor freshwater flow regime). This is because appropriate indicators have not been identified (e.g. because of complexity, lack of ecosystem understanding, costs, etc.).
- In some cases, there may be a list of possible indicators that are only relevant for some types of habitats and communities (e.g. the biological condition indicators used for the stressor nutrients will be different depending on which habitat/community type the stressor occurs in). In this case, choose indicators matching the habitats/communities that are present in the NRM region.

Once a list of potential indicators, based upon relevant stressors, has been identified for a particular NRM region, use the information provided in Section 4 to select which indicators are recommended for use for regional NRM monitoring.

### **How were indicators selected for inclusion in the framework?**

Potential indicators were assessed using the following criteria by a range of technical and non-technical stakeholders. The scores were then used to identify appropriate indicators to recommend for each stressor. In some cases, although indicators may exist or be in development, if they scored poorly then none are recommended.

#### Criteria for assessing which indicators should be recommended:

- Is the indicator appropriate to the NRM stressor?
- Is the indicator currently used by your organisation and how often (Not used; Regularly; after Event; Both regularly and after events)?
- How easy is it to distinguish between anthropogenic impacts and natural variation?
- Complexity - is it easily measured (not highly technical)?
- Complexity - is it easily interpreted (data analysis)?
- Cost per measurement (sampling/analytical cost).
- Capital costs for indicator measuring equipment.
- Overall rating of 'usefulness/practicalness of indicator'.
- Do you have a manual or protocol on how to measure the indicator?
- Do any other organisations use your protocol?
- Do guidelines/reference points exist to determine if the indicator measurement result is good or bad?
- Other comments.

### Biodiversity indicators

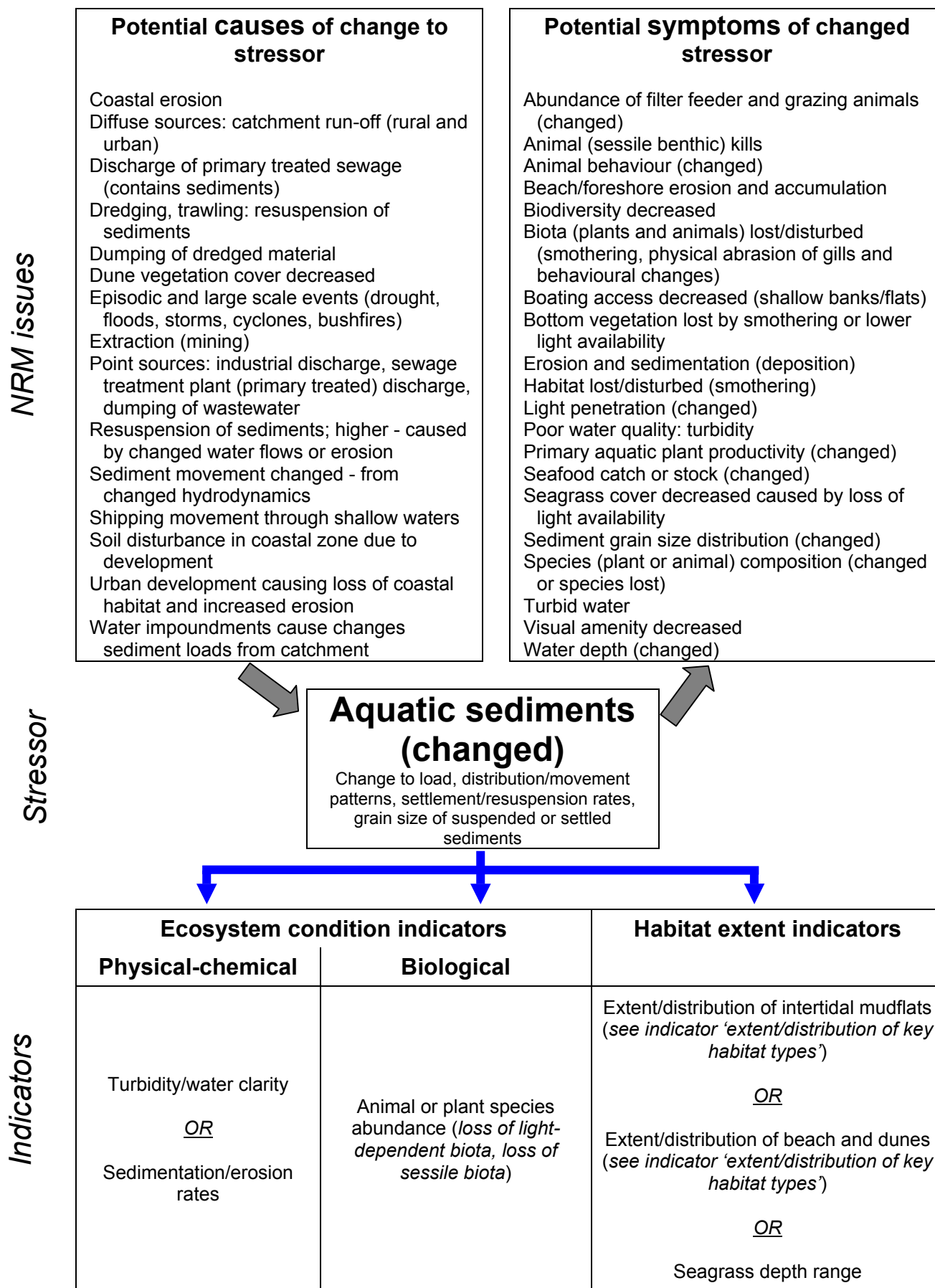
Indicators of biodiversity provide a valuable, high-level assessment of the condition/health of ecosystems, including estuarine, coastal and marine ecosystems. However, because they represent high-level condition, they can be influenced by any/all of the stressors identified above. They are not considered to be useful as indicators of changed natural resource condition in response to

management actions targeting specific NRM issues and stressors. For this reason, indicators specifically targeting biodiversity assessment are not recommended in this document.

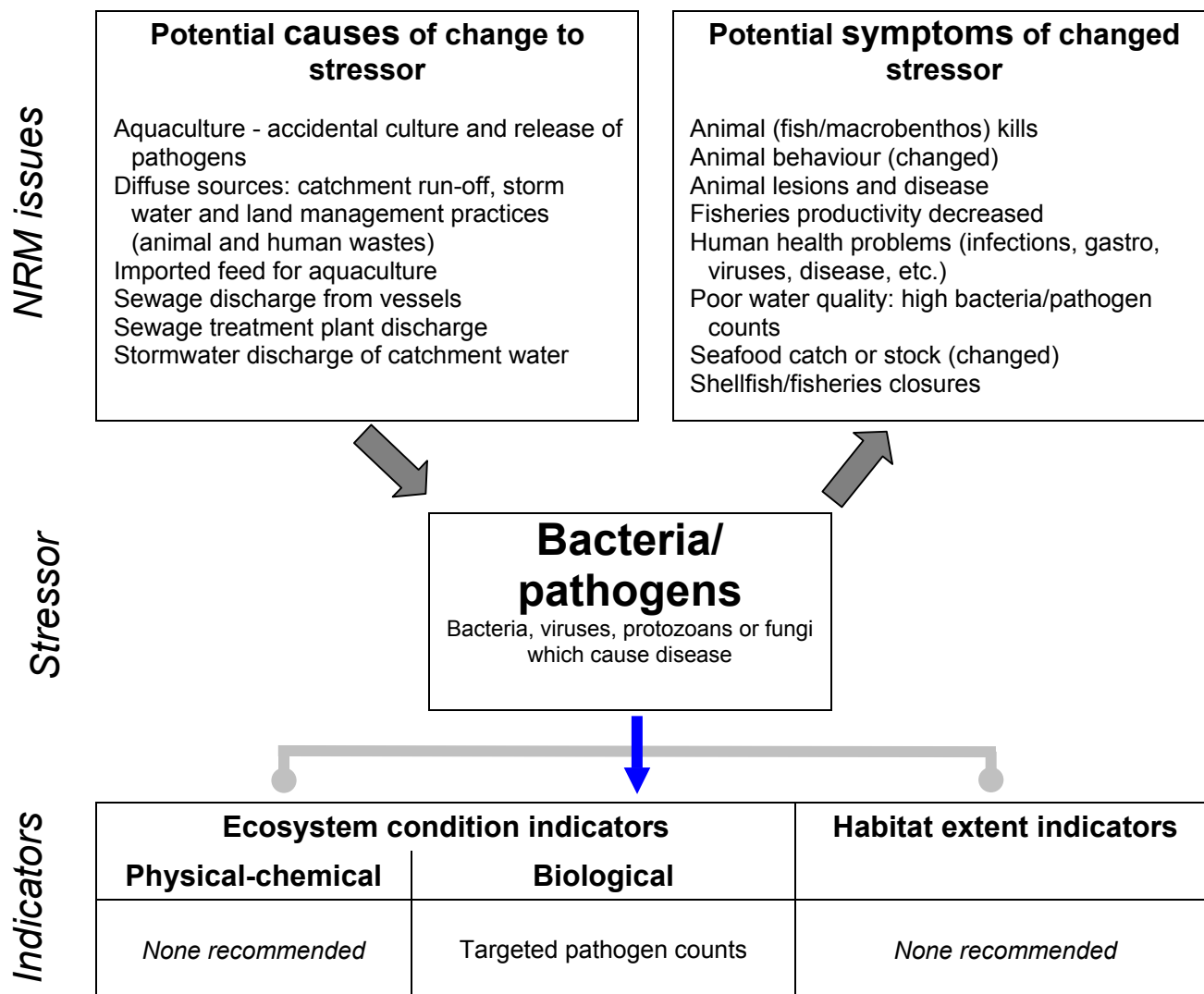
However, monitoring programs that include the purpose of assessing the overall condition/health of estuarine, coastal and marine ecosystems would consider the inclusion of indicators of biodiversity.

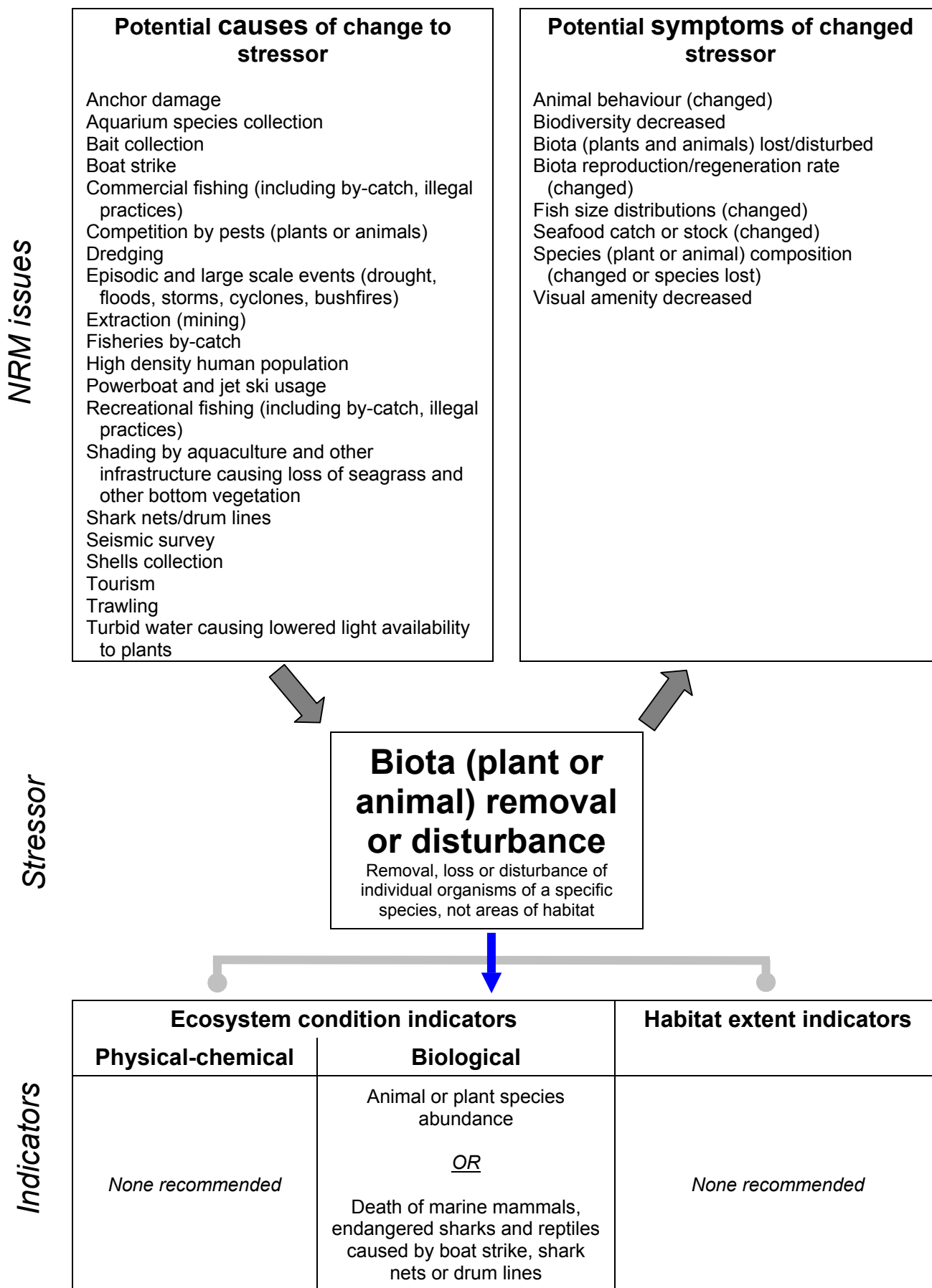
#### Pressure indicators

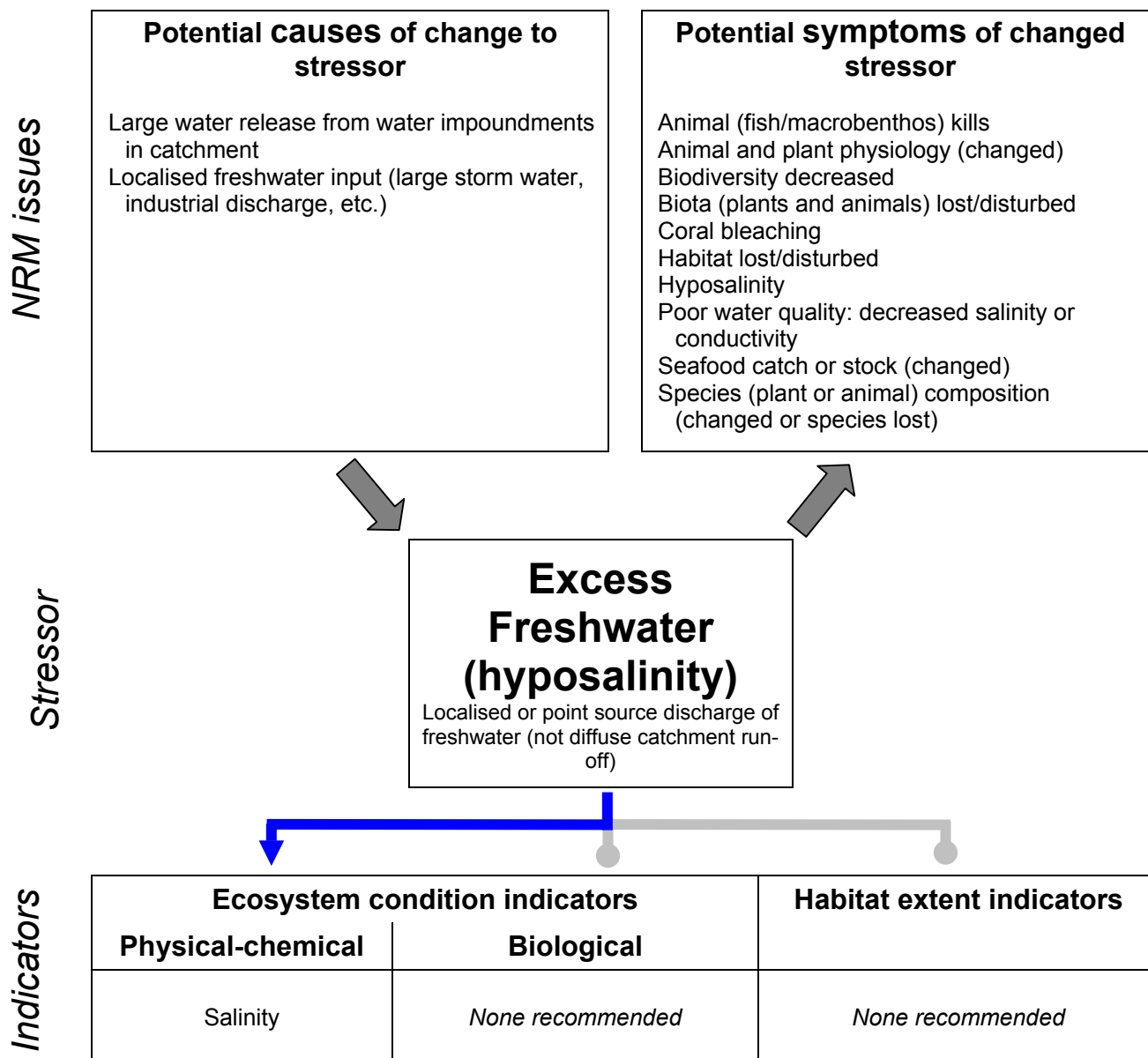
Following the information on stressors and appropriate indicators of natural resource condition is a section providing some information about indicators of pressures relating to the stressors (pg. 37). The value of pressure indicators for regional monitoring is discussed and some guidance on the selection of pressure indicators provided.

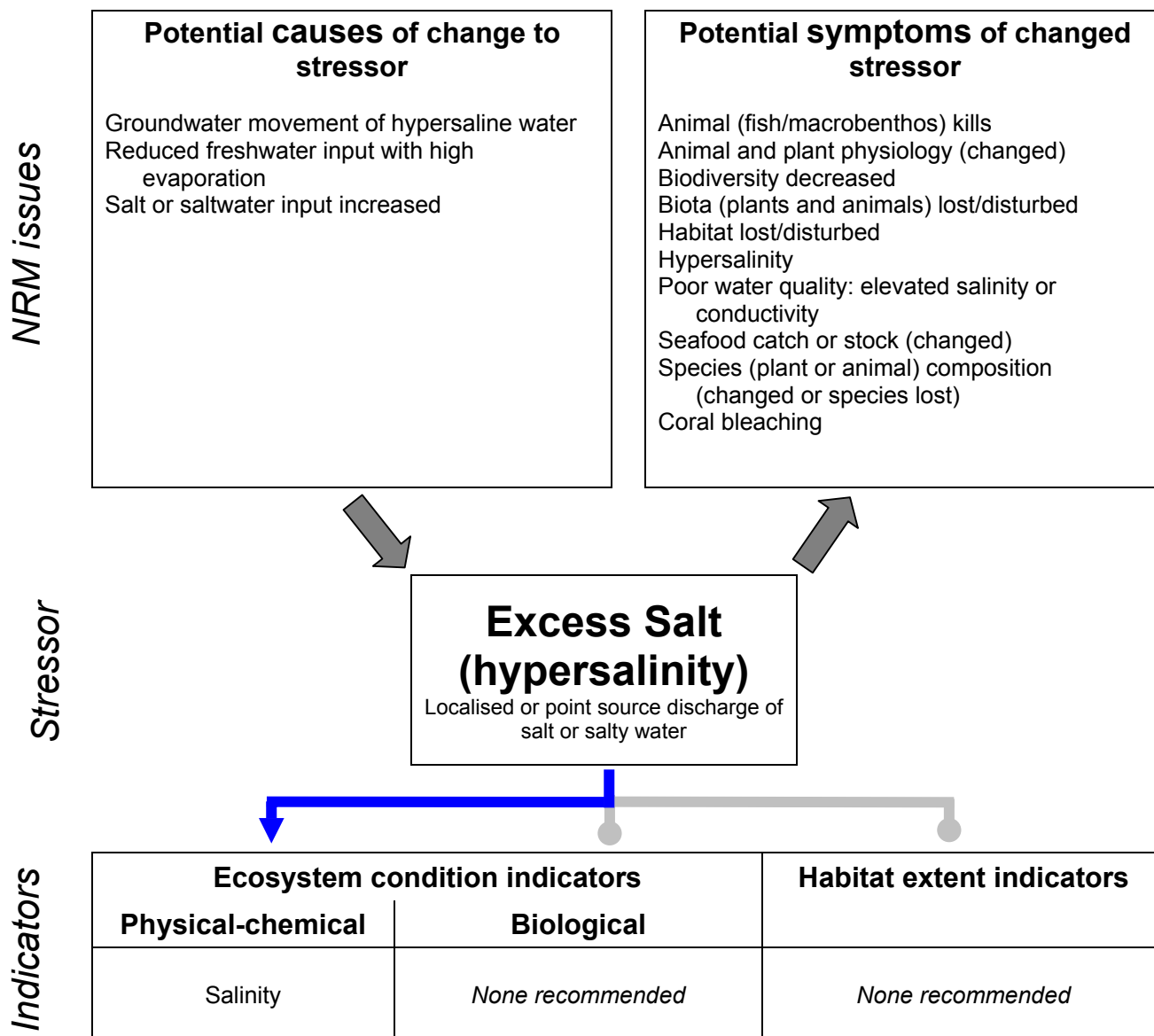


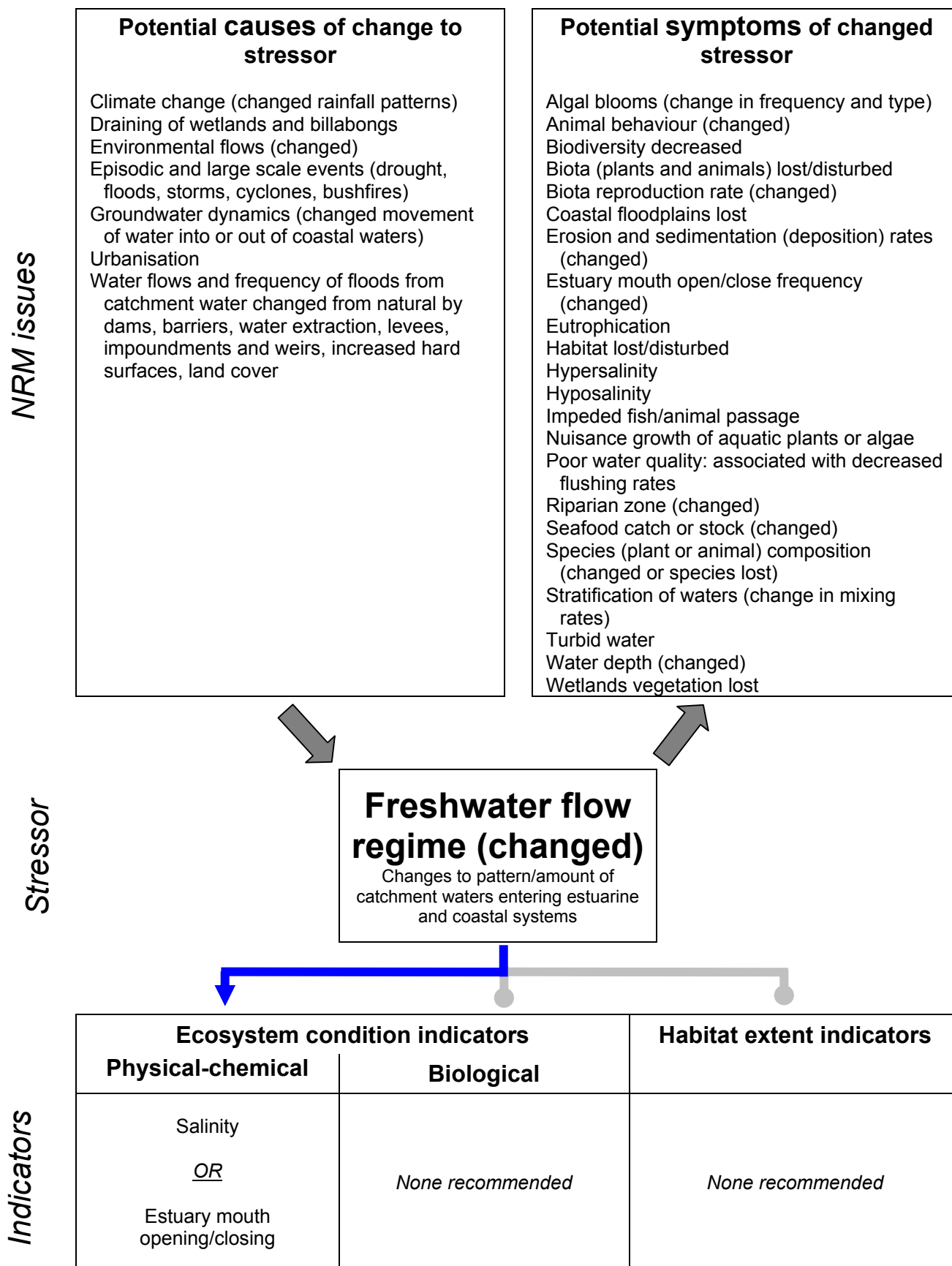












NRM issues

### Potential causes of change to stressor

Boat wash (causing bank and beach erosion)  
 Dredging and extractive operations (sand and gravel mining)  
 Episodic and large scale events (drought, floods, storms, cyclones, bushfires)  
 Filling of floodplains or wetlands  
 Groundwater dynamics (changed movement of water into or out of coastal waters)  
 High density human population  
 Modification of natural drainage pathways  
 Reclamation  
 Recreational off-road vehicles causing loss of coastal vegetation  
 Removal of habitat (e.g. for buildings, construction, foreshore development, roads and bridges, marine facilities and infrastructure, aquaculture, urbanisation, etc.)  
 Sedimentation (change in sediment loads or distribution)  
 Shading by aquaculture and other infrastructure causing loss of seagrass and other bottom vegetation  
 Tourism  
 Trawling  
 Uncontrolled coastal access (especially off-road vehicles)

### Potential symptoms of changed stressor

Beach and foreshore sediment erosion and accumulation  
 Biodiversity decreased  
 Biota (plants and animals) lost/disturbed  
 Coastal erosion  
 Coastal vegetation loss  
 Coastal wetlands lost  
 Dune vegetation cover decreased  
 Estuarine riparian vegetation cover decreased  
 Foreshore vegetation decreased  
 Habitat loss or disturbance  
 Nuisance growth of aquatic plants or algae  
 Poor water quality: associated with habitat removal; turbidity  
 Seafood catch or stock (changed)  
 Shorebirds disturbed/numbers decreased  
 Species (plant or animal) composition (changed or species lost)  
 Turbid water  
 Visual amenity decreased

Stressor

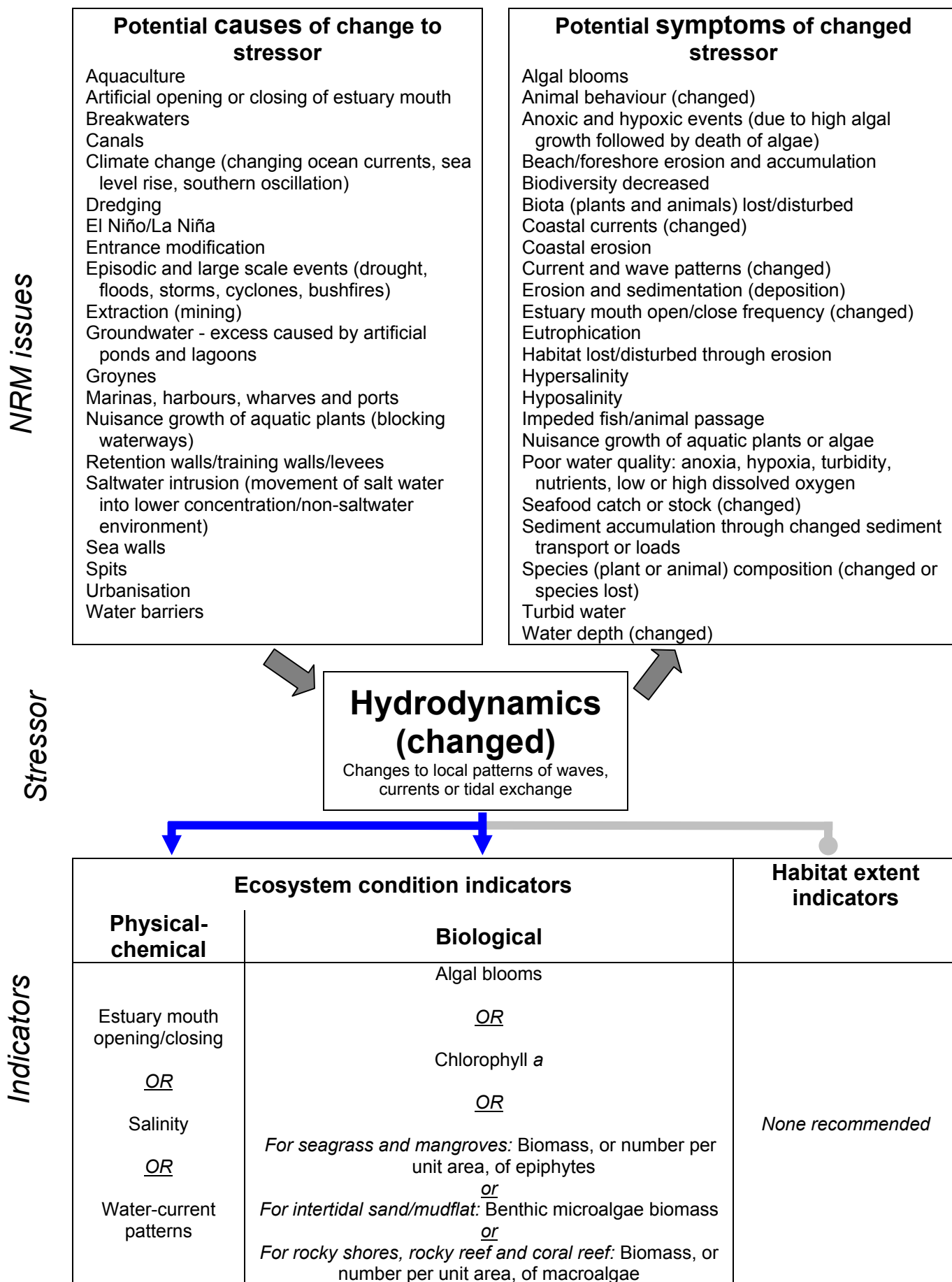
### Habitat removal or disturbance

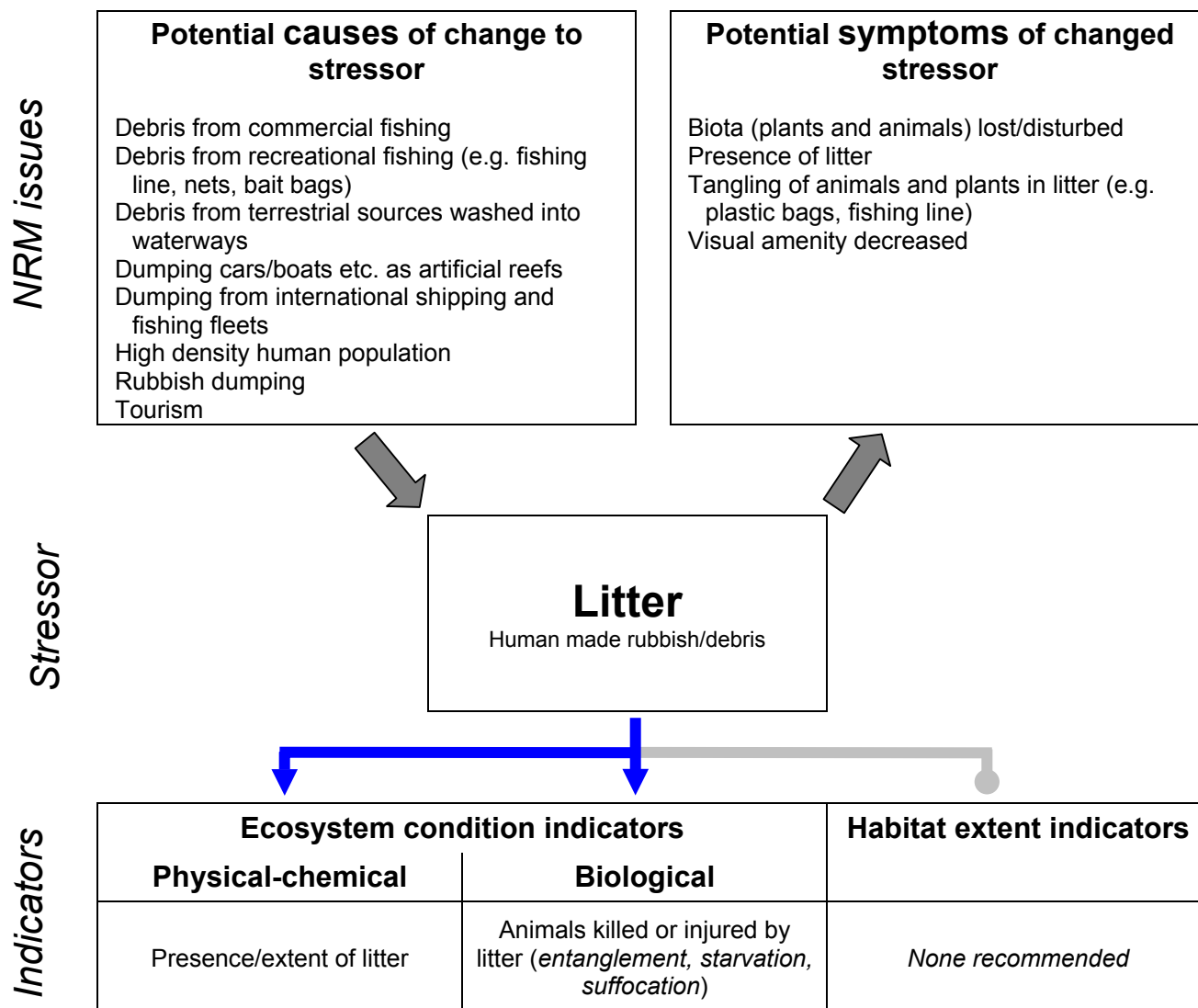
Removal, loss or disturbance of large areas of habitat, such as those listed in the 'Key habitats' indicator profile

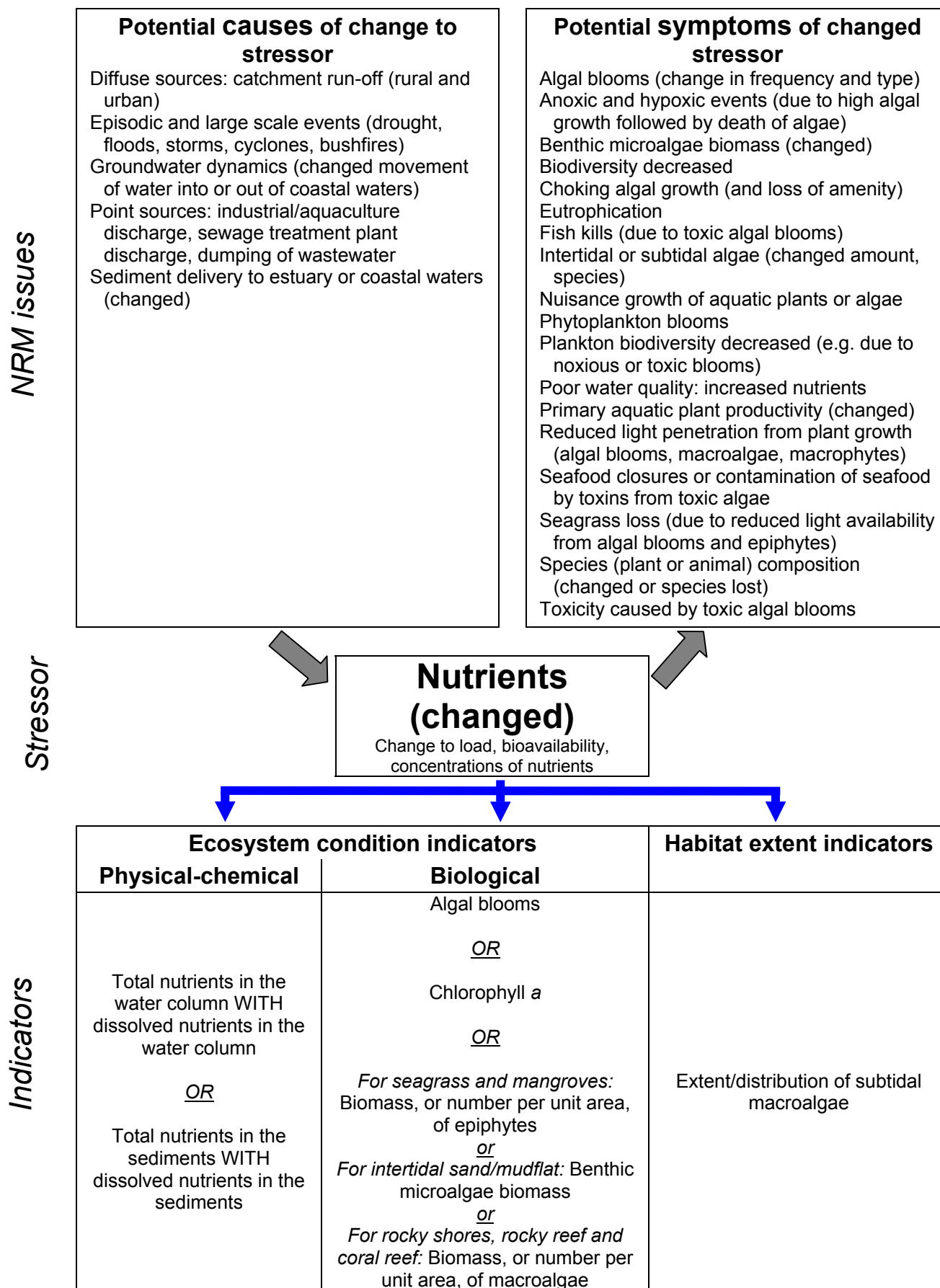
Indicators

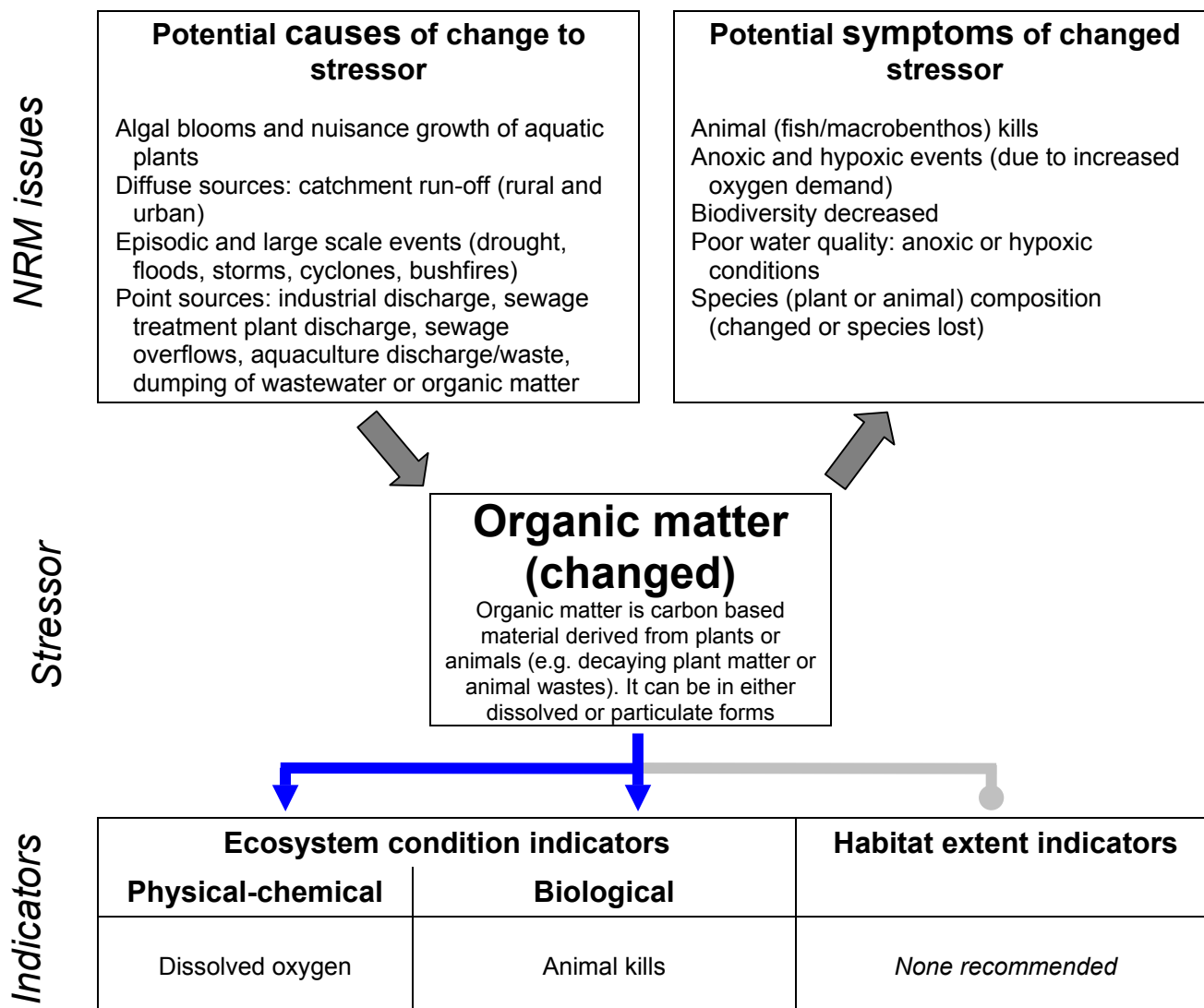
Ecosystem condition indicators		Habitat extent indicators
Physical-chemical	Biological	
None recommended	Animal or plant species abundance ( <i>species dependent on the habitat removed/disturbed</i> )	Extent/distribution of key habitat types

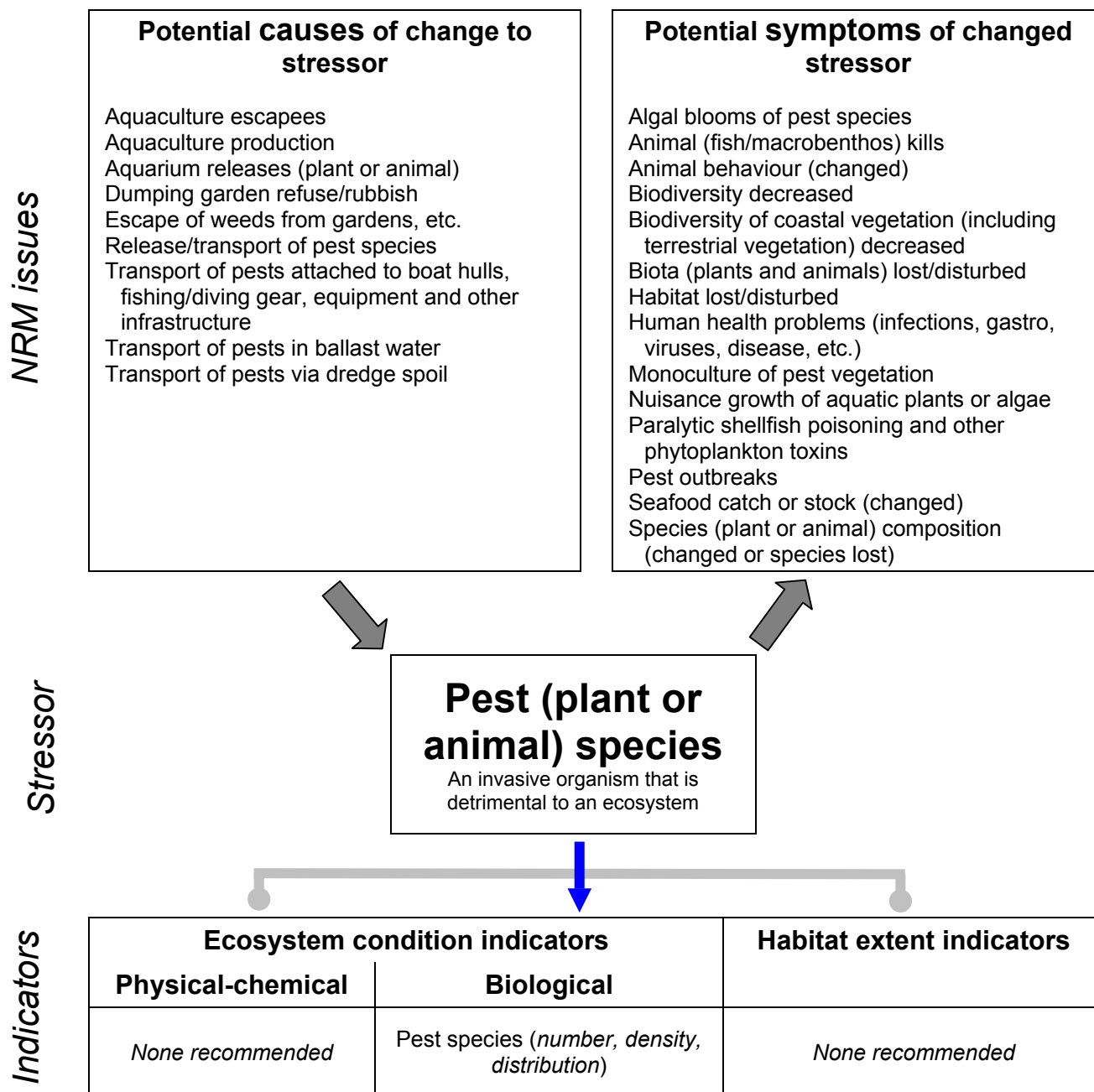


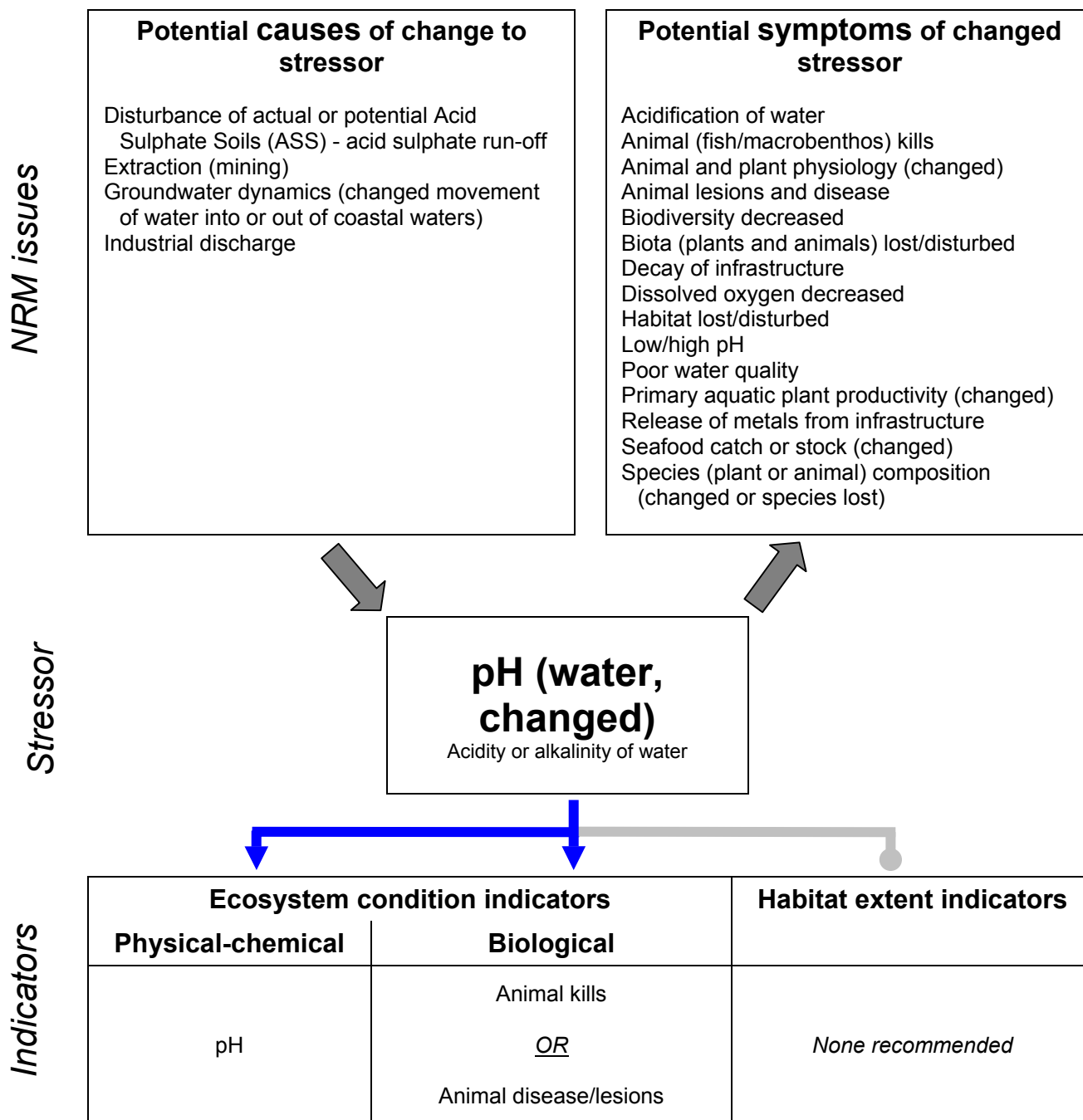




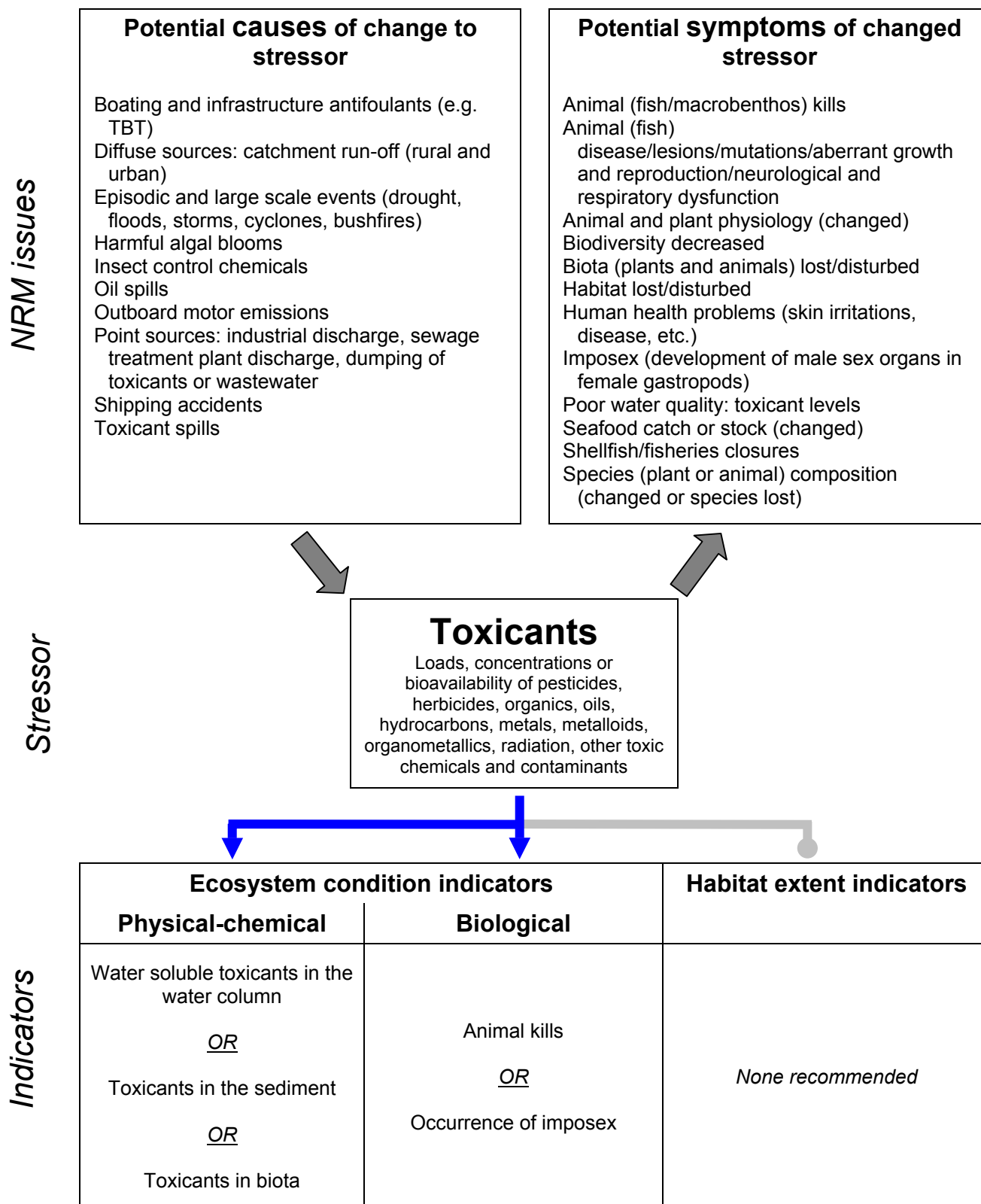


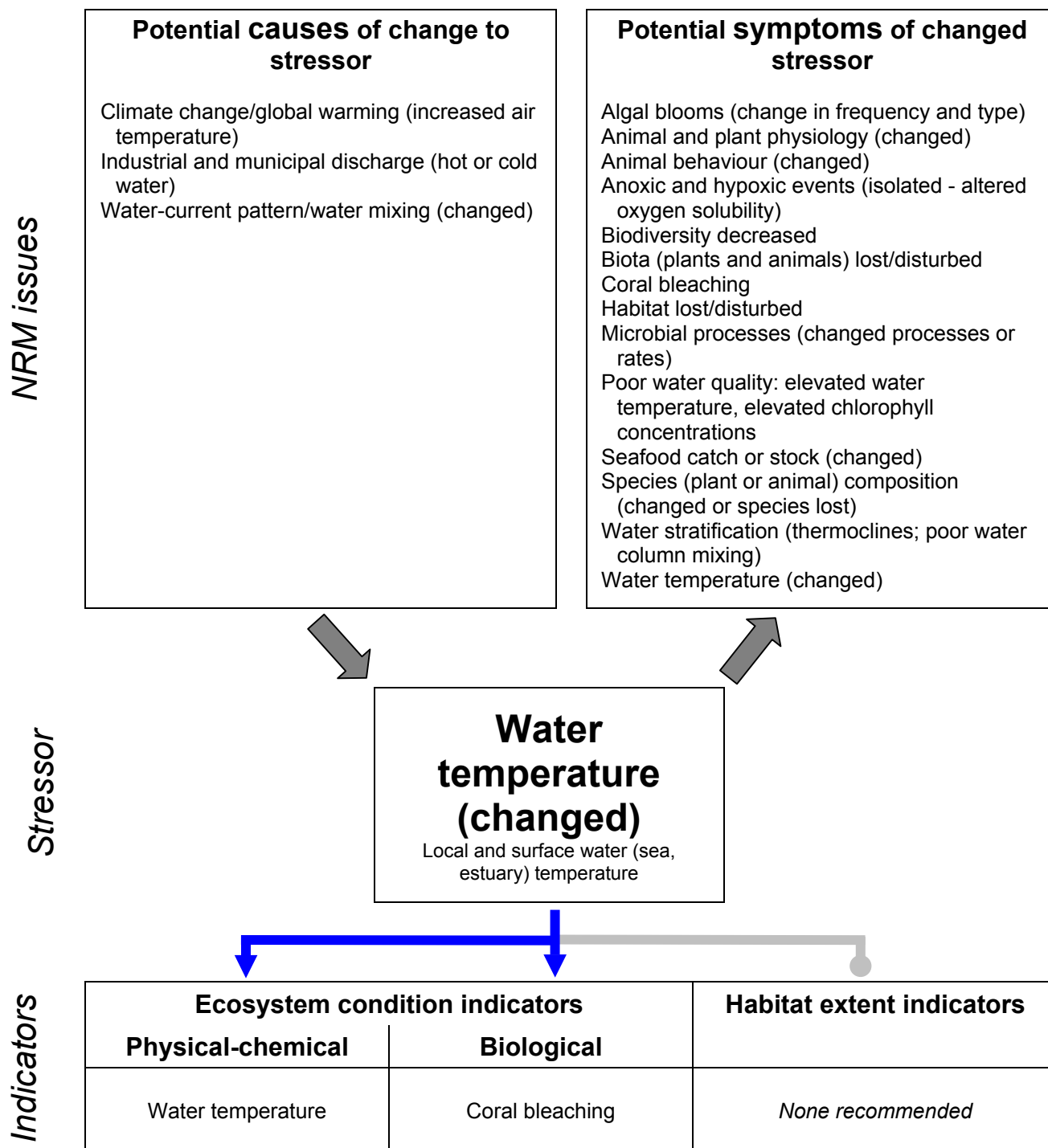












## Pressure indicators

Pressure indicators are not identified in the main indicator framework because the national monitoring and evaluation framework specifies indicators should represent the condition of natural resources. However, in measuring the impact of management actions on the condition of natural resources, other approaches, such as the Australian Government's State of the Environment (SoE) reporting ([www.deh.gov.au/soe](http://www.deh.gov.au/soe)), recommend including pressure indicators because they more directly respond to management actions. The SoE framework defines pressure indicators as those that provide "information about human activities that affect the environment. Pressures do not necessarily imply harm, especially if the activity is appropriately managed."

In relation to Figure 3.1, which describes causes, stressors and symptoms, pressure indicators would directly provide information on the causes of changes to natural resource condition and in some cases, directly measure the stressor itself (rather than the impact of the stressor on natural resource condition).

Table 3.1 below provides some guidance on potential pressure indicators for each of the stressors identified in the preceding pages. For most of the stressors, more than one pressure indicator is listed. This is because more than one appropriate indicator can be used, and the indicators given usually cover a range of complexities, costs, etc. As the determination of pressure indicators is outside the scope of this document, we have not fully examined the appropriateness of these pressure indicators and no pressure indicator profiles are provided.

Here, pressure indicators are divided into two categories, direct and indirect measures. Direct indicators measure the actual pressure influencing a stressor (e.g. measuring the actual change in median freshwater input as a pressure on freshwater flow regime, or the discharge of nutrients from a sewage treatment plant). Indirect indicators are a surrogate measure of the pressure influencing a stressor (e.g. measuring the percentage of median annual freshwater flow impounded or extracted as a pressure on freshwater flow regime). Some of these pressure indicators may also be used by regional NRM groups in developing/as management action targets, especially the indirect indicators.

The Australian Government's State of the Environment Program has also recommended specific pressure indicators for estuarine and coastal environments (Ward et al., 1998), however, these are currently being revised.

Table 3.1. Potential pressure indicators for each stressor.

Stressor	Direct indicators	Indirect indicators
<b>Aquatic sediments (changed)</b>	Total diffuse sediment load entering the estuary/coastal/marine system (monitored or modelled) Total point source sediment load entering the estuary/coastal/marine system (monitored or modelled) Volume of sediment moved/extracted	Catchment landuse (protected/natural/minimal use, livestock grazing, cropping, horticulture, urban) % of farming area using best management practice % of length of stream with healthy riparian zone % of length of streams in grazing area fenced Volume of sediment moved/extracted
<b>Bacteria/pathogens</b>	Total diffuse bacterial load entering the estuary/coastal/marine system (monitored or modelled) Total point source bacterial load entering the estuary/coastal/marine system (monitored or modelled)	Number of sewage overflow events % of sewage effluent disinfected % of urban area % of catchment under intensive livestock % of intensive livestock area using best management practice

<b>Stressor</b>	<b>Direct indicators</b>	<b>Indirect indicators</b>
<b>Biota removal/ disturbance</b>	Commercial seafood catch Recreational seafood catch Bait catch Area disturbed by bait fishing Area disturbed by trawling Area disturbed by boat anchor damage Fisheries by-catch	Number of registered boats in region Length of shark nets/drum line present Recreational usage (e.g. number of facilities on coast (boat ramps, parks, etc.), % estuary, coast and marine systems accessible, tourism (visitation rates, number of marina berths, etc.)) Coastal population size Number of trawlers and dredges using area Number of recreational fishers using area Number of commercial fishing licences Number of licensed collectors (of aquarium fish, shells, etc.) Number of impoundments without fish ladders
<b>Excess freshwater as a pollutant (hyposalinity)</b>	Total point source freshwater load entering the estuary/coastal/marine system (monitored or modelled)	
<b>Excess salt as a pollutant (hypersaline)</b>	Total point source salt load entering the estuary/coastal/marine system (monitored or modelled)	Number of desalinisation plants % of area under saltworks
<b>Freshwater flow regime (changed)</b>	Change in median freshwater input (volume) Base freshwater input compared to total estuary volume Number of times freshwater flow greater than estuary volume Change in seasonality of freshwater input	% of median annual flow impounded/extracted
<b>Habitat removal/ disturbance</b>	% of estuary/coast/marine area modified	% of aquatic area under mining lease Number of boating/shipping visits Number of registered boats in region % of estuary/coast/marine area designated for future modification Coastal population size Recreational usage (e.g. number of facilities on coast (boat ramps, parks, etc.), % estuary, coast and marine systems accessible, tourism (visitation rates, etc.)) % of area under aquaculture
<b>Hydrodynamics (changed)</b>	Change in tidal compartment Change in tidal exchange rates/residence time Change in tidal velocity	Presence of entrance modifications Presence of canals, piers, other estuary modifications Presence of barrages Areal extent of channel dredging
<b>Litter</b>	Quantity and type of litter entering estuary (monitored or modelled)	Coastal population size Number of registered boats in region Recreational usage (e.g. number of facilities on coast (boat ramps, parks, etc.), % estuary, coast and marine systems accessible, tourism (visitation rates, etc.))

<b>Stressor</b>	<b>Direct indicators</b>	<b>Indirect indicators</b>
<b>Nutrients</b> (changed)	Total diffuse nutrient load entering the estuary/coastal/marine system (monitored or modelled) Total point source nutrient load entering the estuary/coastal/marine system (monitored or modelled)	Catchment landuse (protected/natural/minimal use, livestock grazing, cropping, horticulture, urban) Amount of fertiliser applied per unit area (including urban) % of farming area using best management practice % of length of stream with healthy riparian zone % of sewage treatment plants with tertiary treatment Volume/number of sewage overflow events % of urban area under stormwater management plan % of area under aquaculture
<b>Organic matter</b> (changed)	Total diffuse organic matter load entering the estuary/coastal/marine system (monitored or modelled) Total point source organic matter load entering the estuary/coastal/marine system (monitored or modelled)	Catchment landuse (protected/natural/minimal use, livestock grazing, cropping, horticulture, urban) % of each level of sewage treatment Number and volume of licensed discharges Volume/number of sewage overflow events % of catchment area under intensive livestock (e.g. feed lots) % of intensive livestock area using best management practice % of area under aquaculture
<b>Pest (plant, animal) species</b>	Number of new pest species entering the estuary/coastal/marine system Extent and number of pest species present in the estuary/coastal/marine system Rate of spread of pest species through the estuary/coastal/marine system	Presence of pest species in adjacent areas Number of international and/or domestic shipping/boating visits to region Presence of aquaculture facilities using species non-native to the region Presence of port/harbour/marina (domestic and international)
<b>pH</b> (changed)	Volume of run-off from acid affected areas (modelled) Volume and pH differential of discharge/run-off	Areal extent of disturbed acid sulphate soils (% of land <5m AHD cleared/modified) Number of industrial licensed discharges
<b>Toxicants</b>	Total diffuse toxicant load entering the estuary/coastal/marine system (monitored or modelled) Total point source toxicant load entering the estuary/coastal/marine system (monitored or modelled)	Quantity of pesticide/herbicide sold or applied per unit area (rural and urban) Area of catchment treated by pesticide/herbicide (rural and urban) Number of cars per unit urban area (hydrocarbons) % of urban area % of catchment area under mining lease % of mines using best management practice Number of industrial licensed discharges Number of boat visitations Number of berths at ports/harbours/marinas Number of slipways using best management practice
<b>Water temperature</b> (changed)	Volume and temperature differential of discharge	Annual average air temperature Number of industries (e.g. power stations) which discharge hot/cold water Number and volume of dam discharges of cold water

## SECTION 4 INDICATOR PROFILES

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## Indicator: Algal blooms

### Definition

This indicator reports the frequency of algal blooms (macroscopic and microscopic algae) in estuarine, coastal and marine waters.

### Rationale

Algal blooms are a serious coastal problem with consequences for seafood sales, ecosystem and human health, tourism and recreation. Although algal blooms can occur naturally and provide food for other organisms, they may have harmful effects on the system. Some blooms can be toxic to aquatic organisms and cause allergic responses in sensitive people. Blooms of toxic species (e.g. toxic cyanobacteria and dinoflagellates) can produce toxins that harm grazing species and bioaccumulate up the food chain. In addition to the health issues, blooms can cause bad odours and affect visual amenity, thus having major detrimental consequences for tourism. The decomposition of normally harmless blooms (e.g. some cyanobacteria, diatoms, and macroalgae) can result in decreased dissolved oxygen resulting in large scale death of aquatic organisms (e.g. fish kills). Other blooms (e.g. some diatoms, dinoflagellates and raphidophytes) are not toxic but can still be harmful due to physical characteristics (e.g. spines) that affect the gills and tissues of animals. Blooms can also affect pH levels and turbidity (resulting in decreased light penetration with its associated problems for other plants).

The frequency of, and dominant species responsible for algal blooms, is an important indicator for State of the Environment reporting (Ward *et al.*, 1998). Harmful algal blooms was used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

For a detailed explanation of what factors cause algal blooms, the significance of these blooms and which waterways are most susceptible see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients Hydrodynamics	<\$30	Moderate Moderate	Moderate Moderate	DEC, DIPNR (NSW) DIPE, DBIRD (NT) EPA (QLD) EPA (VIC) SASQAP (SA) TASQP (TAS) WRC (WA)

### **Links to stressors**

This indicator is most likely to respond to the following stressors:

- Nutrients
- Hydrodynamics

This indicator may also respond to the following stressors:

- Aquatic sediments
- Freshwater flow regime

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly nutrients (nitrogen) and hydrodynamics.

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Eutrophication
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients, increased turbidity, low dissolved oxygen (increased oxygen demand)
- Toxicity caused by toxic algal blooms

### **Monitoring method**

Detailed monitoring methods for algal blooms can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

The monitoring of this indicator is opportunistic and as such it is not linked with any set monitoring location or frequency. Areas which are most susceptible to algal blooms should be monitored. As estuaries link the land to the sea, estuarine and coastal waters are good monitoring locations, as much of the eutrophication occurring here often the result of land-based activities. Nutrient input into warm, calm and stratified conditions (low flushing/mixing rates and low turbidity) occurring in enclosed bays and systems with small tides (mean tidal range <2m) are also more likely to result in algal blooms.

Conversely, blooms seldom occur in well-flushed (i.e. large freshwater inflow, high tidal exchange) or highly turbid systems. High flushing/mixing rates dilute nutrients and microalgae densities, whereas turbidity reduces the amount of light available for algal growth.

### **Monitoring frequency**

As reported above, the monitoring of this indicator is opportunistic and as such it is not linked with any particular monitoring frequency. Areas which are most susceptible to algal blooms should be monitored more frequently, particularly in summer months or when blooms are more likely.



### **Data measurement methods**

Algae concentrations often become so dense that blooms may appear as streaks, slicks or scums floating on the water, or as greenish, brownish or reddish colourations of the water. Whenever a bloom is suspected visually, algae concentrations must be measured for confirmation. Chlorophyll *a* (see chlorophyll *a* indicator profile) is a good indicator of algal biomass.

The monitoring of water temperature, nutrient concentrations and chlorophyll *a* may be useful in the early warning of blooms.

### **Data analysis and interpretation**

Within each system changes in the frequency of blooms should be assessed using statistical analyses to summarise change. Some baseline data exist in local government and State/Territory agencies, although the observational basis is mostly ad hoc and difficult to compare across jurisdictions.

The frequency of algal blooms is generally considered to be related to nutrient loads coming into the system from land-based sources. Although system hydrodynamics (flushing and mixing), water temperature and turbidity (i.e. light penetration) also influence the occurrence of blooms, however, all things considered, the frequency of algal blooms should decrease with decreased nutrient loads entering the system.

It is important to try and correlate the occurrence of algal blooms to nutrients, hydrodynamics and/or turbidity changes to determine if changes are natural or due to human impacts.

The Department of the Environment and Heritage (Australian Government) provides protocols for State of the Environment reporting on algal blooms (Ward *et al.*, 1998). The effect of nutrient load and environmental conditions on chlorophyll *a* concentrations (a good indicator of algal biomass) in different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The annual bloom frequency, with estimates of uncertainty (e.g. 95% confidence limits), should be reported for each location and is probably best represented by tables and graphs (against time). Once sufficient information on algal blooms is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

### **Proposed responsibilities**

Data on algal blooms has been gathered for many estuarine and coastal waters from around Australia. State agencies, major research institutions and universities have collected and stored most of the data. With the exception of the State of the Environment reporting every four-five years, there are currently no ongoing systematic monitoring programs across regions or larger scales. The National Land and Water Resources Audit compiled information on harmful algal blooms as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor algal blooms themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal kills (indicator)  
Dissolved oxygen (indicator)  
Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)  
Toxicants in biota (indicator)  
Turbidity/water clarity (indicator)  
Nutrients in aquatic environments (matters for targets)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

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(OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

Waterwatch manuals: See <http://www.sa.waterwatch.org.au/programs.htm#manuals> and <http://www.waterwatch.org.au/>

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

Waterwatch Tasmania. *Monitoring algae*. [http://www.tas.waterwatch.org.au/pdf/Part\\_5\\_Monitoring\\_Algae.pdf](http://www.tas.waterwatch.org.au/pdf/Part_5_Monitoring_Algae.pdf)

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

Cyanobacteria – Photosynthetic bacteria previously called blue-green algae.

DBIRD – Department of Business, Industry and Resource Development.

DEC – Department of Environment and Conservation.

Diatom – Microscopic algae with cell walls made of silicon.

Dinoflagellate – Microorganisms with both plant-like and animal-like characteristics, usually classified as protozoans having two lash-like structures (flagella) used for locomotion.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Raphidophyte – Microscopic algae capable of producing environment toxic which may bioaccumulate up the food chain.

SASQAP – South Australian Shellfish Quality Assurance Program.

Spatial – Pertaining to space or distance.

TASQP – Tasmanian Shellfish Quality Assurance program.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Animal disease/lesions

### Definition

This indicator reports the occurrence of animal disease/lesions in estuarine, coastal and marine systems.

### Rationale

Disease causing bacteria and pathogens are naturally present in estuarine, coastal and marine systems. Generally, healthy animals show no ill effects of their presence unless there is a change in a predisposing environmental factor such as overcrowding, nutrition or water quality. Poor environmental condition will stress animals, resulting in a decline in the ability of their immune systems to protect them from disease. Red spot disease (epizootic ulcerative syndrome) is an example of a pathogen which affects fish assemblages which are stressed by unfavourable environmental factors. Low-pH (acidic waters) increases the susceptibility of fish to this fungal disease. Sublethal exposure to acidic runoff can result in physical damage to the gills, skin and eyes of fish, with skin damage increasing its susceptibility to fungal infections.

The prevalence of lesions are either exclusively or significantly increased in fish from contaminated sites. Therefore, a change in the occurrence rate of animal disease/lesions is an indicator of a change in an environmental stressor such as pH or toxicants.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
pH	>\$100	Easy	Moderate	DBIRD (NT) DPI (QLD) DPI (VIC) DPIWE (TAS) DIPNR, DPI (NSW) PIRSA (SA) WRC, Fisheries (WA)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- pH

This indicator may also respond to the following stressors:

- Toxicants
- Bacteria/pathogens

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly pH (i.e. pH).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal disease/lesions/mutations/aberrant growth and reproduction/neurological and respiratory dysfunction
- Animal kills
- Aquaculture - accidental culture and release of pathogens
- Disturbance of actual or potential Acid Sulphate Soils (ASS) - acid sulphate run-off
- Point sources: sewage treatment plant discharge, dumping of toxicants or wastewater
- Poor water quality: high bacteria/pathogen counts, high toxicant levels, low/high pH

### **Monitoring method**

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with State/Territory protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations and frequency**

Animal disease/lesions occur sporadically and as such, are monitored where and when they occur, or at locations where environmental stressors are known/thought to be impacting on the animals present.

### **Data measurement methods**

Animals thought to be affected by disease, (see data analysis and interpretation below) should be collected and sent to a diagnostic laboratory to identify the cause of the disease. It is essential that samples are collected live or correctly preserved to allow accurate diagnosis of the disease. A minimum of three live/preserved animals which show clear signs of disease are needed. Animals that are freshly dead may be suitable for diagnostic purposes. However, not long after death the animal's tissues rapidly breakdown and any parasites (which may be the cause of the lesions) die or drop off the host. A further complication is that isolation of the original bacteria that caused the disease may be difficult as secondary bacteria will rapidly colonise the body upon death, overgrowing the original bacteria.

Collected samples should be placed in sealed containers and stored in the fridge or on ice for transport and analysis within two days. If possible, samples can be transported live, although diseased animals may not survive for long following capture. Samples should not be frozen unless absolutely necessary. Freezing destroys tissue structure and makes bacterial isolation less reliable.

Along with the diseased animal sample and general site information (location, time, date, name, etc.), the following information should be provided to assist in making the correct diagnosis:

- an estimate of the area affected
- weather conditions (including the previous 24 hours)
- the type (species) affected and an estimate of their number and size
- if dead animals are also present
- how the animals are behaving and a description of any observed lesions
- if any unusual or abnormal/foreign materials were present (e.g. chemical slicks, rubbish, etc.)
- any other relevant information (e.g. industries or agricultural activities occurring nearby, water colour, etc.)
- any water quality data collected previously

Water and sediment samples from the site should also be taken for chemical analysis.

### **Data analysis and interpretation**

Following are lists of the types of physical and behavioural changes that may be observed and will indicate the occurrence of disease in animal populations (see <http://msstate.edu/dept/tcnwac/samples.pdf>).

General indicators of the possible presence of disease are:

- sudden mass mortality
- constantly high or increasing mortality over time (i.e. mortality above normal levels)
- fish congregating at the surface
- change in water appearance
- change in smell (algae, hydrogen sulfide, ammonia)
- increased numbers of predators or scavengers

Specific indicators of the presence of disease in fish are:

- behavioural signs
  - anorexia
  - lethargy
  - erratic swimming, porpoising, spiralling or bobbing
  - flashing and rubbing
  - loss of equilibrium
  - gulping at water surface
- clinical signs
  - gill lesions
    - bleeding
    - colour change
    - swelling
    - adherent debris
    - areas of tissue destruction or loss of gill filaments
    - white spots
  - skin lesions
    - abrasions, erosions, or ulcers
    - excessive mucus or dryness
    - haemorrhage
    - areas of discoloration
    - perforations
    - white spots
    - woolly or cottony appearance
  - swollen belly with free fluid
  - bulging eyes
  - physical deformities

A change in the occurrence rate of animal disease/lesions is an indicator of a change in an environmental stressor such as pH or toxicants. For example, exposure of fish to acidic water and toxic heavy metals associated with disturbed acid sulfate soils damages their skin and gills, increasing their susceptibility to fungal infections such as red spot disease.

### ***Data storage***

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The number of disease outbreaks, species affected, disease involved, as well as the number of animals affected in each outbreak, should be reported in tables and graphs for each location. Once sufficient information on animal disease is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

### **Proposed responsibilities**

Existing data on estuarine, coastal and marine animal disease/lesions is limited for waters from around Australia. State/Territory agencies have collected and stored most of the data. There are currently no ongoing systematic monitoring programs across regions or larger scales.

The regional body may or may not choose to monitor animal disease/lesions themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Animal kills (indicator)  
pH (indicator)  
Targeted pathogen counts (indicator)  
Toxicants in biota (indicator)  
Toxicants in sediment (indicator)  
Water soluble toxicants in the water column (indicator)

#### **Further information and references**

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

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Thad Cochran, National Warmwater Aquaculture Center. Submitting Diseased Fish for Diagnostic Evaluation. <http://msstate.edu/dept/tcnwac/samples.pdf>

#### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DBIRD – Department of Business, Industry and Resource Development.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

Epizootic ulcerative syndrome – Red spot disease of fish (caused by a fungus).

PIRSA – Department of Primary Industries and Resource (Animal Health), South Australia.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Animal kills

### **Definition**

This indicator reports the occurrence of the 'unusual' death of a relatively large number of animals, usually fish.

### **Rationale**

Animal kills may have a natural or human related cause like anoxic and hypoxic events, infectious diseases, toxic algae and uncommon weather patterns. The frequency and magnitude of kills are relatively good indicators of biological condition and are generally believed to reflect the integrity of an estuarine, coastal or marine system. "A kill is an unexpected and generally short-lived event marked by the conspicuous death of large numbers of fish (e.g. fish kill) or other organism (e.g. bird kill). Fish and bird kills in excess of one event per year are considered indicative of compromised ecosystem integrity according to criteria established during the National Land and Water Resources Audit." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>). Fish/bird kills was used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

Kills are caused either directly or indirectly by changes to stressors. For example, increased toxicants or changed pH can directly result in kills. Whereas, an increase in organic matter may indirectly cause kills as high amounts of organic matter may result in low dissolved oxygen (DO) – it is this low DO which actually causes the kill. Because of the variety of factors which can potentially cause kills, it is important that the actual cause is accurately determined.

"Fish kills can deplete valuable stocks and render others susceptible to overfishing. A kill can also disrupt food web dynamics and the interdependencies between species. They can promote colonisation by noxious species and eliminate species essential to the healthy functioning of communities. Kills are also aesthetically unpleasant because they litter coastal waters with rotten smelly carcasses. The effects of a fish kill may extend further if birds and other predators consume contaminated fish." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

For further information on animal kills and a detailed explanation of what factors cause kills see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Key information**

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a *rough guide only*. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.



Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
pH Organic matter Toxicants	<\$100	Easy Easy Easy	Moderate Hard Moderate	DEC, DPI (NSW) DIPE (NT) DPIWE (TAS) EPA (VIC) EPA, DPI (QLD) PIRSA (SA) WRC (WA)

**Links to stressors**

This indicator is most likely to respond to the following stressors:

- pH
- Organic matter
- Toxicants

This indicator may also respond to the following stressors:

- Bacteria/pathogens
- Nutrients
- Aquatic sediments (*particularly kills of light-dependent and sessile biota*)

Changes in salinity and water temperature may also affect sessile species. It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly pH, toxicants and organic matter (i.e. dissolved oxygen).

**Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal disease and kills
- Aquaculture - accidental culture and release of pathogens
- Biota (plants and animals) lost/disturbed
- Episodic and large scale events (drought, floods, storms, cyclones)
- Eutrophication
- Harmful algal blooms
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflows, dumping of toxicants, wastewater or organic matter
- Poor water quality: high bacteria/pathogen counts, high toxicant levels, anoxic or hypoxic conditions (i.e. no/low dissolved oxygen), low/high pH

**Monitoring method**

The book 'Investigation and Valuation of Fish Kills' produced by The American Fisheries Association supplies information on the procedures and guidelines for investigating kills. Information on monitoring methods for kills can usually be found in State/Territory Government Department (e.g. Environment Protection Agency or equivalent) publications (e.g. Queensland EPA website) and scientific publications.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with State/Territory protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

**Monitoring locations and frequency**

Animal kills occur sporadically and as such are monitored when and where they occur.

### **Data measurement methods**

Excerpt from the Qld EPA website

([http://www.epa.qld.gov.au/environmental\\_management/water/water\\_quality\\_monitoring/fish\\_kill\\_reporting/](http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/fish_kill_reporting/)):

As much as possible of the following information [relating to a kill] should be recorded:

- Name, address, and contact number of the person who initially report the kill in case further information is required by the investigating scientist;
- The exact location of the kill and an estimate of the area affected;
- The date and time of discovery, and an estimate of when the fish-kill might have happened;
- Weather conditions at the time of discovery and for the 24 hours previously;
- An estimate of the number and size of fish affected, and the names or types of fish or other animals such as crabs involved;
- Whether sick or dying fish are also present, and if so, how they are behaving;
- Whether unaffected fish are also present; if only dead specimens are present, their state of decay, and whether some are less decayed than others;
- Whether any unusual or abnormal materials were present such as oil slicks, discoloured water, recently dumped rubbish;
- Whether any samples of dead fish, affected water, or other materials have been taken, and where they are being kept (see below); and,
- Any other factual information which could be relevant, such as industries or agricultural activities in the vicinity of the kill.

Because of the speed with which dead fish deteriorate and contaminated water flows away, it may help a subsequent investigation if on-the-spot samples are taken.

What to sample:

- Both dead and dying fish (and any other animals affected);
- Sediments (mud or sand) from the water in which dead fish are found;
- Water; and
- Any materials such as oil slicks or other foreign matter in the water.

Clean containers should be used to store the samples. Glass jars or bottles are best, but plastic may be used if glass is not available. Plastic bags are acceptable for dead fish. Large (1-2 litre) soft drink bottles are ideal for storing water samples. Jam jars (150 grams or bigger) are ideal for storing sediment. Anything smaller than these sizes is of limited value for chemical analysis.

Bottles and jars should be pre-cleaned with hot water and detergent and rinsed several times in the water being sampled before a sample is taken.

If possible, several samples of each kind should be taken, for example at least 3 fish, 3 sediment samples, and 3 bottles of water. If a discharge or drain site is suspected as a source of contamination, samples should be taken both upstream and downstream of this, and clearly labelled with a waterproof pen or similar means.

All samples should be preserved by refrigeration, or kept on ice. If the area is remote and/or collection of samples by an investigator is unlikely for more than 24 hours, samples should be kept in a deep freeze. DO NOT freeze water samples without leaving an airspace of about 20% of the volume to allow for expansion.

### **Data analysis and interpretation**

Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

Globally, over half the fish kills result from natural causes (e.g. life cycle events, infectious diseases, bacteria and protozoa, decreasing water levels, reduced water

quality, elevated water temperatures on foreshores, and changes in salinity caused by heavy rain).

Fish kills often occur when dissolved oxygen concentrations drop to lethal levels during the decomposition of organic matter. When oxygen is depleted, anoxic and hypoxic conditions develop and anaerobic organisms take over the degradation of organic matter. Anaerobic respiration gives rise to hydrogen sulfide and ammonia gas which can also be toxic to fish and other organisms (Connell and Miller, 1984). Degradation of algal biomass derived from algal blooms can cause water column oxygen to be consumed, and often results from excessive nutrient loads (e.g. eutrophication). Some point-sources of nutrients to coastal waterways are wastes from aquaculture operations, sewage discharged from yachts, boats and ships and coastal discharges such as outfalls from industry. The risk imposed by point-sources of nutrients in coastal waterways is higher in areas with large population densities or with a significant tourism, and can be estimated by the number of point-sources per unit area of coastline. Nutrient loads from diffuse sources (e.g. intensive agricultural in catchments and urban stormwater) are often larger and more difficult to control. Rainfall following the dry season in tropical regions can also mobilise organic-rich detritus (e.g. rotting weeds, grasses, cane trash and stormwater trash) into coastal waters and these can have a very high biological oxygen demand (Veitch, V. Fish Kills, Sunfish Queensland). Links have also been found between the artificial opening of lagoons and fish kills, because shallow areas can be exposed to air causing the die-back of large amounts of filamentous algae (Wilson *et al.*, 2002).

Inappropriate use of pesticides may also lead to local fish kills. Examples include endosulfan runoff from agricultural areas when this chemical is applied before rainfall [Napier *et al.*, 1998] and drift from chemicals used to control mosquitoes and other biting insects in intertidal wetlands. Birds are also sensitive to the long-term effects of toxicants (e.g. herbicides, pesticides and heavy metals) due to their high metabolic rate. Impacts may be acute and result in death or be chronic, leading to reduced reproductive capacity. The 'Industrial Point Source Hazard' [[http://www.ozestuaries.org/indicators/HA\\_industrial\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_industrial_hazard_f.html)] and 'Stormwater Discharges' [[http://www.ozestuaries.org/indicators/HA\\_stormwater\\_f.html](http://www.ozestuaries.org/indicators/HA_stormwater_f.html)] indicators can be used to assess toxicant risk from urban and industrial sources. The 'Pesticide Hazard' [[http://www.ozestuaries.org/indicators/HA\\_pesticide\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_pesticide_hazard_f.html)] indicator can be used to assess toxicant risk from agricultural sources.

Runoff from acid sulfate soils (ASS) can cause fish kills (see <http://www.deh.gov.au/coasts/cass/index.html>). The fish die from the metabolic impacts of low pH itself, or from the toxicity of heavy metals mobilised with the drainage. This may result from natural processes but in many cases, drainage of wetlands (e.g. mangroves and salt marshes) leads to increased oxidation of ASS and potential acid sulfate soils (PSS), with pH levels becoming extremely low. Coastal waterways with rivers in acid hazard zones are most at risk for acid sulfate drainage.

Outbreaks of harmful algae (e.g. *Pfiesteria*) produce a variety of biotoxins that kill fish and birds (see <http://www.marine.csiro.au/LeafletsFolder/47pfiest/47.html>). Birds and fish that feed on filter-feeding molluscs may be particularly susceptible because such organisms concentrate contaminants.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The number of kills, species involved as well as the number of animals killed should be reported in tables and graphs. The annual changes in animal kill frequency should be reported for each location. Once sufficient information on animal kills is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported

as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

### **Proposed responsibilities**

Government institutions and State/Territory agencies keep records of reported animal kills. The National Land and Water Resources Audit compiled information on fish/bird kills as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor animal kills themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Algal blooms (indicator)  
Animal disease/lesions (indicator)  
Dissolved oxygen (indicator)  
pH (indicator)  
Toxicants in biota (indicator)  
Turbidity/water clarity (indicator)

### **Further information and references**

Connell, D.W. and Miller, G.J. 1984. *Chemistry and Ecotoxicology of Pollution*. John Wiley & Sons, N.Y.

CSIRO (Commonwealth Scientific and Industrial Research Organisation) Marine Research.  
<http://www.marine.csiro.au/LeafletsFolder/47pfiest/47.html>

Department of Environment and Heritage (DEH), (Commonwealth). 2004. Coasts and Oceans. National Coastal Acid Sulfate Soils. <http://www.deh.gov.au/coasts/cass/index.html>

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

*Investigation and Valuation of Fish Kills*. 1992. Pollution Committee (Southern Division) and Socio-economic Section. 96 pages. Published by American Fisheries Society. ISBN 0-913235-81-4. <http://64.224.98.53/publications/catbooks/x51020.shtml>

Napier, G.M., Fairweather, P.G. and Scott, A.C. 1998. Records of fish kills in inland waters of NSW and Queensland in relation to cotton pesticides. *Wetlands (Australia)* 17: 60-71.

NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

(OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Queensland EPA Website:

[http://www.epa.qld.gov.au/environmental\\_management/water/water\\_quality\\_monitoring/fish\\_kill\\_reporting/](http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/fish_kill_reporting/)

Wilson, J., Evans, P. and Kelleher, N. 2002. Fish kills in Cockrone Lagoon - Implications for entrance opening of coastal lakes. *Proceedings of Coast to Coast 2002 - Source to Sea*. Pp. 101-104. Tweed Heads.

Veitch, V. *Fish Kills*. Sunfish Queensland.

### **Glossary**

Anaerobic – In the absence of oxygen.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

PIRSA – Department of Primary Industries and Resource, South Australia.

Sessile – Plants or animals that are permanently attached to a surface.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Animal or plant species abundance

### Definition

This indicator documents the abundance of specific animal or plant species.

### Rationale

Estuarine, coastal and marine systems contain many species that are important to humans for economic, recreational or cultural reasons.

The observed reduction in animal and plant numbers occurring today is a growing global concern. Species abundance is affected by numerous environmental factors and the effects of a change in abundance, (particularly to keystone species), can be dramatic, resulting in significant impacts to ecosystem health and human interests. A reduction in numbers of key animal and plant species from communities within estuarine, coastal, and/or marine subsystems is a good indicator of human-induced changes to environmental conditions. Within most systems there will be an animal or plant species which is susceptible to the slightest change in a particular stressor, and therefore, a good indicator species for changes to that stressor.

Fish abundance and invertebrate abundance were used as one determinant of the fish condition index and sediment quality index, respectively, in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Biota removal/disturbance Habitat removal/disturbance Aquatic sediments	>\$100	Moderate Hard Moderate	Hard Hard Moderate	DBIRD, DIPE (NT) DEC, DIPNR, DPI (NSW) DPI (QLD) DPIWE (TAS) EPA, DEH, PIRSA, SARDI (SA) Parks Victoria Waterwatch WRC (WA)

### Links to stressors

This indicator is most likely to respond to the following stressors:

- Aquatic sediments
- Habitat removal/disturbance
- Biota removal/disturbance

However, this indicator may also respond to any of the other stressors listed in the indicators framework, as a change in any stressor may make a location uninhabitable for some animal or plant species.

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for the appropriate stressors of a region, (e.g. nutrients, turbidity, organic matter (dissolved oxygen), pH, toxicants and water temperature).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal disease and kills
- Biodiversity decreased
- Biota (plants and animals) lost/disturbed
- Catchment landuse and run-off
- Climate change/global warming
- Commercial and recreational fishing, shell collecting, bait collecting (including by-catch, illegal practices)
- Competition by pests (plants or animals)
- Decreased environmental flows (dams, water extraction)
- Dredging and extractive operations (sand and gravel mining)
- Episodic and large scale events (drought, floods, storms, cyclones)
- Eutrophication
- Habitat loss or disturbance (e.g. for buildings, construction, foreshore development, roads and bridges, marine facilities and infrastructure, aquaculture, urbanisation, tourism, trawling, recreational access, etc.)
- Impeded fish/animal passage (barriers, impoundments and weirs)
- Nuisance growth of aquatic plants or algae (harmful algal blooms)
- Point source pollution
- Poor water quality: high bacteria/pathogen counts, high toxicant levels, anoxic or hypoxic conditions (i.e. no/low dissolved oxygen), low/high pH, high turbidity

### **Monitoring method**

Some animals and plants will respond to a change in a particular stressor more readily than others. For example, if monitoring for the changes to the stressor 'aquatic sediments' then light dependent or sessile biota should be chosen. When choosing 'target taxa' the following criteria should be considered (see Saunders *et al.*, 1998):

- Biological/ecological representative
  - Habitat specificity
  - Geographic range
  - Local population size
  - Life span
- Reproductive strategy
- Taxonomic representativeness
- Sensitivity to a particular stressor
- Practicality of sampling and analysis
- Existing knowledge

Detailed monitoring methods for species abundance can be found in numerous publications including: scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with State/Territory protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

Monitoring locations will depend on what species is being monitored, which in turn, will depend on aspects of the management actions and NRM issues being monitored. For example, if the NRM management action is targeting over-harvesting of yabbies for bait, then the abundance of yabbies on sand/mudflats will be monitored at sites where yabbies are currently collected, as well as at control (undisturbed) sites.

### **Monitoring frequency**

Monitoring frequency will depend on what species is being monitored, which in turn, will depend on aspects of the management actions and NRM issues being monitored. Monitoring may occur at monthly (for highly unpredictable and patchy species) through to annual (for more stable species) intervals.

### **Data measurement methods**

This indicator would be measured using standard field sampling techniques for measuring species abundance (e.g. line transects, quadrats, catch per unit effort, etc.). The exact protocols used, need to be defined and developed depending on the species to be monitored. Protocol development may need specialised assessment and pilot studies.

### **Data analysis and interpretation**

In general, due to the highly variable nature of species numbers both temporally and spatially, initially there may be no standard data available to compare against. Results from initial abundance studies will form the baseline data against which future results can be compared.

Species abundance will change naturally (seasonal variation) or due to human impacts (e.g. pollutants, habitat removal, animal/plant collection, etc.). Monitoring of control (undisturbed) and impacted sites over at least a couple of years will be needed to help determine if the change in abundance is natural or not. A constant difference in abundance between the control and impacted site, or a continual decrease at a site can indicate that human activities are impacting on species numbers. When a decrease in abundance is observed together with a reduction in the average size of animals, then this may indicate that the species is being over-harvested.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of species abundance is probably most easily represented in tables or graphs (against time), with an estimate of uncertainty (e.g. 95% confidence limits), for each location. Once sufficient information on species abundance is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change.

### **Proposed responsibilities**

Data on species abundance (particularly fisheries species) has been gathered for many estuarine, coastal and marine waters around Australia. State agencies, major research institutions and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on fish and invertebrate abundance as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor species abundance themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used



by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Animals killed or injured by litter (indicator)

Death of marine mammals, endangered sharks and reptiles caused by boat strike, shark nets or drum lines (indicator)

Extent/distribution of key habitat types (indicator)

Sedimentation/erosion rates (indicator)

Turbidity/water clarity (indicator)

Significant native species and ecological communities (matters for targets)

Ecologically significant invasive species (matters for targets)

Turbidity/suspended particulate matter in aquatic environments (matters for targets)

#### **Further information and references**

NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

#### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DBIRD – Department of Business, Industry and Resource Development.

DEC – Department of Environment and Conservation.

DEH – Department for Environment and Heritage

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

Line transect – A straight line placed on the ground along which ecological measurements are taken.

PIRSA – Department of Primary Industries and Resource, South Australia.

Quadrats – An ecological sampling unit that consists of a square frame of a known area.

SARDI – South Australian Research and Development Institute.

Sessile – Plants or animals that are permanently attached to a surface.

Spatial – Pertaining to space or distance.

Taxa – A taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Animals killed or injured by litter (entanglement, starvation, suffocation)

### Definition

This indicator documents the number of animals killed or injured by litter.

### Rationale

The presence of litter in estuarine, coastal and marine systems can harm animals which eat, become entangled in, or are suffocated by, the litter. Also, toxic substances can leach out of litter which then bioaccumulates up the food chain. "One quite simple example of this is the toxic effect of cigarette butt litter. Toxic substances leach out of cigarette butts and can kill small animals. Animals also mistake butts for food. The toxic chemicals absorbed by cigarettes' cellulose acetate filters and found in butts' remnant tobacco, are quickly leached from the butts by water." (Global litter information gateway, <http://marine-litter.gpa.unep.org/facts/effects-wildlife.htm#top>).

Many species of endangered or threatened marine mammals, turtles and seabirds are particularly at risk from litter. According to figures provided in the 'Global litter information gateway', approximately 100,000 marine mammals and turtles, and 700,000 to 1 million seabirds are killed worldwide by litter every year.

In Australia it has been reported that 0.8% of New Zealand fur-seals on Kangaroo Island suffer entanglements each year (Page *et al.*, 2003). Over a four year period, 136 Australian fur-seals were observed with plastic neck collars in Tasmanian waters alone (Pemberton *et al.*, 1992). At least 10% of Australian pelicans along the NSW coast were found to be suffering from entanglement by fishing line (see NSW Scientific Committee, 2004).

Litter thus poses a large threat to many estuarine, coastal and marine species, particularly threatened or endangered ones.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Litter	<\$5	Easy	Easy	DEC, DPI (NSW) DIPE (NT) DPIWE (TAS) EPA (QLD) EPA (SA) EPA, Parks Victoria (VIC) WWF

### **Links to stressors**

This indicator will respond to the following stressor:

- Litter

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for the stressor litter (i.e. presence/extent of litter).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Rubbish dumping (ships/boats, tourists/recreational users, upstream)
- Rubbish/debris from commercial and recreational fishing (e.g. fishing line, nets, bait bags)
- Tangling/death of animals and plants by litter

### **Monitoring method**

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with State/Territory protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations and frequency**

The monitoring of this indicator is opportunistic and as such it is not linked with any set monitoring location or frequency. Areas where dead or injured animals are most likely to be found should be monitored (i.e. bays – where there is lots of boating, seabird nesting sites, and beaches – where animals and litter often get washed up).

### **Data measurement method**

All dead or injured animals should be collected and taken to an appropriate facility to determine the cause of death or rehabilitate the animal if possible. A vet or skilled specialist may be needed to confirm if the cause of death was litter related. The number and species of animal killed or injured needs to be recorded along with the type of litter responsible.

### **Data analysis and interpretation**

The presence of litter impacts the health of animals living in an area. Through the monitoring of the number and species of animal killed or injured and type of litter responsible, the major sources of this harmful litter can be determined and efforts then put in place to reduce its presence in the environment.

The NSW Scientific Committee (2004) listed three endangered species, eight threatened species and one endangered population of animals in NSW that have been recorded to be entangled with, or ingested, litter. They also reported that in NSW there were four endangered species and ten threatened species that were likely to be affected. The Committee also listed four species or populations that were not currently threatened but might become threatened due to the impacts of litter.

Excerpts from Global litter information gateway (<http://marine-litter.gpa.unep.org/facts/effects-wildlife.htm#top>):

Worldwide, people have reported entanglement for at least 143 marine species, including almost all of the world's sea turtles. At least 162 marine species, including most sea birds, have been reported to have eaten plastics and other litter.

177 species of marine animals are known to accidentally eat plastics. Plastics have been found in the digestive tracts of 111 different species of seabirds.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The number and species of animals affected by litter should be reported for each region or subregion in tables or graphs. Once sufficient information is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. If possible, the size of change that could be statistically detected with the methods used, should also be reported.

The number and species of animals killed, injured and released, or injured and remaining in captivity should be reported. The type of litter causing the death/injury should also be reported on so that trends in its occurrence in the environment can be monitored.

### **Proposed responsibilities**

"The [Queensland] EPA maintains a database of marine wildlife strandings and deaths, called StrandNet. This records information on where injured, dying and dead marine cetaceans (whales and dolphins), pinnipeds (seals and sea lions), dugong and turtles have been found in Queensland. The EPA assesses the cause of the injuries or death where known, and summarises that information in annual reports."

([http://www.epa.qld.gov.au/nature\\_conservation/wildlife/caring\\_for\\_wildlife/marine\\_strandings/](http://www.epa.qld.gov.au/nature_conservation/wildlife/caring_for_wildlife/marine_strandings/)).

Data on animal death and injury resulting from litter has been gathered for many estuarine, coastal and marine waters from around Australia. State/Territory agencies (Parks and Wildlife Service or equivalent), major research institutions and universities, as well as zoos, animal parks and wildlife rehabilitation/protection groups have collected and stored most of the data.

The regional body may or may not choose to monitor animal death and injury resulting from litter themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Presence/extent of litter (indicator)

Significant native species and ecological communities (matters for targets)

### **Further information and references**

Clean Up Australia Online. [www.cleanup.com.au](http://www.cleanup.com.au)

Derraik, J.G.B. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin* 44: 842–852.

Environment Protection Agency (Queensland). 2004. *Marine strandings* website:  
[http://www.epa.qld.gov.au/nature\\_conservation/wildlife/caring\\_for\\_wildlife/marine\\_strandings/](http://www.epa.qld.gov.au/nature_conservation/wildlife/caring_for_wildlife/marine_strandings/)

Faris, J. and Hart, K. 1996. *Seas of Debris: A Summary of the Third International Conference on Marine Debris*. Miami, Florida, 8-13 May 1994. 54 pp. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle.

Global Litter Information Gateway. <http://marine-litter.gpa.unep.org/facts/effects-wildlife.htm#top>

Laist, D.W. 1987. An overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin* 18 (6B): 319-326.

NSW Scientific Committee. 2004. *Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments – key threatening process declaration*. Final determination. NSW National Parks and Wildlife Service.

[http://www.nationalparks.nsw.gov.au/npws.nsf/Content/marine\\_debris\\_ktp\\_declaration](http://www.nationalparks.nsw.gov.au/npws.nsf/Content/marine_debris_ktp_declaration)

Page, B., McKenzie, J., McIntosh, R., Bayliss, A., Morissey, A., Calvert, N., Hasse, T., Berris, M., Dowie, D., Shaughnessy, P.D. and Goldsworthy, S.D. 2003. *A summary of Australian sea lion and New Zealand fur seal entanglements in marine debris pre- and post-implementation of Australian Government fishery bycatch policies*. The Australian Marine Sciences Association Annual Conference 2003, Brisbane, Queensland, 9 - 11th July 2003.

Pemberton, D., Brothers, N.P. and Kirkwood, R. 1992. Entanglement of Australian Fur Seals in man-made debris in Tasmanian waters. *Wildlife Research* 19: 151-159.

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

EPA – Environment Protection Agency.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WWF – World Wildlife Fund.

## Indicator: Benthic microalgae biomass (in intertidal sand/mudflat communities)

### Definition

This indicator documents the benthic microalgae biomass in intertidal sand/mudflat communities.

### Rationale

"Benthic microalgae (BMA) are single-celled microscopic plants (primarily diatoms and dinoflagellates) and cyanobacteria which inhabit the top 0-3 cm of aquatic sediments. Their biomass can be detected and quantified by chlorophyll *a* analysis using the same method described previously [see chlorophyll *a* indicator] for determination of phytoplankton biomass in the water column." (Dennison and Abal, 1999).

BMA are ecologically important in estuarine, coastal and marine systems as they are a source of food for benthic and suspension feeders and they help stabilize sediments. BMA also help regulate nutrients levels in the water column by regulating nutrient exchange rates between the sediment and water.

Increased nutrient loads into estuarine, coastal and marine environments can, under certain conditions, cause increased plant growth. In intertidal and shallow subtidal sand/mudflat communities, these nutrient loads may result in increased benthic microalgae growth.

It has been shown that BMA may be the most productive marine plants within Moreton Bay, Queensland, (Dennison and Abal, 1999).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients Hydrodynamics	>\$100	Moderate Moderate	Hard Hard	DEC, DIPNR (NSW) Geoscience Australia SARDI (SA)

### Links to stressors

This indicator is most likely to respond to the following stressors:

- Nutrients
- Hydrodynamics

This indicator may also respond to the following stressors:

- Freshwater flow regime
- Aquatic sediments

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly nutrients (nitrogen) and hydrodynamics. Data interpretation may also benefit from the monitoring of appropriate habitat extent indicators associated with the stressor nutrients (i.e. extent/distribution of subtidal macroalgae).

### ***Links to issues***

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Eutrophication
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

### ***Monitoring method***

BMA biomass can be ascertained by determining the levels of chlorophyll *a* in sediments using the same method for determination of chlorophyll *a* biomass in the water column (see chlorophyll *a* indicator).

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### ***Monitoring locations***

There can be significant spatial and temporal variation observed in BMA concentrations. Spatial differences are often observed along the length of a waterway, whereas, temporal differences are observed seasonally. This temporal and spatial variation must be accounted for when designing a field monitoring program.

As much of the eutrophication in estuarine and coastal waters (resulting in high plant concentration and production) is thought to be the result of terrestrial human activities, and as estuaries link the land to the sea, they are a good monitoring location for land run-off (Ward *et al.*, 1998).

### ***Monitoring frequency***

The monitoring of BMA concentration needs to be conducted as regularly and frequently as possible to determine whether a change is natural variation, or induced by some stressor.

### ***Data measurement methods***

BMA biomass can be ascertained by determining the levels of chlorophyll *a* in sediments. Chlorophyll *a* concentration is usually determined by filtering a known volume of water sample through 0.45 micron mesh filter paper which is then analysed. The amount of chlorophyll *a* is then determined using a spectrophotometer and the original sample concentration ( $\mu\text{g/l}$ ) calculated.

### ***Data analysis and interpretation***

Low chlorophyll *a* levels suggest good condition. However, high levels are not necessarily bad as increased phytoplankton growth tends to support larger heterotroph (e.g. fish) populations. It is the long-term persistence of elevated levels that is a problem. Excessive growth often leads to poor water quality, noxious odours, oxygen depletion, human health problems and fish kills. It may also be linked to harmful (toxic) algal blooms.



Currently, there is very little information on BMA communities as they have been poorly studied (Dennison and Abal, 1999).

Observed increases in the biomass of BMA in individual waterbodies may be related to increased nutrient concentrations, decreased flow/changed hydrodynamics (increased residence times) and/or decreased turbidity (increased light penetration) (i.e. the increasing eutrophication status). It is therefore important to try and correlate a change in BMA biomass to nutrients, hydrodynamics and/or turbidity changes to determine if changes are natural or due to human impacts.

The effect of nutrient load, turbidity and other environmental conditions on BMA in different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of BMA biomass is probably most easily represented in tables, graphs or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on BMA biomass is available for a location, it will be possible to produce tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The size of change that could be statistically detected with the methods used, should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Little to no data on BMA biomass exists for estuarine, coastal and marine waters from around Australia. What is present has been gathered for specific studies (see Dennison and Abal, 1999).

The regional body may or may not choose to monitor benthic microalgae themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Total nutrients in the sediment WITH total dissolved nutrients in the sediment (indicator)  
Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)  
Nutrients in aquatic environments (matters for targets)

### **Further information and references**

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Dennison, W.C. and Abal, E.G. 1999. *Moreton Bay Study: A Scientific Basis for the Healthy Waterways Campaign*. 246 pp. South East Queensland Regional Water Quality Management Strategy, Brisbane.

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Benthic – On the bottom of a body of water or in the bottom sediments.

**Biomass** – The total weight of all living organisms in a biological community or of a particular species/group.

**Cyanobacteria** – Photosynthetic bacteria previously called blue-green algae.

**DEC** – Department of Environment and Conservation.

**Diatom** – Microscopic algae with cell walls made of silicon.

**Dinoflagellate** – Microorganisms with both plant-like and animal-like characteristics, usually classified as protozoans having two lash-like structures (flagella) used for locomotion.

**DIPNR** – Department of Infrastructure, Planning and Natural Resources.

**Eutrophication** – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

**SARDI** – South Australian Research and Development Institute.

**Spatial** – Pertaining to space or distance.

**Temporal** – Pertaining to time.

## Indicator: Biomass, or number per unit area, of epiphytes (in seagrass or mangrove communities)

### Definition

This indicator documents the change in biomass, or number per unit area, of epiphyte plant growth in seagrass and/or mangrove communities.

### Rationale

Increased nutrient loads into estuarine and marine environments can, under certain conditions, cause increased plant growth. In seagrass and mangrove communities these nutrient loads may result in increased epiphyte plant (and periphyton) growth.

Epiphytes obtain all their nutrients from the water column and are not competitive when nutrient concentrations are relatively low. If nutrient levels increase in the water column, epiphytes become more competitive as they capture and use light more efficiently and are fast growing.

Increased epiphyte growth can have detrimental effects on the plant it grows on as it decreases the diffusion rate of nutrients and gases, decreases photosynthesis through shading, and may break seagrass leaves off their stems due to the weight of the epiphyte.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a *rough guide only*. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients Hydrodynamics	<\$30	Moderate Moderate	Moderate Hard	DEC, DIPNR (NSW) Geoscience Australia SARDI (SA) WRC (WA)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Nutrients
- Hydrodynamics

This indicator may also respond to the following stressors:

- Freshwater flow regime

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for the stressors nutrients (nitrogen) and hydrodynamics. Data interpretation may also benefit from the monitoring of appropriate

habitat extent indicators associated with the stressor nutrients (i.e. extent/distribution of subtidal macroalgae).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Eutrophication
- Loss of seagrass
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

### **Monitoring method**

Information on monitoring methods for epiphytic plant growth can be found in the EPA (1998) publication on seagrass coverage, McMahon *et al.* (1997), other scientific publications and at the DEH (SA) website (<http://www.environment.sa.gov.au/coasts/coastcare/monitoring.pdf>).

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with State/Territory protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

Sites chosen for monitoring will depend on particular aspects of the study. In general, the sites will be in a region where it is thought that nutrients are entering the estuarine or marine system (e.g. river mouths, stormwater inputs, etc.). A control site is also needed as large amounts of epiphyte growth are not always associated with human causes. When comparing different locations, it is important that water depth and wave energy is kept constant. Water depth affects light penetration and hence epiphyte growth, while wave energy affects epiphyte attachment (high wave energy tends to remove epiphytes).

### **Monitoring frequency**

The frequency of monitoring will also depend on particular aspects of the study. For example, if examining diffuse nutrient loads from land run-off, then comparison between the wet and dry seasons would be necessary.

### **Data measurement methods**

Two measurement methods can be used to determine epiphyte growth. Artificial substrates can be used to determine epiphyte growth rates, density, biomass and species composition. These can then be compared to other sites and times. Epiphytes can also be collected directly from the host plant: density and biomass can then be determined and changes compared over time.

### **Data analysis and interpretation**

Increased growth of epiphyte plants (and periphyton) is often observed in response to increased nutrient loads entering the estuarine or marine environment. However, decreased flow/changed hydrodynamics (increased residence times) and/or decreased turbidity (increased light penetration), (i.e. the increasing eutrophication status) may also result in a change in epiphyte growth. It is therefore important to try and correlate a change in epiphyte growth to nutrients, hydrodynamics and/or turbidity changes to determine if changes are natural or due to human impacts.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of epiphyte growth is probably most easily done in the form of graphs showing total dry weight of epiphytes (mg/cm<sup>2</sup>) for each location and time period. Once sufficient information on epiphyte growth is available for a location, it will be possible to produce graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change. The size of change that could be statistically detected with the methods used, should also be reported.

### **Proposed responsibilities**

Data on epiphyte growth has been gathered for several estuarine, coastal and marine waters from around Australia. State agencies, major research institutions and universities have collected and stored most of the data.

The regional body may or may not choose to monitor epiphyte growth themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Total nutrients in the sediment WITH total dissolved nutrients in the sediment (indicator)  
Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)  
Nutrients in aquatic environments (matters for targets)

### **Further information and references**

EPA (Environment Protection Agency, SA), 1998. Changes in seagrass coverage and links to water quality off the Adelaide metropolitan coastline. 27 pp. Government of South Australia.

DEH (Department for Environment and Heritage, SA). Website:  
<http://www.environment.sa.gov.au/coasts/coastcare/monitoring.pdf>

McMahon, K., Young, E., Montgomery, S., Cosgrove, J., Wilshaw, J. and Walker, D.I. 1997. Status of a shallow seagrass system, Geopraphe Bay, south-western Australia. *Journal of the Royal Society of Western Australia* 80: 255-262.

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

DEC – Department of Environment and Conservation.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Epiphytes – Plants or animals that attach themselves to the stem or leaves of plants.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Periphyton – Small epiphytic algae.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Biomass, or number per unit area, of macroalgae (in rocky shore, rocky reef or coral reef communities)

### **Definition**

This indicator documents the change in biomass, or number per unit area, of macroalgae in rocky shore, rocky reef or coral reef communities.

### **Rationale**

Macroalgae (commonly called seaweed) are multicellular plants that obtain dissolved nutrients from the water column. They grow both intertidally and subtidally usually attached to hard substrates (e.g. rocks and dead coral skeletons). Due to different pigments within the macroalgae they can be divided into three colour types; red (Rhodophyta), green (Chlorophyta) and brown (Phaeophyta).

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Subtidal beds of macroalgae are important elements of shallow waters (<50 m depth) in estuaries, bays and coastal regions. Whilst they are mainly concentrated in temperate zones of Australia, where there are high levels of endemism, some taxa (such as *Halimeda*) are also important in the tropics. The distribution of many other tropical genera is highly uncertain. Apart from their intrinsic floral values as a diverse suite of species, algal beds have important ecological roles in shallow marine systems. They harbour many species of fauna valued for commercial and recreational purposes, and are important primary producers in a number of near-shore environments. Algae are generally sensitive to water quality – particularly to turbidity, but also to nutrients and some chemical residues. In temperate areas, algal beds are threatened by invasive pest species (some of which are algae) and by long-term changes in environmental conditions such as sea level and climate changes that result in increased runoff of sediments from land and other threats.

The presence of certain types of macroalgae often indicates nutrient enriched waters as macroalgae thrive in waters that receive nutrient pollution. This strong relationship between macroalgae and water quality has resulted in much research into using them as indicators (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>). In rocky reef, rocky shore and coral reef communities, changes in macroalgal density is a useful indicator of changes to the stressor 'nutrients' or 'aquatic sediments'.

### **Key information**

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients Hydrodynamics	>\$100	Moderate Moderate	Moderate Hard	DEC (NSW) Geoscience Australia SARDI (SA) TAFI (TAS) WRC (WA)

**Links to stressors**

This indicator is most likely to respond to the following stressors:

- Nutrients
- Hydrodynamics

This indicator may also respond to the following stressors:

- Aquatic sediments

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly nutrients (nitrogen) and hydrodynamics.

**Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Eutrophication
- Loss of corals
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

**Monitoring method**

Detailed monitoring methods for determining macroalgal biomass/density can be found in numerous publications including: guidelines for State of the Environment reporting ('algal bed area' and 'algal bed species') (Ward *et al.*, 1998), scientific publications, Reefwatch and Waterwatch monitoring manuals, and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (Ward *et al.*, 1998) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

**Monitoring locations**

The density of macroalgae present in rocky reef, rocky shore and coral reef communities should be monitored using standard field sampling protocols (i.e. line transect or plot methods); the locations being determined via pilot studies or expert knowledge.

**Monitoring frequency**

"Algal beds may change quickly in response to disturbances" (Ward *et al.*, 1998). They should therefore be frequently monitored in areas where stressors (threats/pressures) are thought to be affecting them.

**Data measurement methods**

This indicator would be measured using standard field sampling techniques for measuring algal species biomass or unit per area (i.e. density) (e.g. line transects, quadrats, plots, etc.). The exact

protocols used need to be defined and developed depending on the sites to be monitored. Protocol development may need specialised assessment and pilot studies.

### ***Data analysis and interpretation***

In general, due to the highly variable nature of algal biomass/density both temporally and spatially, initially there will be no standard data available to compare against. Results from initial studies will form the baseline data against which future results can be compared.

Macroalgal biomass/density will change naturally (e.g. seasonal variation, recovery from past impact) or due to human impacts (e.g. sediments, nutrients). Monitoring of control (undisturbed) and impacted sites over at least a couple years will be needed to help determine if the change in biomass/density is natural or not. A constant difference in biomass/density between the control and impacted site, or a continual increase at a site can indicate that human activities are impacting on macroalgal biomass. When an increase in macroalgal biomass is observed, this may indicate that there is an increase in the availability of nutrients in the system.

### ***Data storage***

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### ***Monitoring and reporting products***

Reporting on macroalgal biomass/density is probably most easily represented in maps, tables or graphs (against time), with an estimate of uncertainty (e.g. 95% confidence limits), for each location. Once sufficient information on macroalgal biomass/density is available for a location, it will be possible to produce maps, graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change.

### ***Proposed responsibilities***

Data on macroalgal biomass/density has been gathered for estuarine, coastal and marine waters from around Australia. State agencies, major research institutions and universities have collected and stored most of the data. With the exception of the State of the Environment reporting every four-five years, there are currently no ongoing systematic monitoring programs across regions or larger scales.

The regional body may or may not choose to monitor macroalgae themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### ***Links to other indicators and matters for targets***

Extent/distribution of subtidal macroalgae (indicator)

Total nutrients in the sediment WITH total dissolved nutrients in the sediment (indicator)

Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)

Nutrients in aquatic environments (matters for targets)

### ***Further information and references***

(*OzEstuaries*). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

Reefwatch (South Australia) monitoring manuals. See <http://www.reefwatch.asn.au>



Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

Waterwatch manuals: See <http://www.sa.waterwatch.org.au/programs.htm#manuals> and <http://www.waterwatch.org.au/>

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

DEC – Department of Environment and Conservation.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Genera – A taxonomic group of organisms, one level higher than species.

Line transect – A straight line placed on the ground along which ecological measurements are taken.

Primary producers – Photosynthetic organisms that produce a 'food source' for the next level up the food chain.

Quadrats – An ecological sampling unit that consists of a square frame of a known area.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

Taxa – A taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Chlorophyll a

### **Definition**

This indicator documents the concentration of chlorophyll a in estuarine, coastal and marine open waters (water column) as an indicator of microscopic plant biomass.

### **Rationale**

The concentration of the photosynthetic green pigment chlorophyll a in estuarine, coastal and marine waters is a proven indicator of the abundance and biomass of microscopic plants (phytoplankton) such as unicellular algae. Chlorophyll data are useful over a range of spatial scales from small coastal waters (estuaries, embayments and coastal lagoons) up to shelf seas. It can be employed to give an estimate of primary production, but there is not necessarily a rigorous or coherent relation between biomass and primary productivity. Phytoplankton are the direct or indirect source of food for most marine animals.

Chlorophyll a concentration is a commonly used measure of water quality (as a surrogate of nutrient availability); with low levels suggesting good condition. However, high levels are not necessarily bad and it is the long-term persistence of elevated levels that is a problem. As the long-term levels are important, the annual median chlorophyll a concentration is used as an indicator in State of the Environment reporting (Ward *et al.*, 1998). Chlorophyll a was used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

The main cause of excessive algae growth appears to be increased nutrient inputs (indicating eutrophication) but it is also affected by declines in the abundance of filter-feeders (e.g. oysters and mussels), reduced aquatic sediments (i.e. increased levels of light penetration), increased water temperature and changes in flushing rates (i.e. hydrodynamics and freshwater flow regimes).

For a detailed explanation of what factors influence chlorophyll a concentrations, the significance of these levels and which waterways are susceptible to elevated levels see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Key information**

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients Hydrodynamics	<\$30	Moderate Moderate	Moderate Moderate	DEC, DIPNR (NSW) DIPE, DBIRD (NT) EPA (QLD) EPA (VIC) EPA, AWQC, SARDI (SA) GBRMPA TASQP, TAFI (TAS) Waterwatch WRC (WA)

### Links to stressors

This indicator is most likely to respond to the following stressors:

- Nutrients
- Hydrodynamics

This indicator may also respond to the following stressors:

- Freshwater flow regime
- Water temperature
- Aquatic sediments

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly nutrients (nitrogen) and hydrodynamics. Data interpretation may also benefit from the monitoring of appropriate habitat extent indicators associated with the stressor nutrients (i.e. extent/distribution of subtidal macroalgae).

### Links to issues

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Eutrophication
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

### Monitoring method

Detailed monitoring methods for chlorophyll can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications, Waterwatch monitoring manuals (see Waterwatch Qld, 2003; <http://www.sa.waterwatch.org.au/programs.htm#manuals>) and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### Monitoring locations

There can be significant spatial and temporal variation observed in phytoplankton concentrations. Spatial differences are often observed along the length of a waterway, whereas, temporal differences are observed as some phytoplankton move up and down through the water column in a day/night cycle. This temporal and spatial variation must be accounted for when designing a field monitoring

program. Remote sensing methods reduce the effects of spatial variation by covering large areas at one time.

As much of the eutrophication in estuarine and coastal waters (resulting in high chlorophyll concentrations) is thought to be the result of terrestrial human activities, and as estuaries link the land to the sea, they are a good monitoring location for land run-off (Ward *et al.*, 1998).

### **Monitoring frequency**

The direct monitoring of chlorophyll concentration needs to be conducted as regularly and frequently as possible to determine whether a change is natural variation, or induced by some stressor. The frequency of remote sensing (satellite imagery) measurements will be set by the return interval of the satellite. Remote sensing (aerial scanners) can obtain data regularly but also at times of interest. A disadvantage with both remote methods is that weather conditions (cloud cover, storms) can prevent regular measurements. Automated, *in-situ* field equipment (fluorescence) is advantageous in that it can monitor at a high frequency.

### **Data measurement methods**

Chlorophyll *a* concentrations (expressed as micrograms per litre - µg/l) can be determined through direct (water samples) and indirect (fluorescence, remote sensing) measurement methods. Chlorophyll *a* concentration is usually determined by filtering a known volume of water sample through 0.45 micron mesh filter paper which is then analysed. The amount of chlorophyll *a* is then determined using a spectrophotometer and the original sample concentration (µg/l) calculated.

Chlorophyll can also be measured from within the water column using fluorescence with special equipment or via remote sensing. Remote sensing uses colour scanners from either plane or satellite and can be relatively cost effective. However, different water bodies need specific algorithms that must be ground-truthed. Also, values of chlorophyll measurements using remote sensing of waterways which are highly turbid (e.g. tide dominated estuaries) will be affected by the suspended sediment. Despite these limitations, remote sensing measures minimise the effects of temporal and spatial variation.

### **Data analysis and interpretation**

Low chlorophyll *a* levels suggest good condition. However, high levels are not necessarily bad as increased phytoplankton growth tends to support larger heterotroph (e.g. fish) populations. It is the long-term persistence of elevated levels that is a problem. Excessive growth often leads to poor water quality, noxious odours, oxygen depletion, human health problems and fish kills. It may also be linked to harmful (toxic) algal blooms.

High chlorophyll concentrations need to be distinguished from the natural variation observed seasonally, with latitude, and those associated with hydrodynamic features (e.g. upwelling). However, currently there is very little information to make this distinction (Ward *et al.*, 1998).

Observed increases in the concentrations of chlorophyll in individual waterbodies may be related to increased nutrient concentrations, decreased flow/changed hydrodynamics (increased residence times) and/or decreased turbidity (increased light penetration) (i.e. the increasing eutrophication status). It is therefore important to try and correlate a change in chlorophyll concentration to nutrients, hydrodynamics and/or turbidity changes to determine if changes are natural or due to human impacts.

Default trigger values for chlorophyll *a* concentrations have been listed in the Water Quality Guidelines for coastal waterways in different geographic regions (ANZECC/ARMCANZ, 2000a). The Department of the Environment and Heritage (Australian Government) provides protocols for State of the Environment reporting (Ward *et al.*, 1998). The effect of nutrient load and environmental conditions on chlorophyll *a* concentrations in different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of chlorophyll concentration is probably most easily represented in tables, graphs or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on chlorophyll is available for a location, it will be possible to produce tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The size of change that could be statistically detected with the methods used, should also be reported. The number of times chlorophyll a concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Data on chlorophyll a has been gathered for many estuarine, coastal and marine waters from around Australia, but it is irregular and scattered with some of dubious quality (Ward *et al.*, 1998). State agencies, Waterwatch, Commonwealth institutions and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on chlorophyll a as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor chlorophyll a themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Algal blooms (indicator)

Total nutrients in the sediment WITH total dissolved nutrients in the sediment (indicator)

Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)

Turbidity/water clarity (indicator)

Nutrients in aquatic environments (matters for targets)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

(OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

Waterwatch manuals: See <http://www.sa.waterwatch.org.au/programs.htm#manuals> and <http://www.waterwatch.org.au/>

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

### **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

DBIRD – Department of Business, Industry and Resource Development.

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Embayment – A large indentation of a shoreline, bigger than a cove but smaller than a gulf.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

GBRMPA – Great Barrier Reef Marine Park Authority.

Ground-truthed – To confirm remotely obtained data by physically visiting a site.

*In-situ* – Latin term for 'in the original place'.

Primary production – Production of a 'food source' by photosynthetic organisms at the bottom of the food chain.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

TASQP – Tasmanian Shellfish Quality Assurance program.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.



## Indicator: Coral bleaching

### Definition

This indicator documents the occurrence of coral bleaching.

### Rationale

Bleaching is the result of the release/removal of symbiotic unicellular algae (zooxanthellae) from the coral's tissues. Normally, these zooxanthellae supply the coral with food and give them their normal colour. Coral bleaching occurs in reef corals which are under stress and results in the loss of colour, leaving the coral white.

There are several environmental factors that are thought to cause bleaching. These include: disease, increased ultraviolet radiation, storms and heavy rains, excess shade, sedimentation, nutrient and toxicant pollution, salinity changes and increased temperatures. If the stressful conditions occur over a long time the corals will bleach and die. However, if the stressful conditions stop and the system returns to normal, then the bleached corals may recover their zooxanthellae and survive.

*Excerpts from GBRMPA website*

([http://www.gbrmpa.gov.au/corp\\_site/info\\_services/science/bleaching/index.html](http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/index.html)):

If stressful conditions, such as high water temperatures, prevail at a regional level, large areas of coral reef can be affected in what is known as a mass bleaching event. The mass bleaching events reported on the Great Barrier Reef [GBR] and elsewhere around the world over the last 5-10 years have been triggered primarily by anomalously high water temperatures.

The mass bleaching event that occurred in the summer of 2002 affected between 60% and 95% of reefs in the Marine Park. This was the worst bleaching event ever recorded for the GBR. While most reefs that were surveyed survived with relatively low levels of coral death, some locations suffered severe damage with up to 90% of corals killed. Up to 5% of reefs on the GBR have been severely damaged during each of the last two major bleaching events, including the inshore reefs around Bowen and Mackay, and some reefs in the Coral Sea. Full recovery of these badly damaged reefs will take many years to decades.

Detailed information about coral bleaching can be found at the GBRMPA (<http://www.gbrmpa.gov.au>) and AIMS (<http://www.aims.gov.au>) websites.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Water temperature	<\$100	Moderate	Very hard	CALM (WA) DIPE (NT) GBRMPA

**Links to stressors**

This indicator is most likely to respond to the following stressor:

- Water temperature

This indicator may also respond to the following stressors:

- Aquatic sediments
- Nutrients
- Toxicants

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors.

**Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Climate change/global warming (increased air temperature)
- Coral bleaching
- Poor water quality: elevated water temperature, high nutrients, high turbidity, high toxicants
- Sea surface water temperature (average temperature – changed)

**Monitoring method**

Information of the monitoring of coral bleaching can be found at the GBRMPA website [http://www.gbrmpa.gov.au/corp\\_site/info\\_services/science/bleaching/index.html](http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/index.html), AIMS websites <http://www.aims.gov.au/pages/search/search-coral-bleaching.html>, and in scientific publications.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

**Monitoring locations**

Monitoring locations will be coral reefs within the region. The severity of bleaching can vary substantially according to water depth, location and species of corals, so these factor must be taken into consideration when choosing sites.

The monitoring of this indicator is somewhat opportunistic as the general public may be the source of initial reports on bleaching events. These reports of coral bleaching should be confirmed and the location monitored.

**Monitoring frequency**

Monitoring will generally occur during the hotter summer months and in response to reported bleaching events.

**Data measurement methods**

This indicator would be measured using standard field sampling techniques for measuring species density/percentage cover (e.g. line/video transects, quadrats, etc.). The exact protocols used, need to be defined and developed depending on the area to be monitored. Protocol development may need specialised assessment and pilot studies.

**Data analysis and interpretation**

Coral bleaching is a natural event. However, the rate at which it is occurring today is unnatural.



In general, due to the highly variable nature of coral bleaching events both temporally and spatially, initially there will be no standard data available to compare against. Results from initial studies will form the baseline data against which future results can be compared. A constant difference in coral bleaching events and extent/severity between the control and impacted sites, or a continual increase in coral bleaching at a site can indicate that human activities are impacting on corals.

The stressor most commonly associated with bleaching events is increased sea temperature, but additional stressors such as aquatic sediments, toxicants and nutrients are known to intensify coral bleaching events. Corals generally live in a narrow 'average' temperature range of between 25°C and 29°C. It is the prolonged rise in 'average' monthly summer sea temperature, of as little as 1 or 2°C, and not rapidly changing temperatures that cause bleaching in many coral species.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of coral bleaching is probably most easily represented in tables or graphs (against time), with an estimate of uncertainty (e.g. 95% confidence limits), for each location. Once sufficient information on coral bleaching is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The species affected, area affected and survival rate should all be reported against.

### **Proposed responsibilities**

Data on coral bleaching exist for waters of the Great Barrier Reef. Major research institutions (e.g. GBRMPA, AIMS) and universities have collected and stored most of the data.

The regional body may or may not choose to monitor coral bleaching themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Water temperature (indicator)

Significant native species and ecological communities (matters for targets)

### **Further information and references**

AIMS. 2004. *Coral bleaching index*. Website: <http://www.aims.gov.au/pages/search/search-coral-bleaching.html>

GBRMPA. *Coral Bleaching and Mass Bleaching Events*. Website: [http://www.gbrmpa.gov.au/corp\\_site/info\\_services/science/bleaching/index.html](http://www.gbrmpa.gov.au/corp_site/info_services/science/bleaching/index.html)

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

CALM – Department of Conservation and Land Management.

DIPE – Department of Infrastructure, Planning and Environment.

GBRMPA – Great Barrier Reef Marine Park Authority.

Quadrats – An ecological sampling unit that consists of a square frame of a known area.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

Zooxanthellae – Microscopic algae that live in a symbiotic relationship with certain corals, clams, and some sponges.

## Indicator: Death of marine mammals, endangered sharks and reptiles caused by boat strike, shark nets or drum lines

### Definition

This indicator documents the number of deaths of marine mammals, endangered sharks and reptiles caused by boat strike, shark nets or drum lines.

### Rationale

Many species of endangered or threatened marine mammals, sharks and reptiles are particularly at risk from boat strike, shark nets or drum lines.

Shark nets and drum lines offer some protection to swimmers by 'fishing' for potentially dangerous sharks and reducing their numbers around protected beaches. Unfortunately, they also indiscriminately capture other marine life, including harmless sharks, rays, dolphins, dugong, whales, turtles, etc., some of which are critically endangered.

Boat strike is another human related cause of death for marine mammals and reptiles. These animals are air breathers and must surface regularly, therefore, putting them at risk of boat strike.

The loss of even a couple of critically endangered animals a year due to humans will have a high impact on the chances of survival of the species. Boat strike, shark nets and drum lines thus pose a large threat to many marine mammal, shark and turtle species, particularly the threatened or endangered ones.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Biota removal/disturbance	>\$100	Moderate	Moderate	CALM (WA) DIPE (NT) EPA, DPI (QLD) WWF

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Biota removal/disturbance

### ***Links to issues***

The following list contains the main NRM 'issues' associated with this indicator:

- Biota (plants and animals) lost/disturbed
- Boating and shipping
- Loss of threatened/endangered and culturally significant species
- Recreational use (powerboat and jet ski usage)
- Use of shark nets and drum lines

### ***Monitoring method***

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### ***Monitoring locations and frequency***

The monitoring of this indicator in relation to boat strike is opportunistic and, as such, it is not linked with any set monitoring location or frequency. Areas where animals are most likely to be hit by boats (i.e. estuaries and bays, marinas and ports, etc.), or where dead animals are likely to be found (beaches – where animals often get washed up), should be monitored.

Drum lines or shark nets within the region should be regularly monitored.

### ***Data measurement methods***

The species and number of all dead or entangled (but released alive) animals should be recorded.

### ***Data analysis and interpretation***

The presence of boats, shark nets and drum lines impacts the health of animals living in an area. The full extent of this impact needs to be fully analysed.

### ***Data storage***

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### ***Monitoring and reporting products***

The number and species of animals affected by boat strikes, shark nets and drum lines should be reported for each region or subregion in tables or graphs. Once sufficient information is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

### ***Proposed responsibilities***

"The [Queensland] EPA maintains a database of marine wildlife strandings and deaths, called StrandNet. This records information on where injured, dying and dead marine cetaceans (whales and dolphins), pinnipeds (seals and sea lions), dugong and turtles have been found in Queensland. The EPA assesses the cause of the injuries or death where known, and summarises that information in annual reports."

([http://www.epa.qld.gov.au/nature\\_conservation/wildlife/caring\\_for\\_wildlife/marine\\_strandings/](http://www.epa.qld.gov.au/nature_conservation/wildlife/caring_for_wildlife/marine_strandings/)).

Data on animal death and injury resulting from boat strikes, shark nets and drum lines exist for waters from around Australia, but in general, has been gathered haphazardly. State/Territory agencies, local governments, private contractors, zoos, animal parks (e.g. Sea World) and wildlife rehabilitation/protection groups have collected and stored most of the data.

The regional body may or may not choose to monitor this indicator themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

**Links to other indicators and matters for targets**

Animal or plant species abundance (indicators)

Significant native species and ecological communities (matters for targets)

**Further information and references**

Environment Protection Agency (Queensland). 2004. *Marine strandings*. Website:

[http://www.epa.qld.gov.au/nature\\_conservation/wildlife/caring\\_for\\_wildlife/marine\\_strandings/](http://www.epa.qld.gov.au/nature_conservation/wildlife/caring_for_wildlife/marine_strandings/)

**Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

CALM – Department of Conservation and Land Management.

DIPE – Department of Infrastructure, Planning and Environment.

DPI – Department of Primary Industries.

EPA – Environment Protection Agency.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WWF – World Wildlife Fund.

## Indicator: Dissolved Oxygen (DO)

### Definition

This indicator reports on the amount of dissolved oxygen (DO) present in estuarine, coastal and marine waters.

### Rationale

The majority of aquatic animals need oxygen to survive, and, with the exception of air-breathing animals like marine reptiles and mammals, most use oxygen dissolved in the water. DO concentrations are a result of the interaction between oxygen production (i.e. photosynthesis) and oxygen consumption (i.e. aerobic respiration, nitrification and chemical oxidation) within the water environment and the exchange of oxygen with the atmosphere. Natural processes (e.g. weather, tides and currents) and human pollution (particularly, organic matter) can result in severe reductions in dissolved oxygen levels. Both anoxia (no oxygen) and hypoxia (very low oxygen) are harmful to most marine animals. Anoxia and hypoxia can cause animal kills, a decrease in the available habitat and limit animal movements. Low DO can also result in reducing conditions occurring within the sediments which may cause previously bound nutrients and toxicants to be released into the water column.

Anoxic and hypoxic events, and DO, were used as one determinant of ecosystem integrity and water quality, respectively, in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

For a detailed explanation of what factors influence DO concentrations and the significance of DO levels, as well as related information on anoxic and hypoxic events, see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Organic matter	<\$5	>\$1000	Moderate	Moderate	DEC, DIPNR (NSW) DIPE (NT) EPA (QLD) EPA (VIC) SARDI (SA) TAFI (TAS) Waterwatch WRC (WA)

### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Organic matter

This indicator may also respond to the following stressors:

- Water temperature
- Nutrients
- Hydrodynamics
- pH

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors. Data interpretation will also benefit from the monitoring of appropriate biological condition indicators associated with the stressor organic matter (i.e. animal kills) and nutrients (i.e. algal blooms).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Algal blooms and nuisance growth of aquatic plants
- Animal kills
- Anoxic and hypoxic events (i.e. no/low dissolved oxygen) due to increased oxygen demand
- Diffuse organic matter sources: catchment run-off (rural and urban)
- Episodic and large scale events (drought, floods, storms, cyclones, bushfires)
- Eutrophication
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflows, dumping of organic matter

### **Monitoring method**

Detailed monitoring methods for DO can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

The location of monitoring sites should be determined on the basis of particular aspects of the study. As bottom waters are more likely to have low DO they should therefore be sampled (building a profile through different depths is often useful).

### **Monitoring frequency**

DO should be measured frequently and regularly (continuously if possible). At the very least, two measurement should be taken: during peak oxygen production (midday-early afternoon) and maximum respiration (just pre-dawn) to approximate the diurnal range. Although single DO measurements may be useful for checking for possible low DO causes of animal kills, they are generally not very useful as the diurnal range of DO is required for proper data interpretation.

### **Data measurement methods**

DO levels can be measured using two standard methods (membrane electrodes and the Winkler (iodometric) method). For continuous, *in-situ* measurements, membrane electrodes are the most practical.

Both salinity and water temperature affect the solubility of oxygen. Therefore, DO is often expressed as percentage saturation as this is independent of salinity and water temperature. Most of the equipment used to measure DO is able to convert DO mg/l to % saturation.

### **Data analysis and interpretation**

Dissolved oxygen refers to the amount of oxygen contained in water. The solubility of oxygen in water is limited and DO levels usually ranges from 6 to 14 mg/l. Water bodies are determined to be anoxic at oxygen concentrations of near 0 mg/l and hypoxic at oxygen concentrations of less than 2 mg/l.

Default trigger values for DO have been listed in the Water Quality Guidelines for different coastal waterways in different regions (ANZECC/ARMCANZ, 2000a). The effect of nutrient load and environmental conditions on DO in different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

DO levels change in response to a variety of factors including: salinity, water temperature, atmospheric and hydrostatic pressure, and oxygen consumption and production rates (and therefore factors influencing production and consumption). DO is subject to diurnal (daily) and seasonal variation. It varies over a 24 hour period due to net oxygen production (by plants and algae – photosynthesis) during the day, net respiration at night, and because of the tidal cycle causing mixing of the waters. Therefore, large diurnal variation in DO is more likely to be observed in highly productive systems.

Observed decreases in DO of individual waterbodies are primarily related to an increased organic matter load (e.g. from sewage treatment plants and industry, organic runoff or algal blooms) which leads to increased bacterial activity (decomposition by aerobic microorganisms). This increase in activity (increased oxygen consumption) can deplete available oxygen. Low oxygen levels generally affect bottom waters first and most severely.

The hydrodynamics of the system can affect DO levels. Stratification (non-mixing) of waters isolates the bottom waters from the oxygen enriching processes (i.e. photosynthesis, exchange with the atmosphere) occurring in the surface waters. Wave-dominated coastal systems are more susceptible to stratification and associated low DO because they typically have low tidal mixing.

Acid sulfate runoff may also affect DO, as the oxidation of iron-sulfides can rapidly remove oxygen from the water.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of DO is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on DO is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change. At a gross level, the indicator could be reported as the change in the number of anoxic and hypoxic (or trigger values) events.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Data on DO has been gathered for many estuarine, coastal and marine waters from around Australia. State agencies, Commonwealth institutions, consultancy companies and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on anoxic and hypoxic events and DO as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor DO themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.



While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Algal blooms (indicator)

Animal kills (indicator)

#### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

(OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

The Heinz Center. The state of the nation's ecosystems: Coasts and Oceans. [http://www.heinzctr.org/ecosystems/coastal/depl\\_oxy.shtml](http://www.heinzctr.org/ecosystems/coastal/depl_oxy.shtml)

Waterwatch Australia Steering Committee. 2002. *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra.

Waterwatch manuals: See <http://www.sa.waterwatch.org.au/programs.htm#manuals> and <http://www.waterwatch.org.au/>

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

#### **Glossary**

Aerobic – In the presence of oxygen.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

*In-situ* – Latin term for 'in the original place'.

Microorganism – Microscopic animal or plant.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Estuary mouth opening/closing

### Definition

This indicator documents the frequency of estuary mouth opening and closing.

### Rationale

When the estuary mouth is open, water exchanges freely between the estuary and sea with the tidal cycle. Many estuaries along the coastline of temperate Australia, particularly coastal lagoons, naturally close at times of small freshwater input due to the resulting formation of a sandbar across the mouth. The closure of the estuary causes a 'ponding' of water behind the sandbar and results in reduced/no flushing of the system. This 'closure' becomes particularly important when nutrient inputs are increased above natural levels. The lack of exchange with the sea means that nutrient levels continue to increase within the closed system, often resulting in eutrophication.

The closure of an estuary mouth also affects the movement of animals to and from the sea. This is particularly important for species that migrate to and from estuaries as part of their life cycle.

Many estuaries naturally open and close to the sea as a result of natural processes like droughts or seasonal low rainfall. However, estuarine mouth conditions are often altered through human action such as impoundments or water extraction. This unnatural closure of the estuary, particularly over long time periods, is often detrimental to estuarine animals and plants (see Vivier and Cyrus, 2002).

A change in the frequency of estuary mouth opening and closing is an indicator of a change in the stressors 'freshwater flow regime' and/or 'hydrodynamics'.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Freshwater flow regime	<\$5	Easy	Moderate	DIPNR (NSW)
Hydrodynamics		Easy	Hard	

### Links to stressors

This indicator is most likely to respond to the following stressors:

- Freshwater flow regime
- Hydrodynamics

It would be extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of appropriate biological condition indicators associated with the stressor hydrodynamics.

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Artificial opening or closing of estuary mouth
- Climate change (changed rainfall patterns)
- Entrance modification (dredging)
- Environmental flows – water flows and frequency of floods from catchment water changed from natural by dams, barriers, water extraction, levees, impoundments and weirs, increased hard surfaces, land cover, decreased water velocity
- Episodic and large scale events (drought, floods, storms, cyclones)
- Eutrophication – nuisance growth of aquatic plants or algae
- Impeded fish/animal passage
- Poor water quality: anoxia, hypoxia, turbidity, high nutrients
- Stratification of waters (change in mixing rates)

### **Monitoring method**

The exact details of the monitoring method used will depend on the region and particular aspects of the study. The method will attempt to define the bathymetry of the estuary mouth. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations and frequency**

Estuary mouths which periodically close will be monitored regularly (at the frequency of closure, e.g. during periods of low freshwater flow).

### **Data measurement methods**

Visits to the estuary mouth at similar tidal states (e.g. lowest water spring tides) will report visually and/or photographically on whether the estuary is opened or closed to the sea. Tide gauges in estuaries can also be used to monitor mouth opening and closing as a loss of tidal signal indicates that the mouth is closed.

### **Data analysis and interpretation**

Many estuaries open and close to the sea as a result of natural processes. A change from natural in the frequency of estuary mouth opening and closing is an indication of human-induced change.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The frequency of estuary mouth opening and closing should be reported for each estuary monitored and is probably best represented by maps with soundings, cross sections or photos of the estuary mouth. Once sufficient information on an estuary is available, it will be possible to produce similar products showing trends. These trends can then be reported as an estimate of change from previous baseline data. The size of change, that could be detected with the methods used, should also be reported.

### **Proposed responsibilities**

Data on estuary mouth opening and closing exist for some coastal lagoons from temperate Australia. State agencies and university researchers have collected and stored most of the data.

The regional body may or may not choose to monitor estuary mouth opening/closing frequency themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Algal blooms (indicator)  
Chlorophyll a (indicator)  
Water-current patterns (indicator)  
Salinity (indicator)

#### **Further information and references**

Vivier, L. and Cyrus, D.P. 2002. Ichthyofauna of the sub-tropical Nhlabane Estuary, KwaZulu-Natal: drought-related changes in the fish community during extended mouth closure. *Marine and Freshwater Research* 53: 457–464.

Young, G.C. and Potter, I.C. 2002. Influence of exceptionally high salinities, marked variations in freshwater discharge and opening of estuary mouth on the characteristics of the ichthyofauna of a normally-closed estuary. *Estuarine, Coastal and Shelf Science* 55: 223–246.

#### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Bathymetry – Measuring water depths to determine the topography of the sea floor.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Ichthyofauna – Fish fauna.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

Temporal – Pertaining to time.

## Indicator: Extent/distribution of key habitat types

### Definition

This indicator documents the extent/distribution of key habitats in estuarine, coastal and marine ecosystems.

The following is a list of key habitat types that were identified to be used as habitat extent indicators in the national State of the Environment reporting (see Ward *et al.*, 1998):

- Algal bed
- Beach and dune
- Coral reef
- Dune vegetation
- Intertidal reef
- Intertidal sand/mudflat
- Mangrove
- Saltmarsh
- Seagrass

However, the National State of the Environment (SoE) Program is presently reviewing the usefulness of all SoE indicators, including these habitat extent indicators and users should refer to the latest documentation for the recommendations on indicators ([www.deh.gov.au/soe](http://www.deh.gov.au/soe)).

Some of these habitat types are also recommended for monitoring for the Matter for Targets: "Native vegetation extent and distribution".

Other habitat types may be defined by regional communities as key habitat types as part of their NRM plans and may also be assessed for extent change.

### Rationale

Habitat loss and its effects on biodiversity is a growing global concern. Loss of habitat is a major cause of the decline of coastal species. These habitats support key communities within estuarine, coastal, and/or marine subsystems and have a high biodiversity, tourism, human use and conservation value. The health of coastal waterways depend on the maintenance of a diverse range of coastal habitat types. These habitats provide a variety of benefits including, shelter, food, breeding grounds, nursery areas and migratory corridors for marine life. Many habitats also help to protect/buffer water quality and resists storm-related erosion.

Not all habitat types will be present in a NRM region: reporting only needs to be undertaken for those habitats present and where the stressor 'habitat removal/disturbance' is present. Although other stressors may result in loss of key habitat, other indicators are more suitable for monitoring against those stressors because extent (area – hectares or km<sup>2</sup>) is a gross level indicator. For example, increased aquatic sediments, toxicants or nutrients, or any combination of these (and other stressors), may result in a change in seagrass extent. However, other indicators (as given in Section 3) are more directly linked to each stressor than is a change in seagrass extent.

Critical habitat loss used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the

indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Habitat removal/disturbance	>\$100	Easy	Moderate	DEC, DIPNR, DPI (NSW) DIPE (NT) DPI (QLD) EPA, SARDI (SA) Geoscience Australia Parks Victoria, DSE (VIC) TAFI (TAS) Waterwatch WRC (WA)

#### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Habitat removal/disturbance

This indicator (depending on the habitat type) may also respond to the following stressors:

- Nutrients
- Toxicants
- Aquatic sediments
- Water temperature
- Freshwater flow regime
- Hydrodynamics
- Pest species

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors and an appropriate biological condition indicator associated with the stressor habitat removal/disturbance (i.e. animal or plant species abundance).

#### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Beach and foreshore sediment erosion and accumulation
- Biodiversity decreased
- Episodic and large scale events (drought, floods, storms, cyclones, bushfires)
- Habitat removal, loss and disturbance: trawling, tourism, uncontrolled coastal access (especially off-road vehicles), buildings, construction, foreshore development, roads and bridges, marine facilities and infrastructure, aquaculture, urbanisation, dredging and extractive operations (sand and gravel mining), reclamation, etc.
- Human use and clearing
- Plants or animals disturbed/lost
- Poor water quality: turbidity, nutrients
- Visual amenity decreased

#### **Monitoring method**

Information on protocols for determining a change in habitat extent can be found in the guidelines for State of the Environment reporting (Ward *et al.*, 1998, and

[www.deh.gov.au/soe/publications/envindicators.html](http://www.deh.gov.au/soe/publications/envindicators.html)), scientific publications and OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

In general, mapping changes in the extent/distribution of habitat is relatively straightforward, and can often be undertaken by community groups such as Seagrass-Watch. Aerial photography and satellite imagery can be used, although ground-truthing by local groups is advised (see information provided in OzEstuaries). Certain aspects of some methods used to monitor habitat extent/distribution will require expert knowledge (e.g. plant identification, satellite imagery and sonar interpretation).

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (Ward *et al.*, 1998) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

The extent of each habitat type should be monitored for the whole region using remote sensing tools (satellite platforms, aerial photography) with ground-truthing. More information on monitoring design and strategies for different habitats can be found in Ward *et al.* (1998) and OzEstuaries.

### **Monitoring frequency**

Where key habitats are in areas with relatively high pressures/threats, their extent should be assessed annually. In other areas, where pressures are thought to be less, they should be assessed every 3-5 years.

### **Data measurement methods**

Depending on the habitat type being measured, aerial photography, satellite imagery, sonar, line transect or quadrats, and/or systematic towed video surveys can be used to estimate the area of habitat. With recent technological improvements, remote sensing has become a cost-effective tool for monitoring and mapping the diversity, distribution and abundance of habitat, at a range of spatial and temporal scales. "Although there would be a significant increase in the cost of data acquisition, hyperspectral data provide many more opportunities than multispectral imagery. Hyperspectral data have been used to successfully map rock platform vegetation, seagrass species, mangroves, saltflats and water quality parameters such as total suspended sediment (TSS), chlorophyll and coloured dissolved organic matter (CDOM) concentrations (Dekker *et al.*, 2001; Brando and Dekker, 2003). Remote sensing technology is of limited value in tide-dominated coastal systems (e.g. deltas, estuaries and tidal creeks) because of poor water transparency." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

The area of cover should be mapped to within 10 to 100m of true position. This is readily achievable with modern equipment.

### **Data analysis and interpretation**

The causes of habitat expansion or contraction should be defined as habitats are subject to natural forces including storm damage and changes in rainfall and sea level as well as human-induced impacts. It is therefore essential to try and determine what change in habitat extent is natural or not. Information on seagrass, mangrove, saltmarsh, and beach and dune habitat, including what they are and the potential causes of their loss, is given in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

The area of each habitat type, with an estimate of uncertainty (e.g. 95% confidence limits), should be recorded for each subregion, and for the region as a whole. "The difference between this estimate and any previous (or baseline) estimate should then be expressed as an estimate of change. An estimate of the size of change that could be statistically detected with the methods used, should also be recorded." (Ward *et al.*, 1998).



### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The reporting products should be in the form of maps and/or tables of area of habitat type by subregion and region, together with tables summarising the percentage of significant change. Graphs showing significant change over time should also be produced for each habitat type by subregion and region.

### **Proposed responsibilities**

Special-purpose studies have been undertaken over much of Australia and have created a baseline of historical data of area covered by various habitat types.

The National Land and Water Resources Audit compiled information on the coverage of several habitat types (habitat condition index) and critical habitat loss as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>) and the Australian Natural Resources Atlas (<http://audit.ea.gov.au/ANRA>).

Data on habitat extent and distribution exist for most habitat types occurring in, or next to, estuarine, coastal and marine waters around Australia. State agencies, major research institutions and universities have collected and stored most of the data. Existing information and data on seagrass, mangrove, saltmarsh and, beach and dune habitat extent is provided in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

The regional body may or may not choose to monitor habitat extent and distribution themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal or plant species abundance (indicator)  
Extent/distribution of subtidal macroalgae (indicator)  
Native vegetation communities' integrity (matters for targets)  
Significant native species and ecological communities (matters for targets)

### **Further information and references**

Brando, V.E. and Dekker, A.G. 2003. Satellite hyperspectral remote sensing for estimating estuarine and coastal water quality. *IEEE Transactions on Geosciences and Remote Sensing* 41: 1-10.

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Dekker, A.G., Brando, V.E., Anstee, J.M., Pinnel, N., Kutser, T., Hoogenboom, H.J., Pasterkamp, R., Peters, S.W.M., Vos, R.J., Olbert, C. and Malthus, T.J. 2001. Imaging spectrometry of water. In: *Imaging Spectrometry: Basic principles and prospective applications*, vol. IV, Remote Sensing and Digital Image Processing. Pp. 307-359. Kluwer Academic Publishers.

NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.

(OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

DPI – Department of Primary Industries.

DSE – Department of Sustainability and Environment.

EPA – Environment Protection Agency.

Ground-truthed – To confirm remotely obtained data by physically visiting a site.

Line transect – A straight line placed on the ground along which ecological measurements are taken.

Quadrats – An ecological sampling unit that consists of a square frame of a known area.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Extent/distribution of subtidal macroalgae

### Definition

This indicator documents the extent/distribution of subtidal macroalgal beds in estuarine, coastal and marine ecosystems.

### Rationale

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Subtidal beds of macroalgae are important elements of shallow waters (<50 m depth) in estuaries, bays and coastal regions. Whilst they are mainly concentrated in temperate zones of Australia, where there are high levels of endemism, some taxa (such as *Halimeda*) are also important in the tropics. The distribution of many other tropical genera is highly uncertain. Apart from their intrinsic floral values as a diverse suite of species, algal beds have important ecological roles in shallow marine systems. They harbour many species of fauna valued for commercial and recreational purposes, and are important primary producers in a number of near-shore environments. Algae are generally sensitive to water quality – particularly to turbidity, but also to nutrients and some chemical residues. In temperate areas, algal beds are threatened by invasive pest species (some of which are algae) and by long-term changes in environmental conditions such as sea level and climate changes that result in increased runoff of sediments from land and other threats.

The presence of certain types of macroalgae often indicates nutrient enriched waters as macroalgae thrive in waters that receive nutrient pollution. This strong relationship between macroalgae and water quality has resulted in much research into using them as indicators (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients	>\$100	Moderate	Easy	DIPNR (NSW) DPIWE (TAS) – supports kelpwatch EPA, DPI, Parks Victoria (VIC) Geoscience Australia SARDI (SA) TAFI (TAS) WRC (WA)

### **Links to stressors**

This indicator is most likely to respond to the following stressors:

- Nutrients

This indicator may also respond to the following stressors:

- Habitat removal/disturbance
- Aquatic sediments
- Toxicants
- Freshwater flow regime
- Pest species

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors, particularly nutrients (nitrogen), but also aquatic sediments, toxicants and hydrodynamics. Data interpretation may also benefit from the monitoring of appropriate biological condition indicators associated with the stressor nutrients.

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Entrance modification (decreased flushing, increased residence times)
- Decreased environmental flows
- Eutrophication
- Nuisance growth of aquatic plants or algae (and loss of amenity)
- Point sources: industrial discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

### **Monitoring method**

Department of Environment and Heritage guidelines for State of the Environment reporting (Ward *et al.*, 1998) provide information on the indicator 'algal bed area', which is included here. Information can also be found in other publications, including: scientific papers and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

See also, monitoring method information provided in the indicator profile for 'change extent/distribution of key habitat types'.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (Ward *et al.*, 1998) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

The subtidal algal beds should be monitored using a combination of remote sensing tools and ground-truthing based on diver and video surveys. The most appropriate mix of remote sensing tools can be determined only by pilot studies at a range of relevant spatial and temporal scales, and across the relevant national scale of distribution of algal beds.

### **Monitoring frequency**

Algal beds may change quickly in response to disturbances, and they should be assessed annually in areas where threats/pressures are suspected to be adversely influencing them. In areas where threats are less important or suspected, they should be assessed every 4-5 years.

### **Data measurement methods**

The assemblages and area of cover should be mapped to within 10 to 100 m of true position. This is readily achievable with modern positioning and navigational equipment.

### **Data analysis and interpretation**

Estimates of the area covered by individual assemblage types should be part of the analysis of the survey data. Surveys of algal beds have been conducted in Tasmania, Victoria and South Australia. Errors in the mapping and survey process should be estimated (or measured) and tracked throughout an aggregation process across individual patches of assemblages. The extent of change in either the overall area of beds, or in individual assemblages, that is important is unknown, and a precautionary approach would be to adopt the position that any detectable change is adverse. No estimates are available of the power of any of the routine survey programs to detect change. The level of important change will be evaluated by assessment of the time-series of monitoring data, and an assessment of the trajectory of changes.

Information of what causes macroalgae tissue chemistry, extent and species composition to change is provided in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting on the extent of each assemblage of subtidal macroalgae is probably most easily represented in maps, tables or graphs (against time), with an estimate of uncertainty (e.g. 95% confidence limits), for each location. Once sufficient information on subtidal macroalgal extent is available for a location, it will be possible to produce maps, graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change.

### **Proposed responsibilities**

“Special-purpose studies have been undertaken in Victoria, Tasmania and South Australia, and CSIRO is conducting a coarse scale (1:100 000) national assessment of algal bed distribution. This work has created a data baseline. However, most studies have been carried out using different methods, and intercomparison would be difficult. The State agencies involved are those responsible for environment and conservation and fisheries management.” (Ward *et al.*, 1998).

Data on subtidal macroalgal extent exist for estuarine, coastal and marine waters from around Australia, but it is sporadic and has been gathered for specific studies. State agencies, major research institutions and universities have collected and stored most of the data. With the exception of the State of the Environment reporting every four-five years, there are currently no ongoing systematic monitoring programs across regions or larger scales.

The regional body may or may not choose to monitor subtidal macroalgae themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Extent/distribution of key habitat types (indicator)

Total nutrients in the sediment WITH total dissolved nutrients in the sediment (indicator)

Total nutrients in the water column WITH total dissolved nutrients in the water column (indicator)

Nutrients in aquatic environments (matters for targets)

### **Further information and references**

(*OzEstuaries*). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

Sanderson, J.C. 1997. *Subtidal Macroalgal Assemblages in Temperate Australian Coastal Waters*. Australia: State of the Environment Technical Paper Series (Estuaries and the Sea). 129 pp. Department of the Environment, Canberra. <http://www.deh.gov.au/soe/techpapers/series1/pubs/subtidal.pdf>

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DIPNR – Department of Infrastructure, Planning and Natural Resources.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Genera – A taxonomic group of organisms, one level higher than species.

Ground-truthing – To confirm remotely obtained data by physically visiting a site.

Primary producers – Photosynthetic organisms that produce a 'food source' for the next level up the food chain.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

Taxa – A taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Occurrence of imposex

### Definition

This indicator documents the occurrence of imposex within gastropod mollusc populations in estuarine, coastal and marine systems.

### Rationale

Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

Imposex is the occurrence of induced male sex characteristics superimposed on normal female gastropods, with the development of male sex organs, the penis and/or the vas deferens.

Imposex was first reported in the early 1970s for the common dogwhelk *Nucella lapillus* found along the coastline of the United Kingdom (Blaber, 1970). *Nucella lapillus* remains the most thoroughly studied species in relation to imposex, although the phenomenon has now been observed and studied in many other species of gastropods worldwide.

In a series of studies of the intertidal mud snail *Nassarius obsoletus* (= *Ilyanassa obsoleta*), the imposex condition was linked firstly to pollution in marinas, then antifouling bottom paints, and finally the chemical tributyltin (TBT), a major component of the antifouling paints (Smith, 1981). This was confirmed by long-term field and laboratory experiments with *N. lapillus* (Gibbs and Bryan, 1986; Bryan *et al.*, 1987), which showed that the bioaccumulation of tin within the female correlated with an increase in the development of imposex. Gastropods bioaccumulate TBT and its endocrine disruptive effects result in elevated testosterone levels giving rise to imposex (Matthiessen and Gibbs, 1998).

Gibbs and Bryan (1986) described three distinct stages of imposex in *Nucella lapillus* as early, intermediate and late, with reproductive failure the ultimate outcome. They went on to propose the use of *Nucella lapillus* as a bioindicator of TBT contamination and developed the relative penis size index (RPSI) as a measure of imposex (Gibbs *et al.*, 1987).

Measurement of imposex can provide a relatively rapid and inexpensive indication of the status of pollution by TBT in a given ecosystem (Rees *et al.*, 2001).

Information on which waterways are most susceptible to imposex is given in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.



Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Toxicants	>\$100	Very hard	Hard	DEC (NSW) EPA (VIC) SARDI (SA) WRC (WA)

### Links to stressors

This indicator will respond to the following stressor:

- Toxicants

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of appropriate physical-chemical condition indicators for the stressor toxicants.

### Links to issues

The following list contains the main NRM 'issues' associated with this indicator:

- Biota (plants and animals) lost/disturbed – particularly marine gastropod snails
- Boating and infrastructure antifoulants (e.g. TBT)
- Imposex (development of male sex organs in female gastropods)
- Point sources: slipways
- Shipping accidents

### Monitoring method

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### Monitoring locations

The use of TBT on ship hulls has been restricted in most countries (including Australia) to vessels greater than 25 m long and as such the incidence of imposex is greatest in areas of high intensity shipping activity (e.g. around ports). However, TBT may still occur in port and marina sediments which act as a TBT sink left over from its previous use. Therefore, sites close to ports should be monitored for imposex. Remote, control sites should also be chosen.

### Monitoring frequency

Monitoring should be done every five years or more frequently in highly threatened systems. However, it is important to note that "Mensink *et al.* (1996) found juvenile *Buccinum undatum* exposed to TBT soon after hatching developed imposex in a dose dependent manner, whilst adult females exposed to the same conditions showed no signs of imposex. If this applies to other species and imposex is irreversible in individuals as it is for most species (Foale, 1993), then frequency measures of imposex may be confounded by the life-time of the species concerned. This may not present a problem for species with shorter life spans, but there may be a considerable lag time for longer lived species between lower TBT levels in the environment and correspondingly lower observed incidences of imposex." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### Data measurement methods

One hundred snails should be collected from each site and sent to a diagnostic laboratory for identification of imposex. It is essential that samples are collected live and either kept alive or correctly preserved to allow accurate analysis. Imposex is determined by penis or vas deferens development in female snails which is visible through a dissecting microscope.

### Data analysis and interpretation

Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

Although antifouling agents are of course highly toxic by design, TBT is probably the most toxic substance that has ever been deliberately introduced to the marine



environment and its widespread use has often led to detrimental effects on non-target organisms. It can induce imposex, and cause other adverse biological effects even though it may be present at very low concentrations in the water column.

The scientific literature detailing the adverse impacts of TBT on the aquatic environment is now quite extensive. Apart from imposex, a wide variety of acute and chronic toxic effects on numerous aquatic organisms have been reported. In addition to direct mortality, sublethal effects include growth and behavioural abnormalities, reduced larval growth, reproductive failure, immune system dysfunction, and nervous system disorders. These effects can be observed across a range of water concentrations of TBT, depending on the sensitivity of the species (Fent, 1996).

In some species, the vas deferens interferes with the oviducts leading to infertility and population decline (Matthiessen and Gibbs, 1998).

Nias *et al.* (1993) found imposex in *Lepsiella vinosa* at 14 of the 20 sites sampled, but reported that laboratory experiments showed other factors such as copper and environmental stress may also induce imposex. That imposex in some species may be a less specific indicator of TBT pollution than previously thought has also been noted by Evans *et al.* (1995), who nevertheless concluded that TBT has been the major cause of imposex in *N. lapillus*, and measuring it is still valuable in monitoring the recovery of populations.

#### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

#### **Monitoring and reporting products**

The percentage of females with imposex should be reported for each site in tables or graphs. Once sufficient information on imposex is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

#### **Proposed responsibilities**

Data on the occurrence of imposex is fairly limited and exists only for limited waters from NSW (Wilson *et al.*, 1993; Gibson and Wilson, 2003), Port Phillip Bay (Vic) (Foale, 1993), South Australia (Nias *et al.*, 1993) and Western Australia (Perth - Reitsema *et al.*, 2003; the Dampier Archipelago – Reitsema and Spickett, 1999), being gathered for specific studies.

The regional body may or may not choose to monitor the occurrence of imposex themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring occurs then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Toxicants in biota (indicator)

Toxicants in the sediment (indicator)

Water soluble toxicants in the water column (indicator)

#### **Further information and references**

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## **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Bioaccumulation – the process by which chemical are accumulated in biota with levels increasing up the food chain (i.e. small animals and plants take up toxicants from the waters, and when they are eaten by other animals, the toxicants move up the food chain with higher concentrations being found in higher predators).

Bioindicator – An organism and/or biological process whose change in numbers, structure, or function points to changes in the integrity or quality of the environment.

DEC – Department of Environment and Conservation.

EPA – Environment Protection Agency.

Imposex – Development of male sex organs in females.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TBT – Tributyltin. A toxic chemical used to prevent the fouling of ship hulls.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Pest species (number, density, distribution)

See matter for target: Ecologically significant invasive species

### Definition

This indicator is a measure of the number and identity of introduced species documented to be pests at a location.

### Rationale

Pests are animal or plant species that have been introduced to a new location, outside their natural range, by human dispersal. A native species which has dramatically increased in numbers to the detriment of other species may also be classed as a pest. Pests may pose the most important long-term threat to coastal ecosystems (Cappo *et al.*, 1995). Pests have a wide range of destructive impacts on native biodiversity, harvested resources and cultured species, and potentially on humans because of a reduction in recreational amenity.

For these reasons, marine pests are an important indicator for State of the Environment reporting (Ward *et al.*, 1998), and were used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

Information on how pests are introduced, waterways susceptible to marine pests, the environmental significance and detecting and reporting of pests can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

Information on specific marine pests in Australia can be accessed through the National Introduced Marine Pest Information System (<http://crimp.marine.csiro.au/nimpis/>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Pest species	>\$100	Hard	Hard	DBIRD (NT) DPI (NSW) DPIWE (TAS) EPA, SARDI, PIRSA (SA) Major Ports (Nationally) Parks Victoria, DSE (VIC) WRC (WA)

### **Links to stressors**

This indicator will respond to the following stressor:

- Pest species

This indicator may also respond to any of the other stressors listed in the indicators framework, as a change in any stressor may make a waterbody more vulnerable to pest species invasion and outbreaks.

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Aquaculture escapees
- Aquarium releases (plant or animal)
- Biodiversity decreased
- Biota (plants and animals) lost/disturbed
- Escape of weeds from gardens, dumping garden refuse/rubbish, etc.
- Habitat lost/disturbed
- International and domestic shipping/boating
- Ports/harbours/marinas
- Pest outbreaks
- Transport of pests attached to boat hulls, equipment and other infrastructure, in ballast water, via dredge spoil

### **Monitoring method<sup>1</sup>**

Excerpt from *OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

CSIRO's Centre for Research on Introduced Marine Pests (CRIMP) is the national research centre for impacts and management of introduced species. The CRIMP website contains information about marine pests, technical reports, information on community projects, publications, and links to other web-based information sources. CRIMP also developed [a National Introduced Marine Pest Information System] NIMPIS (Hewitt *et al.*, 2002) which provides managers, students, researchers and the general public with access to accurate and up to date information on the ecology, biology, and distribution of known and potential introduced marine species, and control options for those considered pests. Tidal ranges, depths and maximum and minimum values for salinity, temperature and pH where different introduced species occur are also included in NIMPIS. A comprehensive literature review on Australian ports (Harris and O'Brien, 1998) documents the availability of water temperature, bathymetry and layout, surficial sediment, dredging activity, stratigraphy, habitat, water quality, current and wave, and introduced pest data for 66 Australian ports, and can be used in conjunction with NIMPIS to help in risk assessment.

Detailed information on how community groups can monitor and detect marine pests has been produced (see Sutton and Hewitt, 2004).

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national protocols (see CRIMP, <http://crimp.marine.csiro.au/>). This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

In general, high risk (i.e. port, harbour and marina) areas are suggested as pest monitoring sites. This is because an "important factor in the establishment of exotic species is the number of visits by international ships (i.e. import opportunities). Australia has 78 ports, and receives more than 6000 ship

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<sup>1</sup> Note that CRIMP and the Australian Ballast Water Management Advisory Council no longer exist (December 2004) with CRIMP being incorporated back into the broader CSIRO framework. Their work continues along similar lines, but is now more focussed on research to support the development of the National System for the Prevention and Management of Marine Pest Incursions. Consistent monitoring methods to be implemented nationally are under development through the National System.

visits per year in which ballast water is released

([http://crimp.marine.csiro.au/Reports/Infosht2\\_Ballastwater\\_A3S.pdf](http://crimp.marine.csiro.au/Reports/Infosht2_Ballastwater_A3S.pdf)). Shoreline habitats such as salt marshes, mangroves and beach and dune (Hilton, 2002) areas can also be invaded by exotic species (Cappo *et al.*, 1995)." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### **Monitoring frequency**

In general, sites should be monitored for pests at least every three months, (i.e. summer, autumn, winter and spring), as the chances of their complete eradication once introduced are poor, especially once they have become established. Many pest species become reproductive relatively quickly and produce large numbers of young. Therefore, early detection is essential for any chance of their successful removal from an area. If monitoring a well established pest, the frequency of monitoring may be longer.

### **Data measurement methods**

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

This indicator would be documented in conjunction with the CSIRO Centre for Research on Introduced Marine Pests, where national inventories will be maintained for the Australian Ballast Water Management Advisory Council. The specific protocols used will depend on the development of measurement and tracking procedures under the Ballast Water Management Strategy. These protocols should form the basis for a national standard operating procedure for State of the Environment reporting purposes for marine pests. For some pests, particularly macroscopic ones, monitoring might be assisted by volunteers organised and managed within community-based groups. Where volunteers are to have a role, they will need to operate under an appropriate SoE [State of the Environment] SOP [standard operating procedure].

### **Data analysis and interpretation**

Determining whether a species is a pest can be difficult. Criteria have been developed (see Williams *et al.*, 2002) to help determine if an out-of-the ordinary species is a pest. Over 80 exotic pest species that are currently found in Australian waters are described, illustrated and pictured in NIMPIS (Hewitt *et al.*, 2002). Information on another 35 species, which are thought to pose a significant threat to Australian waters if introduced is also provided. Relevant State/Territory government agencies can also help with identification through the supply of pest guides and pamphlets.

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Changes in the recorded numbers of pest species in various regions and subregions indicate both an increased awareness of pest species and their associated problems and changes in the numbers of species classified as pests. Species identified as pests are likely to be responsible for detrimental effects on fishing, aquaculture and recreational amenity, and local biodiversity and ecological processes. The number of pest species is a subset of the number of species introduced to Australian ecosystems from other jurisdictions. The number of introduced species is likely to be much larger than that of recognised pest species because many introduced species are likely to be cryptic, and become recognised only when they create ecological or other problems. Within each location, changes in the number of documented pests and area of infestation should be assessed using univariate statistical approaches using explicit statistical models. The level of important change will be evaluated by assessment of the time-series of monitoring data, and an assessment of the trajectory of changes.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

The changes in pest numbers, identities and area infested should be summarised by [location]. The changes should be recorded for each region together with estimates of uncertainty (say 95% confidence limits). The difference between these estimates and



any previous (or baseline) estimates should then be expressed as an estimate of change, together with an estimate of the size of change that could be statistically detected with the methods used.

The outputs should be presented in the form of maps annotated with new pests documented, and tables summarising changes in pest numbers and area by subregion, together with tables summarising the percentages of significant change (positive or negative change of statistical significance), preferably as a cumulative frequency distribution based on the data for each subregion. The extent of areas affected should be summarised in tables accompanying each [location] represented in the maps.

The relevant state authorities for marine pest reporting are listed in the 'Report a Pest' page of the NIMPIS website (<http://crimp.marine.csiro.au/nimpis>).

### **Proposed responsibilities**

"The CSIRO Centre for Research on Introduced Marine Pests holds considerable data on marine pests and their distributions. State fisheries and environment agencies also hold considerable data on pest species in their local areas." (Ward *et al.*, 1998). Information on specific marine pests in Australia can be accessed through the National Introduced Marine Pest Information System (<http://crimp.marine.csiro.au/nimpis/>). The National Land and Water Resources Audit compiled information on invasive species as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

Data on pest species exist for estuarine, coastal and marine waters from around Australia. Government agencies, major research institutions and universities have collected and stored most of the data.

The regional body may or may not choose to monitor pests themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Ecologically significant invasive species (matters for targets)

### **Further information and references**

Cappo, M., Alongi, D.M., Williams, D. and Duke, N. 1995. A review and synthesis of Australian Fisheries Habitat Research: Major threats, issues and gaps in knowledge of coastal and marine fisheries habitats. Fisheries Research and Development Corporation.  
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- Williamson, A.T., Bax, N.J., Gonzalez, E. and Geeves, W. 2002. *Development of a Regional Risk Management Framework for APEC Economies for Use in the Control and Prevention of Introduced Marine Pests*. APEC MRC-WG Final Report. 208 pp. [http://crimp.marine.csiro.au/Reports/APEC\\_Report.pdf](http://crimp.marine.csiro.au/Reports/APEC_Report.pdf)

## **Glossary**

- Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).
- Bathymetry – Measuring water depths to determine the topography of the sea floor.
- DBIRD – Department of Business, Industry and Resource Development.
- DPI – Department of Primary Industries.
- DSE – Department of Sustainability and Environment.
- EPA – Environment Protection Agency.
- PIRSA – Department of Primary Industries and Resource, South Australia.
- SARDI – South Australian Research and Development Institute.
- Spatial – Pertaining to space or distance.
- Temporal – Pertaining to time.
- Univariate - Statistical tests for comparing two or more groups with only one variable.
- WRC – Water and Rivers Commission.



## Indicator: pH

### Definition

This indicator documents the pH of estuarine, coastal and marine waters.

### Rationale

Excerpts from *OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

pH is a measure of acidity or alkalinity of water on a log scale from 0 (extremely acidic) through 7 (neutral) to 14 (extremely alkaline).

Most aquatic organisms and some bacterial processes require that pH be in a specified range. For example, the activity of nitrifying bacteria is optimal over a narrow pH range from 7 to 8.5 (Henriksen and Kemp, 1988). If pH changes to beyond the preferred range of an organism (including microbes), physiological processes may be adversely affected (ANZECC/ARMCANZ, 2000a). This is especially true for most organisms if the ambient pH drops to below ~7 or rises to above 9. Physical damage to the gills, skin and eyes of can also occur when pH is sub-optimal for fish, and skin damage increases susceptibility to fungal infections such as red spot disease. pH values are driven to more frequent and greater extremes under eutrophic conditions, allowing algal species with tolerance to extreme pH levels to grow and dominate communities, and to potentially form algal blooms (Hinga, 2002).

Changes in pH can also have indirect impacts on aquatic organisms. For example, changes in pH can alter the biological availability of metals, and the toxicities of ammonium, aluminium and cyanide (ANZECC/ARMCANZ, 2000a). Increases in pH can also cause the electrostatic forces that bind viruses to particles to be overcome, thus facilitating their release to the water column (Miller, 2001). pH is important in calcium carbonate solubility, which may be important for some shell-forming organisms.

pH was used as one determinant of water quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
pH	<\$5	<\$500	Easy	Moderate	DIPE (NT) DIPNR, DEC (NSW) EPA (QLD) EPA (VIC) SARDI (SA) Waterwatch WRC (WA)

**Links to stressors**

This indicator is most likely to respond to the following stressor:

- pH

This indicator may also respond to the following stressors:

- Nutrients
- Organic matter

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of other indicators for these stressors, e.g. nutrients (algal blooms) and organic matter (DO). Data interpretation will also benefit from the monitoring of an appropriate biological condition indicator associated with the stressor pH (i.e. animal kills or animal disease/lesions).

**Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal (fish/macrobenthos) kills
- Animal lesions and disease
- Decay of infrastructure
- Disturbance of actual or potential Acid Sulphate Soils (ASS) - acid sulphate run-off
- Extraction (mining)
- Habitat lost/disturbed
- Industrial discharge
- Poor water quality: lowered dissolved oxygen, low pH
- Release of metals and other toxicants

**Monitoring method**

Detailed monitoring methods for pH can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

**Monitoring locations**

Sites threatened by pH change should be monitored. However, the actual location will depend on aspects of the management actions and NRM issues being monitored. For example, if monitoring for pH change resulting from acid sulfate runoff then monitoring will occur in waters adjoining disturbed acid sulfate soils.

**Monitoring frequency**

The frequency of monitoring will depend on what management actions and NRM issues are being monitored. pH can be monitored continuously or during/after specific events. Generally, pH

measurements are most useful when the full diurnal range is known – pH is usually lowest at dawn and highest during the day (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>). Therefore, continuous monitoring of pH using moored, continuously recording pH sensors is advisable. However, if this is not possible, then pH should be measured at dawn and midday to allow for diurnal variation.

In some studies pH may be measured after a particular event. For example, if monitoring for pH change resulting from acid sulfate runoff, then monitoring will occur after low/moderate rainfall (runoff) events in waters adjoining disturbed acid sulfate soils.

#### **Data measurement methods**

“It is generally good practice to take pH measurements with all physical, chemical and biological samples. pH of water is best measured *in situ* using a meter equipped with a pH electrode. A high degree of precision can be expected from the method if careful attention is paid to the calibration and to the maintenance of electrodes and buffer solutions. Values are reported in standard pH units and usually to one or two decimal places. Repeated measures of pH should be reported as medians and ranges of measured values.” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

#### **Data analysis and interpretation**

“The pH of marine waters is close to 8.2, whereas most natural freshwaters have pH values in the range from 6.5 to 8.0. Most waters have some capacity to resist pH change through the effects of the carbonate-buffer system which helps maintain pH at a near constant level.” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>). However, it is necessary for data interpretation that baseline (reference) data for the site is known as some waters will have naturally low or high pH levels.

“The pH of coastal waters responds to changes in: (i) dissolved carbon dioxide concentrations; (ii) alkalinity; (iii) hydrogen ion concentrations; and (iv) in a small way to temperature. The magnitude of the change varies with salinity because various ions are involved in acid-base reactions, and because the concentration of salt influences various equilibrium constants (Hinga, 2002).” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Changes to pH levels can result from the following (see OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>):

- changes in salinity;
- seawater mixing with freshwater/river water;
- photosynthetic consumption of carbon dioxide (especially in algal blooms);
- decomposition of organic matter;
- nitrification and denitrification;
- disturbance of acid sulfate soils and the reclamation of coastal wetlands;
- mine drainage;
- discharge from coal-fired power stations and other industrial operations;
- acid rain;
- humic acid waters; or
- chemical spills or the dumping of chemicals into stormwater drains.

“In a diurnal cycle, the lowest pH is expected at dawn because CO<sub>2</sub> produced by decomposition and aerobic respiration would have accumulated since the previous dusk. Conversely highest pH is expected during the daylight hours, because pH rises at the rate at which carbon dioxide is fixed by plants.” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Default trigger values for pH have been listed in the Water Quality Guidelines for different coastal waterways in different regions but they recommended the development of local objectives for values – they include protocols for determining local pH trigger values (ANZECC/ARMCANZ, 2000a).

“As a general rule, pH values in coastal waters that are higher than 9 and lower than 7 should be investigated.” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

The ratio of chloride to sulfate (SO<sub>4</sub>) may be measured to check if a drop in pH is the result of acid sulfate soil runoff. Potential acid sulfate soils are present throughout most low-lying coastal regions in

Australia. Sulfate input into waterways can occur from acid sulfate runoff, acid rain (sulfur dioxide (SO<sub>2</sub>) air pollution), organic acids from swamps/bogs or mine site acid runoff. In most regions of Australia this indicator (i.e. pH) will respond to acid sulfate runoff.

Potential acid sulfate soils refer to soils containing sulfides (particularly, iron sulfide or pyrite). When these soils are exposed to oxygen and water they produce sulfuric acid runoff which may result in higher sulfate concentrations and low pH in groundwater and waterways.

The ratio of chloride to SO<sub>4</sub> (by mass) in seawater is generally constant at approximately 7.2 – in seawater the concentration of chloride is approximately 19,400 mg/l and sulfate is approximately 2,700 mg/l. This ratio remains roughly constant when diluted with uncontaminated rainwater/freshwater. Therefore, estuaries can be expected to have a similar ratio. Increased levels of sulfate relative to chloride combined with low pH indicate the presence of acid sulfate runoff. A chloride to SO<sub>4</sub> ratio of less than four, and certainly less than two, is a strong indication of an extra source of sulfate from sulfide oxidation (i.e. acid sulfate runoff) (Mulvey, 1993).

#### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

#### **Monitoring and reporting products**

Reporting of pH is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on pH is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change. The number of times pH levels exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

#### **Proposed responsibilities**

Data on pH exist for estuarine, coastal and marine waters from around Australia. A variety of organisations including: government agencies, local government, major research institutions, community groups, environmental consultant companies, universities, etc. have collected and stored most of the data. The National Land and Water Resources Audit compiled information on pH as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor pH themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Animal kills (indicator)

Animal disease/lesions (indicator)

#### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

- Australian Government, Department of Environment and Heritage. Coasts and oceans. National coastal acid sulfate soils. <http://www.deh.gov.au/coasts/cass/index.html>
- Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>
- Henriksen, K. and Kemp, W.M. 1988. Nitrification in Estuarine and Coastal Marine Sediments. In: T.H. Blackburn and J. Sorensen (eds), *Nitrification in Estuarine and Coastal Marine Sediments. Nitrogen Cycling in Coastal Marine Environments*. Pp. 207-249. John Wiley and Sons.
- Hinga, K.R. 2002. Effects of pH on coastal marine phytoplankton. *Marine Ecology Progress Series* 238: 281-300.
- Miller, B.M. 2001. *Issues for the modelling of fate and transport of viruses in estuarine environments*. 15th Australasian Coastal and Ocean Engineering Conference, September 2001, Gold Coast.
- Mulvey, P.J. 1993. Pollution prevention and management of sulfidic clays and sands. In: R. Bush (ed.), *Proceedings of the National Conference on Acid Sulfate on Acid Sulfate Soils*. Pp. 116-129. Cooloongatta, June 1993. NSW Department of Agriculture, Wollongbar, NSW.
- NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.
- (OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>
- OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']
- Waterwatch Australia Steering Committee. 2002. *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra.
- Waterwatch manuals: See <http://www.sa.waterwatch.org.au/programs.htm#manuals> and <http://www.waterwatch.org.au/>
- Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

### **Glossary**

Aerobic – In the presence of oxygen.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Humic acid – Acidic water derived from humus (decaying organic matter).

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Presence/extent of litter

### Definition

This indicator reports on the presence/extent of litter occurring in estuarine, coastal and marine systems.

### Rationale

The presence of litter in estuarine, coastal and marine systems detracts from the visual amenity of an area and can harm humans (e.g. broken glass, used needles, etc.) or animals (which eat, become entangled in, or are suffocated by, the litter). Toxic substances can leach out of litter which then bioaccumulates up the food chain. "One quite simple example of this is the toxic effect of cigarette butt litter. Toxic substances leach out of cigarette butts and can kill small animals. Animals also mistake butts for food. The toxic chemicals absorbed by cigarettes' cellulose acetate filters and found in butts' remnant tobacco, are quickly leached from the butts by water." (Global litter information gateway, <http://marine-litter.gpa.unep.org/facts/effects-wildlife.htm#top>). Floating litter may aid in the movement (introduction) of marine animals and plants which may become pests.

Many species of endangered or threatened marine mammals, turtles and seabirds are particularly at risk from litter. According to figures provided in the 'Global litter information gateway' approximately 100,000 marine mammals and turtles, and 700,000 to 1 million seabirds are killed worldwide by litter every year.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Litter	<\$5	<\$100	Very Easy	Easy	EPA (SA) EPA (VIC) SARDI (SA) Waterwatch

### Links to stressors

This indicator will respond to the following stressor:

- Litter

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition indicator associated with the stressor litter (i.e. animals killed or injured by litter).

### ***Links to issues***

The following list contains the main NRM 'issues' associated with this indicator:

- Presence of litter
- Rubbish dumping (ships/boats, tourists/recreational users, upstream)
- Rubbish/debris from commercial and recreational fishing (e.g. fishing line, nets, bait bags)
- Tangling/death of animals and plants by litter
- Visual amenity decreased

### ***Monitoring method***

Detailed monitoring methods for beach litter can be found in Waterwatch Queensland's 'Community Estuarine Monitoring Manual'.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### ***Monitoring locations and frequency***

The monitoring locations (e.g. beach, river reach, etc.) and frequency will vary with the goals of the monitoring program and the resources available (e.g. time intensive to monitor, volunteers, etc.). However, in most cases, monitoring every three months would be adequate.

Seasonal variation in the movement of litter (e.g. wet season (storms) versus dry season, hot summers increased beach use versus cold winters) should be considered when developing a monitoring strategy.

### ***Data measurement methods***

All litter should be collected from a predetermined area, then sorted into different categories and weighed. The different categories used will depend on the goals of the monitoring program (i.e. management actions monitored). For example, litter may be divided by origin (e.g. catchment (storm water, recreation, etc.) and marine (shipping, fishing boat, etc.)) or by type (e.g. plastic, foam, netting, metal, biohazard, etc.).

### ***Data analysis and interpretation***

The presence of any litter impacts the visual amenity and health of an area. Through the monitoring of the amount and type of litter present, the major sources, quantities and types of litter can be determined.

Recent storms, cyclones, strong winds and strong currents are likely to cause increased litter transport and deposition, particularly of floating debris.

### ***Data storage***

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### ***Monitoring and reporting products***

Depending on the location monitored, the amount of litter collected can be reported against either length or area monitored, or effort. For example, beach litter is generally accumulated along the high tide mark so litter should be recorded against length of beach. Weight of litter is generally a better measure of the amount of litter present than number of pieces collected because litter often breaks up.

The amount of litter per unit area/length/effort should be reported against each of the litter categories used, as well as the litter's source in tables and graphs. Once sufficient information on litter is available for a location, litter category or source, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change.



### **Proposed responsibilities**

The regional body may need to monitor litter themselves or use other litter clean up activities such as 'Clean up Australia day'. The incorporation of data from a previous regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring occurs then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal or plant species abundance (indicator)

Animals or plants killed or injured by litter (indicator)

### **Further information and references**

Clean Up Australia Online. [www.cleanup.com.au](http://www.cleanup.com.au)

Derraik, J.G.B. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin* 44: 842–852.

Faris, J. and Hart, K. 1996. *Seas of Debris: A Summary of the Third International Conference on Marine Debris*. Miami, Florida, 8-13 May 1994. 54 pp. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle.

Frost, A. and Cullen, M. 1997. Marine debris on northern New South Wales beaches (Australia): Sources and role of beach usage. *Marine Pollution Bulletin* 34: 348-352.

Global Litter Information Gateway. <http://marine-litter.gpa.unep.org/facts/effects-wildlife.htm#top>

Herfort, A. 1997. *Marine debris on beaches in New South Wales with a special focus on fishing debris*. Ocean Watch Australia, Sydney.

Laist, D.W. 1987. An overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin* 18 (6B): 319-326.

Waterwatch Queensland, 2003. *Community Estuarine Monitoring Manual*. The State of Queensland (Department of Natural Resources and Mines).

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

EPA – Environment Protection Agency.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

## Indicator: Salinity

### Definition

This indicator documents the salinity of estuarine, coastal and marine waters.

### Rationale

Salinity is a measure of the amount of salt present in water.

Excerpts from *OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

Salinity is important in coastal waterways for the following reasons:

- salinity is a dynamic indicator of the nature of the exchange system. The salinity of the water within the estuary tells us how much fresh water has mixed with sea water. Also, plots that show the relationship between salinity and other soluble substances (e.g. nutrients) can be used to demonstrate the dynamic or conservative nature of those substances in 'mixing plots';
- salinity is an important determinant of the mixing regime (see Salinity Regime) - because of the density variation associated with salinity variation, salinity stratification tends to inhibit vertical mixing in an estuary;
- it is an important ecological parameter in its own right; and
- it is important in some chemical processes.

Most aquatic organisms function optimally within a narrow range of salinity. When salinity changes to above or below this range, an organism may lose the ability to regulate its internal ion concentration - that is 'osmoregulation' becomes so energetically expensive that the organism may succumb to biotic pressures such as predation, competition, disease or parasitism. Consequently, shifting salinity distributions can affect the distributions of macrobenthos (Boesch, 1977) as well as those of rooted vegetation (e.g. seagrasses) and sessile organisms (Alber, 2002).

The nature of the longitudinal salinity gradient (and the position of certain isohalines) is an important factor in the successful recruitment of larval and juvenile fish (Odum, 1970; Whitfield, 1994). Salinity is also an important control on the types of pathogenic organisms and invasive species that can occur in a coastal waterway, on the types species that can occur in algal blooms (Chan and Hamilton, 2001; Kirst, 1995), and on the activity of nitrifying and denitrifying bacteria (Rysgaard *et al.*, 1999). As a general rule, widely varying salinity regimes tend to select for a low-abundance and low-diversity suite of species, which are adapted to a broad range of ionic concentrations (e.g. euryhaline species).

Salinity was used as one determinant of water quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little

experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressors this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>†</sup> :
Freshwater flow regime Hydrodynamics Excess salt Excess Freshwater	<\$5	>\$500	Easy Easy Easy Easy	Moderate Moderate Easy Moderate	DEC, DIPNR (NSW) DIPE (NT) EPA (QLD) EPA, SARDI, AWQC (SA) EPA (VIC) TASQP (TAS) Waterwatch WRC (WA)

### **Links to stressors**

This indicator is most likely to respond to the following stressors:

- Freshwater flow regime
- Hydrodynamics
- Excess Salt (as a pollutant)
- Excess Freshwater (as a pollutant)

If monitoring the stressor hydrodynamics, then it would be extremely beneficial for data interpretation if the monitoring of this indicator is associated with the monitoring of the appropriate biological condition indicator for this stressor.

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Climate change (changed rainfall patterns, changing ocean currents, sea level rise, southern oscillation)
- Desalinisation wastes
- Environmental flows – water flows and frequency of floods from catchment water changed from natural by dams, barriers, water extraction, levees, impoundments and weirs, increased hard surfaces, land cover
- Episodic and large scale events (drought, floods, storms, cyclones)
- Estuary mouth open/close frequency (changed)
- Groundwater - excess caused by artificial ponds and lagoons, changed movement of water into or out of coastal waters, movement of hypersaline/hyposaline water
- Hypersalinity/hyposalinity
- Large water release from water impoundments in catchment
- Localised freshwater input (large storm water, industrial discharge, etc.)
- Poor water quality: decreased/elevated salinity or conductivity
- Saltwater intrusion (movement of salt water into lower concentration/non-saltwater environment)
- Stratification of waters (change in mixing rates)

### **Monitoring method**

Detailed monitoring methods for salinity can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

Sites threatened by salinity change should be monitored. However, the location will depend on aspects of the management actions and NRM issues being monitored. For example, if monitoring for salt as a pollutant, then monitoring will occur near the source of the pollutant (e.g. desalination plants). If monitoring for changes in salinity due to hydrodynamics, then a variety of sites along the length of a river, as well as at different depths, may need to be examined for salinity stratification (i.e. lack of mixing).

### **Monitoring frequency**

The frequency of monitoring will depend on what management actions and NRM issues are being monitored. Salinity can be monitored continuously or during/after specific events. Generally, salinity measurements are most useful when continuously monitored using moored, continuously recording sensors.

In some studies, salinity may be measured after a particular event (e.g. high rainfall, salt dumping, dredging activities, etc.).

### **Data measurement methods**

Water salinity is best measured *in situ* using a salinity meter.

“The presence of charged ionic species in solution enables water to conduct an electrical current, and it is common practice to estimate salinity from electrical conductivity (EC) measurements. Conductivity is best measured in the field using an electronic probe that applies a voltage between two electrodes. The international standard temperature for laboratory conductivity measurements is 25°C, and most modern field instrumentation will compensate for measurements made at other temperatures. However, different standard temperatures were used in the past, so the water temperature at which the measurement was taken should always be reported. Up until around the late 1970's the units of EC were micromhos per centimetre ( $\mu\text{mhos cm}^{-2}$ ) after which they were changed to microSiemens  $\text{cm}^{-2}$  ( $1\mu\text{S cm}^{-1} = 1\mu\text{mho cm}^{-1}$ ).” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### **Data analysis and interpretation**

Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

Seawater has a global average salinity of  $35\text{ kg m}^{-3}$ , or  $35\text{ g/L}^{-1}$  or 35 parts per thousand (ppt). Salinity levels grade from fresh ( $< 1\text{ ppt}$ ) to almost oceanic ( $> 30\text{ ppt}$ ) within an estuary, as freshwater entering from rivers and streams gradually mixes with seawater. The vertical salinity structure and the nature of salinity variation along the estuary (i.e. how rapidly salinity varies in the vertical and horizontal) reflect the salinity regime of coastal waterways.

There are three main salinity regimes in coastal waterways: stratified; partially mixed and fully mixed.

Stratified coastal waterways are characterised by a distinct increase in salinity with water depth. Stratification occurs when riverine flow is sufficient to produce a plume of low-density freshwater which can flow over higher-density seawater, and where tidal currents and waves are not strong enough to mix the water column. Such conditions can lead to anoxic and hypoxic events because bottom waters can become isolated from dissolved oxygen enriching processes, including gas exchange across the water surface and photosynthesis by plants in shallow water.

In partially mixed coastal waterways, tidal currents generate turbulence which promote vertical mixing. However, the tidal currents are of insufficient strength to fully mix the water column, and salinity varies both vertically and horizontally.

Fully mixed conditions occur in coastal waterways in cases where tide, river or wave energy produces enough turbulence to mix the water column. In this case, salinity is uniform through the water column, but varies between the riverine and oceanic ends.

Information on the factors which may cause a change to salinity and the chemical processes affected by salinity can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

“Conceptual models that show the interaction between 'freshwater' and marine water in embayments, and wave-dominated (deltas, estuaries and strandplains) and tide-dominated (deltas, estuaries and tidal creeks) coastal waterways are available in the OzEstuaries website. The influence of oceanic exchange times and fresh water replacement times on salinity in different types of coastal waterways can be explored in the Simple Estuarine Response Models (SERM II).” (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of salinity is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on salinity is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values).

### **Proposed responsibilities**

Data on salinity exist for estuarine, coastal and marine waters from around Australia. A variety of organisations including: government agencies, local government, major research institutions, community groups, environmental consultant companies, universities, etc. have collected and stored most of the data. The National Land and Water Resources Audit compiled information on salinity as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor salinity themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal or plant species abundance (indicator)  
Estuary mouth opening/closing (indicator)  
Water-current patterns (indicator)

### **Further information and references**

Alber, M. 2002. A conceptual model of estuarine freshwater inflow management. *Estuaries* 25: 1246-1261.

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

Boesch, D.F. 1977. A new look at the zonation of benthos along an estuarine gradient. In: B.C. Coull (ed.), *Ecology of the marine benthos*. Pp. 245-266. University of South Carolina Press, Columbia, South Carolina, USA.

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## **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Embayment – A large indentation of a shoreline, bigger than a cove but smaller than a gulf.

EPA – Environment Protection Agency.

Hypersaline – Above normal levels of salinity.

Hyposaline – Below normal levels of salinity.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

Sessile – Plants or animals that are permanently attached to a surface.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

TASQP – Tasmanian Shellfish Quality Assurance program.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Seagrass: depth range

### Definition

This indicator reports the change in the depth range of seagrass.

### Rationale

Seagrass depth range refers to the maximum depth that seagrass is found. Seagrass is light dependant and its depth range is a function of the amount of sunlight reaching it. Therefore, light attenuation in the water due to turbidity levels (i.e. due to suspended solids, microscopic algae, dissolved organic matter, etc.) directly impacts of the depth at which seagrass can survive.

“Areas where seagrass meadows have been lost or their depth ranges are unstable correlate closely with degraded water quality, particularly from high turbidity.” (EHMP, 2004).

Seagrass habitats are important because they provide food for many species (including endangered or threatened species such as dugong and green turtles) and habitat/nursery grounds for fish and invertebrates (including species which are commercially important). Seagrass beds also assist with nutrient cycling and sediment stabilisation.

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. ‘Easy’ complexity would mean that a person with little experience could easily learn how to collect/interpret the data. ‘Moderate’ would require a person with a couple years experience, and ‘hard’ would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Aquatic sediments	<\$30	Moderate	Moderate	DEC, DPI (NSW) DIPE (NT) EPA (VIC) EPA, DPI, EHMP (QLD) SARDI (SA) WRC (WA)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Aquatic sediments

This indicator may also respond to the following stressors:

- Nutrients
- Habitat removal/disturbance
- Toxicants

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors,



particularly aquatic sediments (i.e. turbidity/water clarity). Data interpretation may also benefit from the monitoring of an appropriate biological condition indicator associated with the stressor aquatic sediments (i.e. animal or plant species abundance).

#### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Bottom vegetation lost by smothering or lower light availability
- Diffuse sediment sources: catchment clearing, landuse and run-off (rural and urban)
- Dredging, trawling: resuspension of sediments
- Dumping of dredged material
- Episodic and large scale events (drought, floods, storms, cyclones)
- Erosion and sedimentation (deposition)
- Habitat lost/disturbed (smothering)
- Poor water quality: turbidity
- Seagrass cover decreased caused by loss of light availability
- Shipping movement through shallow waters
- Soil disturbance in coastal zone due to development
- Urban development causing loss of coastal habitat and increased erosion

#### **Monitoring method**

Detailed monitoring methods for seagrass depth range can be found at the EHMP website ([http://www.coastal.crc.org.au/ehmp/tools\\_seagrass.html](http://www.coastal.crc.org.au/ehmp/tools_seagrass.html)) and in scientific publications.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

#### **Monitoring locations**

Sites chosen for monitoring will depend on the region but must include sites where threats (turbidity) are thought to be high and control sites where threats are thought to be negligible. The EHMP website ([http://www.coastal.crc.org.au/ehmp/tools\\_seagrass.html](http://www.coastal.crc.org.au/ehmp/tools_seagrass.html)) provides information on site selection for Moreton Bay, Queensland.

#### **Monitoring frequency**

EHMP (2004) states that "sites should be monitored biannually, ideally during the same month each year". Seagrass depth range may also be measured after a particular event (e.g. high rainfall, algal blooms or dredging activities).

#### **Data measurement methods**

Seagrass depth range measures the difference in height between the shallow distributional limit and the deep distributional limit of a species of seagrass at a site.

*Excerpts from the EHMP website ([http://www.coastal.crc.org.au/ehmp/tools\\_seagrass.html](http://www.coastal.crc.org.au/ehmp/tools_seagrass.html)); describing the measurement methods used in Moreton Bay, Queensland:*

*Zostera capricorni* is used as the indicator species as it is the most abundant seagrass in Moreton Bay, it is not the preferred food for dugong and turtles and has minimal seasonal variation in distribution. The presence of other seagrass species, macroalgae (e.g. *Caulerpa taxifolia*) and the toxic cyanobacteria *Lyngbya majuscula* is noted along the transect, as well as geomorphological features such as sandbars, deep holes and evidence of disturbance (bait worming holes, propeller scars).

[To measure seagrass depth range] an autotest level (dumpy level) and graduated staff are used to calculate elevations and distances.

The depth range and general profile of the seagrass bed is determined along a main transect using basic surveying techniques. Ten replicate transects, approximately 10m

apart, 5 on either side of the main transect, are surveyed to record the upper and lower distributional limits (i.e. no profile information is recorded).

Where possible, all transects at a site are related back to a Permanent Survey Mark (PSM) to give absolute elevations relative to Australian Height Datum (AHD). This allows us to compare the seagrass depth range of more than one site over time.

To ensure that changes in the upper and lower distributional limits can be recorded, each successive survey at a site starts at the same position and elevation (e.g. a stake in the ground, paint on a rock wall, marked tree, etc.).

If the horizontal distance between the upper and lower distributional limits is too great and/or the water depth prevents the autotest level from being set up, the depth range is approximated within 10-20cm by using a combination of measurements. To do this, the water depth at the deepest seagrass limit is measured at the same time as the elevation of the water level on the intertidal zone. The elevation of the upper limit is also recorded and related back to the deepest seagrass limit.

### **Data analysis and interpretation**

"The use of seagrass depth range as an indicator of ecosystem health is based on the assumption that the shallow distributional limit of seagrass is determined by the tolerance of the seagrass to desiccation at low tide, and that the lower distributional limit is determined by light availability." (EHMP, 2004). "The most common factor leading to seagrass loss is an increase in suspended sediments from terrestrial inputs and sediment re-suspension leading to a long-term reduction in light." (EHMP, 2004).

The effect of a variety of environmental factors on seagrass depth range, in different types of waterways, can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of seagrass depth range is probably most easily represented graphically (against time), with an estimate of uncertainty (e.g. 95% confidence limits), for each location. Once sufficient information on seagrass depth range is available for a location, it will be possible to produce graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change.

### **Proposed responsibilities**

Data on seagrass depth range has been gathered for many estuarine and coastal waters from around Australia. State agencies, major research institutions and universities have collected and stored most of the data. EHMP (2004) has been monitoring seagrass depth range in Moreton Bay (Qld) annually since 1992.

The regional body may or may not choose to monitor seagrass depth range themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Sedimentation/erosion rates (indicator)

Turbidity/water clarity (indicator)

Turbidity/suspended particulate matter in aquatic environments (matters for targets)

### **Further information and references**

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

EHMP (Ecosystem Health Monitoring Program). 2004. *Seagrass depth range*.  
[http://www.coastal.crc.org.au/ehmp/results\\_seagrasses\\_depthrange.html](http://www.coastal.crc.org.au/ehmp/results_seagrasses_depthrange.html)

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<http://www.deh.gov.au/soe/techpapers/series1/pubs/seagrass.pdf>

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Cyanobacteria – Photosynthetic bacteria previously called blue-green algae.

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DPI – Department of Primary Industries.

EHMP – Ecosystem Health Monitoring Program (Moreton Bay Waterways and Catchments Partnership).

EPA – Environment Protection Agency.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Sedimentation/erosion rates

### Definition

This indicator reports on the sedimentation or erosion rates within an estuarine, coastal or marine system.

### Rationale

Sedimentation is the process by which material is deposited from the water column to the bed. Conversely, erosion occurs when material is removed. The sedimentation/erosion rate encountered in waterways is naturally variable because of the variability in natural processes causing it (e.g. water-current/flow patterns, climate (rainfall, seasonality), geology, slope (or topography), etc.). Human activity, (e.g. dredging, impoundments, hydrodynamic alterations, land clearing, etc.), may also result in changes to sedimentation/erosion rates.

Enhanced sedimentation/erosion rates can result in important changes to the form and function of waterways (e.g. they may cause: changed shoreline and mudflats area, channel infilling, habitat/benthic community smothering or removal, increased turbidity levels, and the burial or resuspension of nutrients, trace elements, toxicants and organic matter).

"The net result of enhanced sedimentation rates are an increase in the maturity of coastal waterways, and a decrease in their overall lifespans. Reductions in the biodiversity, health and integrity of coastal ecosystems may also occur. In order to make better-informed management decisions there is clearly a need to accurately assess the rate and nature of sedimentation within coastal waterways and any changes in other sedimentological parameters over time." (OzEstuaries, [http://www.ozestuaries.org/indicators/In\\_sedimentation\\_rates\\_f.html](http://www.ozestuaries.org/indicators/In_sedimentation_rates_f.html)).

Information on sedimentation and erosion can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Aquatic sediments Hydrodynamics	<\$30	Hard Hard	Hard Hard	DEH, Coastal Protection Board (SA) DIPE (NT)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Aquatic sediments
- Hydrodynamics

This indicator may also respond to the following stressors:

- Freshwater flow regime

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition and extent indicators associated with the stressors aquatic sediments and hydrodynamics. Data interpretation may also benefit from the monitoring of appropriate physical-chemical condition indicators associated with the stressor hydrodynamic.

### ***Links to issues***

The following list contains the main NRM 'issues' associated with this indicator:

- Beach/foreshore erosion and accumulation
- Biota (plants and animals) lost/disturbed (smothering, filter feeder and grazing animals, physical abrasion of gills and behavioural changes, lower light availability for benthic plants)
- Boating access decreased (shallow banks/flats)
- Diffuse sediment sources: catchment clearing, landuse and run-off (rural and urban)
- Dredging, trawling: resuspension of sediments, dumping of dredged material
- Environmental flows – water and frequency of floods from catchment water changed from natural by dams, barriers, water extraction, levees, impoundments and weirs, increased hard surfaces, land cover, decreased/increased water velocity
- Episodic and large scale events (drought, floods, storms, cyclones, bushfires)
- Erosion and sedimentation (deposition)
- Estuary mouth open/close frequency (changed)
- Habitat lost/disturbed (smothering, erosion)
- Poor water quality: turbidity
- Urban development causing loss of coastal habitat and increased erosion

### ***Monitoring method***

Detailed monitoring methods for sedimentation/erosion rates can be found in numerous scientific publications.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### ***Monitoring locations***

In general, the monitoring of this indicator will occur in estuarine and coastal areas where human induced changes to sedimentation/erosion rates are thought to be having detrimental impacts on the system. Control sites should also be monitored.

### ***Monitoring frequency***

Annual monitoring would be sufficient for most studies. However, more frequent monitoring may be needed, depending on the study and aspects of the management actions and NRM issues being monitored.

### ***Data measurement methods***

Both sedimentation and erosion rates are measured in terms of vertical change in sediment surface (i.e. accumulation or loss) over time. Sedimentation rate may also be measured in terms of sediment mass accumulation (i.e. density per unit area over time). This is more accurate in systems where compaction or change in sediment composition is important.

The method commonly used to determine sedimentation/erosion rates is to install rods in the sea bed to measure depth changes due to sediment accumulation/loss. Large changes in sedimentation/erosion rates occurring over longer time periods can be measured from the differences observed in bathymetric maps from different time periods; this methods cannot estimate recent sedimentation rates.

### **Data analysis and interpretation**

Changes in sedimentation/erosion rate data can be used to determine whether a waterway has been subjected to enhanced sediment loads or erosion caused by human action.

A significant increase in sedimentation rate within an area is often the result of increase sediment load entering the system (e.g. from land clearing) or increased resuspension and deposition from within the system (e.g. from dredging activities). Changes to the hydrodynamics of a waterbody will result in changes to sedimentation and/or erosion rates, (e.g. sea walls can change the water-current pattern occurring along the coast and cause increased beach erosion in some areas and increase sand accumulation in others).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

The annual changes in sedimentation/erosion rate, with estimates of uncertainty (e.g. 95% confidence limits), should be reported for each location and is probably best represented by tables and graphs. Once sufficient information on sedimentation/erosion rates is available for a location, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change from previous baseline data. The size of change that could be statistically detected with the methods used, should also be reported.

### **Proposed responsibilities**

Data on sedimentation and erosion rates has been gathered for a few estuarine and coastal areas from around Australia. Some State/Territory agencies, major research institutions (in particular, CSIRO) and universities have collected and stored most of the data.

The regional body may or may not choose to monitor sedimentation/erosion rates themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal or plant species abundance (indicator)

Turbidity/water clarity (indicator)

### **Further information and references**

(*OzEstuaries*). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>

### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Benthic – On the bottom of a body of water or in the bottom sediments.

DEH – Department for Environment and Heritage.

DIPE – Department of Infrastructure, Planning and Environment.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

Topography – Detailed study of the surface features of a region.

## Indicator: Targeted pathogen counts

### Definition

This indicator documents the numbers (counts) of targeted pathogens in estuarine, coastal and marine systems.

### Rationale

A pathogen is a bacterium, virus, protozoan or fungi which causes disease in humans or estuarine/marine organisms. "Pathogens present a hazard to humans recreating in infected waters or beach sands when an infective dose colonizes a suitable growth site in the body and leads to disease. Sites of infection are the alimentary canal, ears, eyes, nasal cavity, skin and upper respiratory tract (WHO, 2001a). Some exposure pathways include head or face immersion, swallowing water (including splashed water during boating), entering water up to or beyond waist level and skin abrasions (WHO, 2001a). Consumption of contaminated shellfish also exposes humans to marine pathogens." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

"Faecal streptococci/enterococci are the recommended indicator for human pathogens in marine waters and gastrointestinal symptoms are a frequent health outcome associated with exposure (WHO, 2001a). Other illnesses and conditions caused by contact with pathogen-contaminated waters include skin rashes, typhoid fever, acute febrile respiratory illness (AFRI) (Fleisher *et al.*, 1996a), salmonellosis, meningo-encephalitis, cryptosporidiosis and giardiasis (Prüss, 1998). An example of a pathogenic disease affecting fish assemblages is epizootic ulcerative syndrome. Low-pH increases the susceptibility of fish to this fungal disease." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Pathogens and shellfish closures were used as two determinants of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Bacteria/pathogens	<\$100	Moderate	Moderate	DEC, DIPNR (NSW) EPA (QLD) EPA, AWQC (SA) EPA (VIC) TASQP (TAS)



### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Bacteria/pathogens

This indicator may also respond to the following stressors:

- Aquatic sediments
- Freshwater flow regime
- Hydrodynamics
- Organic matter
- pH
- Water temperature

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors. Information on the relationship between these stressors and water quality parameters with pathogen levels can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal (fish/macrobenthos) kills
- Animal behaviour (changed)
- Animal lesions and disease
- Aquaculture - accidental culture and release of pathogens
- Diffuse sources: catchment run-off, storm water and land management practices (animal and human wastes)
- Human health problems (infections, gastro, viruses, disease, etc.)
- Poor water quality: high bacteria/pathogen counts
- Sewage discharge from vessels
- Sewage treatment plant discharge, sewage overflow events
- Shellfish/fisheries closures

### **Monitoring method**

Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

It is not possible to routinely measure all viruses, parasites and dangerous bacteria in seawater. Therefore, faecal indicator bacteria are used as 'indicators' (e.g. faecal/thermotolerant coliforms, *E. coli*, enterococci/faecal streptococci). The presence of these organisms in high numbers indicates contamination by faecal material from warm-blooded animals (including humans). For marine waters, only faecal streptococci (or enterococci) show a dose-response relationship for both gastrointestinal illness (Kay *et al.*, 1994) and AFRI (Fleisher *et al.*, 1996b). Faecal streptococci are therefore recommended as the faecal indicator for monitoring marine water quality for recreational use (WHO, 2001a).

A new approach recommended by the World Health Organisation (WHO) includes conducting a sanitary assessment of recreational water catchments (including interviews and site visits to determine all contamination sources) and use of the enterococci group as bacterial indicators. This is a two-component approach to assessing risk of illness from recreational bathing. It is expected that Australia will adopt the WHO approach. Guidelines for conducting sanitary assessments in Australia using the WHO approach have been completed by the Water Services Association of Australia. The WSAA guidelines will be considered for inclusion into guidelines presently being developed by the National Health and Medical Research Council (NHMRC).

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with international (World Health Organisation (WHO)) or national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert

local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

Sites chosen for monitoring will depend on the region and which pathogen/bacteria is being monitored. In general, sites where pathogen threats are thought to be high (e.g. sewage overflow sites) should be monitored. The movement of viruses through estuarine and coastal waters can be predicted via the use of conceptual models depicting sediment transport in different coastal waterway types which are available at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>). Prediction of pathogen movement may help with the choice of monitoring location.

### **Monitoring frequency**

Monitoring should occur at regular intervals not exceeding one month. During the summer (i.e. the swimming season) and in waterways susceptible to faecal contamination, monitoring should occur more frequently. Event monitoring (i.e. after sewage overflow events) should also occur.

### **Data measurement methods**

"Faecal indicator bacterial densities should be assessed according to national guidelines (ANZECC 1992; reproduced in ANZECC/ARMCANZ 2000a). Detection methods are standardised: AS4276.8 for the estimation of the most probable number or AS 4276.9 for the membrane filtration method (Standards Australia, 1995a,b)." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### **Data analysis and interpretation**

Default trigger values for pathogen (microbiological) concentrations have been listed in the Water Quality Guidelines for Australian waterways (ANZECC/ARMCANZ, 2000a).

*Excerpts from OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

Some pathogens occur naturally in marine waters. Others are carried into waterways after defecation/urination/shedding from human or animal hosts (e.g. via sewage effluent, agriculture and stormwater runoff, sewage from ships, recreational population using the water, industrial processes, wildlife, septic tanks near the shore and urban development) (WHO, 2001a). Rivers discharging into coastal areas may carry abundant micro-organisms from these diverse sources. High concentrations of pathogens usually occur after storms due to surface runoff, sediment re-suspension and because rainwater gets into sewerage pipes through faults and illegal connections and causes sewage to overflow. Contamination from human sources (e.g. faecal pollution) presents a greater risk to humans than contamination from animal sources because many animal pathogens are not infectious to humans. Risks to humans from pathogenic organisms are higher in areas with large population densities or with a significant tourism, and are perhaps best assessed by the volume of stormwater and coastal discharges indicators.

Different pathogen-indicator organism relationships may exist between saline and fresh waters, so the same level of faecal indicator bacteria in freshwater and marine environments does not mean the health risk is the same (WHO, 2001b).

Information on which waterways are susceptible to pathogens, the environmental consequences of high pathogen levels, and the factors affecting pathogen numbers and survival is given in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of pathogen concentrations is probably most easily represented graphically (against time) or in box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on pathogen levels is available for a location, it will be possible to produce graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change. The number of times pathogen concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

"If monitoring of recreational waters and assessment of a catchment shows the location to be unsuitable, contaminant sources should be identified and the contamination reduced. Signs should also be posted advising of health risks and beaches may be closed." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

### **Proposed responsibilities**

Data on pathogens has been gathered for many estuarine and coastal waters from around Australia. State agencies, Commonwealth institutions, consultancy companies and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on pathogens and shellfish closures as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor pathogens themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal disease/lesions (indicator)  
Animal kills (indicator)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

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- OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']
- Prüss, A. 1998. A review of epidemiological studies from exposure to recreational water. *International Journal of Epidemiology* 27: 1-9.
- Standards Australia 1995a. *Method 8: Faecal streptococci-Estimation of most probable number (MPN)*. AS4276.8.
- Standards Australia. 1995b. *Method 9: Faecal streptococci-Membrane filtration method*. AS4276.9.
- WHO (World Health Organisation). 2001a. *Guidelines for safe recreational-water environments. Volume 1: coastal and fresh waters*.
- WHO (World Health Organisation). 2001b. *Bathing water quality and human health. Outcome of an expert consultation*. Farnham, UK, April 2001.

## **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Cryptosporidiosis – A disease caused by the protozoan *Cryptosporidium*, which is most commonly transmitted to humans by contact with animal faeces.

DEC – Department of Environment and Conservation.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Enterococci – A group of bacteria found primarily in the intestinal tract of warm blooded animals.

EPA – Environment Protection Agency.

Epizootic ulcerative syndrome – Red spot disease of fish (caused by a fungus).

Giardiasis – Intestinal disease caused by an infestation with a *Giardia* protozoan.

Meningo-encephalitis – Inflammation of the brain and its membranes.

Salmonellosis – Infection caused by *Salmonella* (bacteria).

Spatial – Pertaining to space or distance.

Streptococci – Spherical gram-positive bacteria.

TASQP – Tasmanian Shellfish Quality Assurance program.

Temporal – Pertaining to time.

Thermotolerant – Able to survive in a wide range of temperatures.

## Indicator: Total nutrients in the sediments WITH dissolved nutrients in the sediments

See matter for target: Nutrients in aquatic environments

### Definition

This indicator documents the concentrations of total nutrients and dissolved nutrients in estuarine, coastal and marine sediments.

### Rationale

*Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

The nutrients nitrogen (N) and phosphorus (P) are elements, and are essential building blocks for plant and animal growth. Nitrogen is an integral component of organic compounds such as amino acids, proteins, DNA and RNA. Phosphorus is found in nucleic acids and certain fats (phospholipids). Chemical and biological processes transfer nitrogen and phosphorus through the lithosphere, atmosphere, hydrosphere and biosphere. This is called nitrogen and phosphorus cycling. Nitrogen-fixing bacteria convert di-nitrogen gas into organic nitrogen species that can enter the hydrological cycle and food webs. Phosphorus is made biologically available through the weathering of rocks.

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Nitrogen is one of the main plant nutrients, and in marine systems it is most often the limiting nutrient – the one whose concentration governs the viability and growth of plant species. This contrasts with freshwater systems where phosphorus is often the limiting nutrient. Abundant and bioavailable nitrogen, combined with other favourable conditions, can lead to eutrophication of waterways – in extreme situations familiar to most Australians is the graphic choking of coastal lagoons, estuaries and other confined marine systems by excessive growth of algae. In less severe circumstances, excess levels of nitrogen cause initially subtle but eventually chronic changes to marine ecosystem structure. Sediments can often serve as a reservoir for nutrients that regularly recharge overlying waters, and thus serve to trigger a perennial cycle of algal blooms. Hence, this indicator should warn of, or identify the potential for, eutrophication and problem algal blooms in marine waterways.

Nutrients exist both as organic and inorganic species, and in dissolved and particulate forms. Total nutrients is the total amount of a nutrient present in all its forms (e.g. total nitrogen (TN) is the sum of the nitrogen present in all nitrogen-containing components). Dissolved nutrients occur as dissolved organic and inorganic forms (e.g. total dissolved nitrogen (TDN) is the sum of the dissolved organic nitrogen (DON) (e.g. proteins, amino acids, urea) and dissolved inorganic nitrogen (DIN) (e.g. nitrate and ammonia)). Dissolved nutrients are readily available for plant uptake. Determining the amounts of both total and dissolved nutrients present within the sediments will give an indication of the amount of bioavailable nutrients present.

Nutrient concentration within sediments is important as most of the microbial processing of nutrients occurs here.

Sediment loads of total nitrogen and total phosphate were used as two determinants of sediment quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

Information on sediment nutrient loads, concentrations and budgets, nutrient transport, and on what causes nutrient loads and concentrations to change can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>). See also, the National Eutrophication Management Program website (<http://www.rivers.gov.au/research/nemp/index.htm>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for

comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>†</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients	>\$100	Moderate	Moderate	DEC (NSW) EPA (QLD) EPA (VIC) SARDI, AWQC (SA) WRC (WA)

#### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Nutrients

This indicator may also respond to the following stressors:

- Hydrodynamics
- Freshwater flow regime
- Aquatic sediments

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors and appropriate biological condition and habitat extent indicators associated with the stressor nutrients.

#### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows and entrance modification (decreased flushing, increased residence times)
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Eutrophication
- Nuisance growth of aquatic plants or algae (harmful algal blooms), and loss of amenity
- Point sources: industrial and aquaculture discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

#### **Monitoring method**

Detailed monitoring methods for nutrients in sediments can be found in several publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), scientific publications and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure



that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Spatial scales: Nutrients are typically measured at scales from estuary-wide in surveys in coastal regions to broad expanses of ocean (104–105 km<sup>2</sup>) in offshore research voyages. Individual stations in key locations, when monitored over time, can give valuable insight into nutrient levels. Examples of this approach are the CSIRO coastal station network, and international time-series stations in the Atlantic and Pacific Oceans.

Since most of the increase in nutrients entering coastal waters is the result of terrestrial activities, estuaries are an appropriate monitoring location for land run-off. They act both as a filter and as a channelling conduit between land and sea, and are thus sensitive to change.

Choice of estuaries within regions could be on the basis of catchments characterised by different land uses – urban/industrial, rural, mining/forest operations or undisturbed landforms (national parks, 'old-growth' forest or similar). Within each estuary, a sub-sampling approach could involve five sites sampled monthly.

Stratified random sampling is normally used to account for sediment heterogeneity (i.e. a location composed of several different habitats is deliberately divided up so that each individual habitat is randomly sampled).

Information on which waterways are susceptible to excessive nutrient loads (and therefore more likely to be monitored) is given in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Monitoring frequency**

Monitoring should be done at least monthly.

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Temporal scales: Nutrient levels respond to change on a very broad range of scales, from perhaps minutes as a flash flood sweeps sediments and wastes into an urban stream, to seasonal as a result of cycles of planktonic growth and decay, and out to decadal as changes in land use are reflected in coastal ecosystems (mangroves, reefs, seagrass beds etc.). Therefore, surveys need to be conducted at different scales.

### **Data measurement methods**

At each site, surface sediment samples would be collected and analysed for the total amount of a nutrient and the amount in its dissolved form.

*Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Sediment carbon and nitrogen are best measured by high temperature oxidation methods (e.g. CHN analyser) (Craft *et al.*, 1991), while phosphorus contents are determined by wet chemical oxidation (Nicholls, 1975). Appropriate standard reference materials should be analysed to check recovery.

Nutrient mass accumulation rates in sediment (nutrient cm<sup>-2</sup> year<sup>-1</sup>) are probably more indicative of nutrient loads than sediment nutrient concentrations because the latter are subject to dilution effects caused by the co-deposition of mineral sediment (Radke, 2002). Calculation of nutrient mass accumulation rates requires that sedimentation rates and bulk density be determined in addition to carbon and nutrient concentrations.

### **Data analysis and interpretation**

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Concentrations of nitrogen species should initially be compared with regional baseline levels for the nutrient. Here we are taking baseline to mean existing data obtained from marine waters unperturbed by human activities, and presumably representative of historical natural conditions. The Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992) [see ANZECC/ARMCANZ, 2000a] provided some data for baseline nutrient levels for a few Australian coastal waters. These would need to be developed further, to provide a comprehensive nutrient index for all coastal waters and to have the potential to be extended to estuaries. In the current revision of the ANZECC guidelines one proposition is to include a 'trigger' concentration for individual nutrient species on a bioregional basis. This trigger concentration is the level below which adverse effects have not been reported. In making the comparison between observed and baseline nitrogen concentrations, an estimate of nutrient status might be made. 'Snapshot' observations of nitrogen concentrations may not be typical; interpretations should be made cautiously, mindful of other environmental conditions and the possibility of missing short-term fluctuations (i.e. aliasing of data). Moreover, nutrient data must be used in concert with biological indicators to obtain a complete picture of impending problems for waterway management.

*Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Nutrient loads alone cannot dictate whether a waterway will have a nuisance plant problem (ANZECC/ARMCANZ, 2000a). Nutrient impacts on coastal waterways vary as a function of both the loads and bioavailability of the nutrients, and the extent to which hydrodynamic features (e.g. water volumes, residence times and extent of mixing) and turbidity levels modulate the stimulatory effects of nutrients on plants and algae (ANZECC/ARMCANZ, 2000a; Harris, 2001).

Chlorophyll *a* is probably a better 'instantaneous' indicator of trophic status than nutrient concentrations. This is because nutrient concentrations are affected by biological uptake, which in turn are influenced by uptake capabilities, interaction with grazers, temperature, turbulence and turbidity levels (Hinga *et al.*, 1995). Concentrations of N (or P) taken from water column samples can also underestimate nutrient availability in a system because large pools of nutrients can be found in sediment.

Trigger values for total phosphorous (TP), filterable reactive phosphate (FRP), total nitrogen, total oxidised nitrogen (e.g.  $\text{NO}_x = \text{NO}_3^- + \text{NO}_2^-$ ) and ammonium are provided on a bioregional basis in the ANZECC/ARMCANZ Water Quality Guidelines (ANZECC/ARMCANZ, 2000a). Water Quality Targets Online (<http://www.deh.gov.au/water/quality/targets/>) list water quality targets for DIN and FRP for each of ecosystem protection, recreation and aquaculture/human consumption values.

Given the strong influence of tidal action on water column stability and turbidity levels (which affect the potential of plants to take up nutrients), it would be advantageous to derive separate sets of default trigger values and water quality targets for tide- and wave-dominated systems.

The effect of nutrient load on environmental conditions (including benthic microalgae) of different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

Information on the significance of excessive nutrient loads can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.



### **Monitoring and reporting products**

Reporting of both total nutrient and dissolved nutrient concentrations in the sediments is probably most easily represented in tables, graphs or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. "These data would be compared with the 'trigger' concentrations mooted in the revised ANZECC Water Quality Guidelines, becoming a set of threshold levels. At the estuary scale, waterbodies that exceed the ANZECC threshold level will be identified in map form with annotated tables of data showing monthly mean concentrations." (Ward *et al.*, 1998). "Tabulation of peak values associated with floods and other events that cause mass transport of sediments would also be valuable." (Ward *et al.*, 1998).

Once sufficient information on nutrient concentrations is available for a location, it will be possible to produce graphs and annotated tables on the maps showing trends and their statistical significance. These trends can then be reported as an estimate of change. The number of times nutrient concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Various amounts of data exist from around Australia on nutrient concentrations in estuarine, coastal and marine sediments. This data is collected and held by the State/Territory Government agencies, research organisations and environmental consultants. The National Land and Water Resources Audit compiled information on sediment load of total nitrogen and total phosphate as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

In a review of existing nutrient data, Brodie (1995) noted that "few long-term records of nutrient (or phytoplankton) concentrations, taken on a regular basis at consistent sites in Australian coastal waters, are available". An exception is the CSIRO coastal station network, with some water quality records extending back 50 years; four stations remain operational out of a peak of 13 stations. State agencies are routinely monitoring some eutrophic and other important coastal waterbodies. A plethora of Environmental Impact Assessments and compliance monitoring measurements for water quality, including nutrients, is performed each year around the nation by local government, industry and environmental consultants. However, this work is often limited in scope, data integrity and availability. (Much of the older data is possibly of dubious quality).

National data management for environmental quality is on the horizon; it is sorely needed for the effective gathering, integration, quality control and assurance, and security of data. A national database will facilitate a revision of Rochford's (1980) landmark paper on the nutrient status of the oceans around Australia, and enable a similar interpretative exercise on estuaries nationally.

The National Pollutant Inventory (<http://www.npi.gov.au/>) has limited data on nutrient loads entering Australia's coastal waterways.

The regional body may or may not choose to monitor nutrients themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Algal blooms (indicator)

Chlorophyll a (indicator)

Total nutrients in the water column WITH dissolved nutrients in the water column (indicator)

Nutrients in aquatic environments (matters for targets)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

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OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

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Rochford D.J. 1980. *Nutrient status of the oceans around Australia*. Division of Fisheries and Oceanography Report, 1977–1979. CSIRO. pp 9–20.

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

Waterwatch Australia Steering Committee. 2002. *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra.

### **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Benthic – On the bottom of a body of water or in the bottom sediments.

DEC – Department of Environment and Conservation.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Grazers – Animals which feed (graze) on small organic particles and algae.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Total nutrients in the water column WITH dissolved nutrients in the water column

See matter for target: Nutrients in aquatic environments

### Definition

This indicator documents the levels of total nutrients and dissolved nutrients in estuarine, coastal and marine waters.

### Rationale

Excerpt from *OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

The nutrients nitrogen (N) and phosphorus (P) are elements, and are essential building blocks for plant and animal growth. Nitrogen is an integral component of organic compounds such as amino acids, proteins, DNA and RNA. Phosphorus is found in nucleic acids and certain fats (phospholipids). Chemical and biological processes transfer nitrogen and phosphorus through the lithosphere, atmosphere, hydrosphere and biosphere. This is called nitrogen and phosphorus cycling. Nitrogen-fixing bacteria convert di-nitrogen gas into organic nitrogen species that can enter the hydrological cycle and food webs. Phosphorus is made biologically available through the weathering of rocks.

Excerpt from the guidelines for State of the Environment reporting (Ward *et al.*, 1998):

Nitrogen is one of the main plant nutrients, and in marine systems it is most often the limiting nutrient – the one whose concentration governs the viability and growth of plant species. This contrasts with freshwater systems where phosphorus is often the limiting nutrient. Abundant and bioavailable nitrogen, combined with other favourable conditions, can lead to eutrophication of waterways – in extreme situations familiar to most Australians is the graphic choking of coastal lagoons, estuaries and other confined marine systems by excessive growth of algae. In less severe circumstances, excess levels of nitrogen cause initially subtle but eventually chronic changes to marine ecosystem structure. Sediments can often serve as a reservoir for nutrients that regularly recharge overlying waters, and thus serve to trigger a perennial cycle of algal blooms. Hence, this indicator should warn of, or identify the potential for, eutrophication and problem algal blooms in marine waterways.

Nutrients exist both as organic and inorganic species, and in dissolved and particulate forms. Total nutrients is the total amount of nutrient present in all its forms (e.g. total nitrogen (TN) is the sum of the nitrogen present in all nitrogen-containing components). Dissolved nutrients occurs as dissolved organic and inorganic forms (e.g. total dissolved nitrogen (TDN) is the sum of the dissolved organic nitrogen (DON) (e.g. proteins, amino acids, urea) and dissolved inorganic nitrogen (DIN) (e.g. nitrate and ammonia)). Dissolved nutrients are readily available for plant uptake. Determining the amounts of both total and dissolved nutrients present within the water column will give an indication of the amount of bioavailable nutrients present.

Nutrient concentrations within the water column is important as it is from here that nutrients are taken up by phytoplankton which may then form blooms if excess nutrients are present.

Water nutrients is an important indicator for State of the Environment reporting (Ward *et al.*, 1998), and was used as one determinant of water quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

Information on water column nutrient loads, concentrations and budgets, nutrient transport, and on what causes nutrient loads and concentrations to change can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>) and the National Eutrophication Management Program website (<http://www.rivers.gov.au/research/nemp/index.htm>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for

comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>†</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Nutrients	<\$100	Moderate	Moderate	DEC, DIPNR (NSW) DIPE (NT) EPA (QLD) EPA (VIC) SARDI, AWQC (SA) TAFI (TAS) Waterwatch WRC (WA)

#### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Nutrients

This indicator may also respond to the following stressors:

- Hydrodynamics
- Freshwater flow regime
- Aquatic sediments

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors and appropriate biological condition and habitat extent indicators associated with the stressor nutrients.

#### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Decreased environmental flows and entrance modification (decreased flushing, increased residence times)
- Diffuse nutrient sources: catchment landuse and run-off (rural and urban)
- Eutrophication
- Nuisance growth of aquatic plants or algae (harmful algal blooms), and loss of amenity
- Point sources: industrial and aquaculture discharge, sewage treatment plant discharge, sewage overflow events, dumping of nutrient rich wastewater
- Poor water quality: increased nutrients

#### **Monitoring method**

Detailed monitoring methods for nutrients in the water column can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Spatial scales: Nutrients are typically measured at scales from estuary-wide in surveys in coastal regions to broad expanses of ocean (104–105 km<sup>2</sup>) in offshore research voyages. Individual stations in key locations, when monitored over time, can give valuable insight into nutrient levels. Examples of this approach are the CSIRO coastal station network, and international time-series stations in the Atlantic and Pacific Oceans.

Since most of the increase in nutrients entering coastal waters is the result of terrestrial activities, estuaries are an appropriate monitoring location for land run-off. They act both as a filter and as a channelling conduit between land and sea, and are thus sensitive to change.

Choice of estuaries within regions could be on the basis of catchments characterised by different land uses – urban/industrial, rural, mining/forest operations or undisturbed landforms (national parks, 'old-growth' forest or similar). Within each estuary, a sub-sampling approach could involve five sites sampled monthly.

Information on which waterways are susceptible to excessive nutrient loads (and therefore more likely to be monitored) is given in OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Monitoring frequency**

Monitoring should be done at least monthly.

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Temporal scales: Nutrient levels respond to change on a very broad range of scales, from perhaps minutes as a flash flood sweeps sediments and wastes into an urban stream, to seasonal as a result of cycles of planktonic growth and decay, and out to decadal as changes in land use are reflected in coastal ecosystems (mangroves, reefs, seagrass beds etc.). Therefore, surveys need to be conducted at different scales.

With automated nutrient analysers for field measurement just gaining acceptance, it would be strongly advisable to consider the incorporation of this type of instrument, when proven, into the survey design to give continuous monitoring at one of the five estuarine stations (as described in the Survey strategy for indicators 3.17 chlorophyll concentrations and 6.3 turbidity). Short-term nutrient fluctuations — missed with intermittent sampling — would then be observed.

### **Data measurement methods**

At each site, water samples would be collected, and analysed for the total amount of a nutrient and the amount in its dissolved form.

*Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Total nitrogen and total phosphorus are determined by analysing unfiltered water samples. Dissolved nutrients pass through a 0.45µm filter and are reported as: soluble reactive phosphorus (SRP) or filterable reactive phosphorus (FRP) in the case of phosphorus; and total dissolved nitrogen (TDN) in the case of nitrogen. TDN can be further analysed for nitrate, nitrite, ammonium and organic nitrogen. The term 'reactive' implies that the nutrient readily reacts with the analytical chemical process.



The widely accepted analytical techniques for quantifying nutrients and producing comparable data, are a set of wet chemical processes used in combination with spectrophotometry (also termed colorimetry). The techniques involve blending precise amounts of sample and wet chemicals. A reaction occurs with the 'reactive' nutrient and the solution develops a specific colour. The depth of the colour is proportional to the concentration of the nutrient, and is measured with a spectrophotometer. Total nutrients are measured the same way except the nutrients being quantified are initially converted to a reactive form through a chemical digestion process. There are different techniques and instrumentation for quantifying select nutrients, such as ion chromatography, fluorescence, probes and inductively coupled plasma. When comparing data from less conventional techniques one should always confirm what form of the nutrient is being quantified.

### **Data analysis and interpretation**

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Concentrations of nitrogen species should initially be compared with regional baseline levels for the nutrient. Here we are taking baseline to mean existing data obtained from marine waters unperturbed by human activities, and presumably representative of historical natural conditions. The Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992) [see ANZECC/ARMCANZ, 2000a] provided some data for baseline nutrient levels for a few Australian coastal waters. These would need to be developed further, to provide a comprehensive nutrient index for all coastal waters and to have the potential to be extended to estuaries. In the current revision of the ANZECC guidelines one proposition is to include a 'trigger' concentration for individual nutrient species on a bioregional basis. This trigger concentration is the level below which adverse effects have not been reported. In making the comparison between observed and baseline nitrogen concentrations, an estimate of nutrient status might be made. 'Snapshot' observations of nitrogen concentrations may not be typical; interpretations should be made cautiously, mindful of other environmental conditions and the possibility of missing short-term fluctuations (i.e. aliasing of data). Moreover, nutrient data must be used in concert with biological indicators to obtain a complete picture of impending problems for waterway management.

*Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Nutrient loads alone cannot dictate whether a waterway will have a nuisance plant problem (ANZECC/ARMCANZ, 2000a). Nutrient impacts on coastal waterways vary as a function of both the loads and bioavailability of the nutrients, and the extent to which hydrodynamic features (e.g. water volumes, residence times and extent of mixing) and turbidity levels modulate the stimulatory effects of nutrients on plants and algae (ANZECC/ARMCANZ, 2000a; Harris, 2001).

Chlorophyll *a* is probably a better 'instantaneous' indicator of trophic status than nutrient concentrations. This is because nutrient concentrations are affected by biological uptake, which in turn are influenced by uptake capabilities, interaction with grazers, temperature, turbulence and turbidity levels (Hinga *et al.*, 1995). Concentrations of N (or P) taken from water column samples can also underestimate nutrient availability in a system because large pools of nutrients can be found in sediment (see sediment nutrients).

Trigger values for total phosphorous (TP), filterable reactive phosphate (FRP), total nitrogen, total oxidised nitrogen (e.g.  $\text{NO}_x = \text{NO}_3^- + \text{NO}_2^-$ ) and ammonium are provided on a bioregional basis in the ANZECC/ARMCANZ Water Quality Guidelines (ANZECC/ARMCANZ, 2000a). Water Quality Targets Online (<http://www.deh.gov.au/water/quality/targets/>) list water quality targets for DIN and FRP for each of ecosystem protection, recreation and aquaculture/human consumption values.

Given the strong influence of tidal action on water column stability and turbidity levels (which affect the potential of plants to take up nutrients), it would be advantageous to

derive separate sets of default trigger values and water quality targets for tide- and wave-dominated systems.

The effect of nutrient load on environmental conditions (including chlorophyll *a* concentrations) of different types of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

Information on the significance of excessive nutrient loads can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

The Department of the Environment and Heritage (Australian Government) provides water quality targets online (<http://www.deh.gov.au/water/quality/targets/>) for TN, oxides of nitrogen, TP and filterable reactive phosphate.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of both total nutrient and dissolved nutrient concentrations in the water column is probably most easily represented in tables, graphs or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. "These data would be compared with the 'trigger' concentrations mooted in the revised ANZECC Water Quality Guidelines, becoming a set of threshold levels. At the estuary scale, waterbodies that exceed the ANZECC threshold level will be identified in map form with annotated tables of data showing monthly mean concentrations." (Ward *et al.*, 1998). "Tabulation of peak values associated with floods and other events that cause mass transport of sediments would also be valuable." (Ward *et al.*, 1998).

Once sufficient information on nutrient concentrations is available for a location, it will be possible to produce graphs and annotated tables on the maps showing trends and their statistical significance. These trends can then be reported as an estimate of change. The number of times nutrient concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Large amounts of data exists from around Australia on nutrient concentrations in estuarine, coastal and marine waters. This data is collected and held by the State/Territory, local government, research organisations, community groups and environmental consultants. The National Land and Water Resources Audit compiled information on nutrients (including: ammonia, oxidised nitrogen and phosphate) as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

#### ***Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):***

In a review of existing nutrient data, Brodie (1995) noted that "few long-term records of nutrient (or phytoplankton) concentrations, taken on a regular basis at consistent sites in Australian coastal waters, are available". An exception is the CSIRO coastal station network, with some water quality records extending back 50 years; four stations remain operational out of a peak of 13 stations. State agencies are routinely monitoring some eutrophic and other important coastal waterbodies. A plethora of Environmental Impact Assessments and compliance monitoring measurements for water quality, including nutrients, is performed each year around the nation by local government, industry and environmental consultants. However, this work is often limited in scope, data integrity and availability. (Much of the older data is possibly of dubious quality).



National data management for environmental quality is on the horizon; it is sorely needed for the effective gathering, integration, quality control and assurance, and security of data. A national database will facilitate a revision of Rochford's (1980) landmark paper on the nutrient status of the oceans around Australia, and enable a similar interpretative exercise on estuaries nationally.

The National Pollutant Inventory (<http://www.npi.gov.au/>) has limited data on nutrient loads entering Australia's coastal waterways.

The regional body may or may not choose to monitor nutrients themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Algal blooms (indicator)

Chlorophyll a (indicator)

Total nutrients in the sediment WITH dissolved nutrients in the sediment (indicator)

Nutrients in aquatic environments (matters for targets)

#### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

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Cosser, P.R. (ed.). 1997. *Nutrients in marine and estuarine environments*. State of the Environment Technical Paper Series (Estuaries and the Sea). 53 pp. Department of the Environment, Canberra. <http://www.deh.gov.au/soe/techpapers/series1/pubs/09compen.pdf>

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

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- OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']
- Rochford D.J. 1980. *Nutrient status of the oceans around Australia*. Division of Fisheries and Oceanography Report, 1977–1979. CSIRO. pp 9–20.
- Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>
- Waterwatch Australia Steering Committee. 2002. *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra.

### **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Grazers – Animals which feed (graze) on small organic particles and algae.

SARDI – South Australian Research and Development Institute.

Spatial – Pertaining to space or distance.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Toxicants in biota

### Definition

This indicator documents the levels of toxicants in the biota of estuarine, coastal and marine waters.

### Rationale

Toxicants are chemicals that harm animals or plants. They can be natural (e.g. metals such as zinc and copper) which are essential for life but become toxic at high concentrations) or unnatural (i.e. man-made substances such as pesticides). A list of potential toxicants is provided in the Water Quality Guidelines (ANZECC/ARMCANZ, 2000a).

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Chemical residues and industrial chemicals are found in estuaries and bays near the major urban and industrial agglomerations, and potentially near regions of intensive agriculture. However, most marine and estuarine waters have low concentrations of these residues, and so measurements by traditional bulk water chemistry techniques are time consuming, laborious and expensive. Oysters, mussels and other taxa have been used to monitor the water column levels of many chemicals, and represent an early warning device to detect the spread of unpredicted residues into otherwise uncontaminated areas. Measurement of levels of contaminants in natural biological tissues is also a useful way to track long-term trends in levels of most contaminants in marine and estuarine systems, and complements measurements of total concentrations made in sediment systems.

Unlike sediments, living organisms 'see' only the biologically available fractions of pollutants in waters and sediments. These may be dynamic (that is, pollutants may move from non-available to available fractions), and since we have only very limited understanding of how this process operates for most pollutants biological sentinel accumulators must be used to assess the extent to which total environmental levels of contaminants are biologically active. This is achieved by measuring their body burdens of the individual chemical residues. Overseas programs such as Mussel Watch have been used successfully to evaluate distribution and changes in pollutants (NOAA, 1986; O'Connor, 1992).

Another advantage of monitoring toxicants in biota (via bioaccumulation) over water, is that toxicants are often introduced into the system as a result of an isolated event and therefore concentrations in the water may be too low to be measured most of the time.

Contaminated biota may be harmful to human health if eaten.

Toxicants in biota, (see 'seafood quality (contaminants)', 'sentinel accumulator program' and 'seabird eggs (contamination)'), is an important indicator for State of the Environment reporting (Ward *et al.*, 1998).

For further information on toxicants including a detailed explanation of what toxicants are, the sources of toxicants, environmental significance of toxicants, and coastal habitats susceptible to toxicants see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the

indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Toxicants	>\$100	Hard	Moderate	DBIRD (NT) DEC (NSW) EPA (QLD) EPA (SA) EPA, PIRVIC (VIC) WRC (WA)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Toxicants

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition indicator associated with the stressor (i.e. animal kills or occurrence of imposex).

### Links to issues

The following list contains the main NRM 'issues' associated with this indicator:

- Animal kills and disease
- Biota (plants and animals) and habitat lost/disturbed
- Boating and infrastructure antifoulants (e.g. TBT), slipways
- Human health problems (eating contaminated seafood)
- Imposex (development of male sex organs in female gastropods)
- Point sources: industrial discharge, dumping of toxicants
- Poor water quality: toxicant levels
- Shellfish/fisheries closures
- Toxicant release: spills, oil spills, insect control chemicals, pesticides/herbicides, outboard motor emissions, etc.

### Monitoring method

Detailed monitoring methods for toxicants in biota can be found in the guidelines for State of the Environment reporting (see 'seafood quality (contaminants)', 'sentinel accumulator program' and 'seabird eggs (contamination)') (Ward *et al.*, 1998), scientific publications and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (Ward *et al.*, 1998) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

Information provided in OzEstuaries on 'pesticide hazard'

([http://www.ozestuaries.org/indicators/HA\\_pesticide\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_pesticide_hazard_f.html)), 'industrial point source hazard'

([http://www.ozestuaries.org/indicators/HA\\_industrial\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_industrial_hazard_f.html)) and 'wastewater discharges'

([http://www.ozestuaries.org/indicators/HA\\_stormwater\\_f.html](http://www.ozestuaries.org/indicators/HA_stormwater_f.html)) is useful for assessing toxicant risk from agricultural and/or urban and industrial sources.

### **Monitoring locations and frequency**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

The indicator would be monitored annually (or as otherwise specified in the SOP [Standard Operating Procedure]) in a small number of carefully selected refuge/reference areas (possibly nature reserves/marine parks) and other randomly and explicitly selected sites.

Development of the detailed techniques for an SOP will need a specialised assessment and pilot study for each site and IMCRA [Interim Marine and Coastal Regionalisation of Australia] subregion based on individual estuary catchments and an analysis of existing data derived from previous major programs that have determined baseline levels of contaminants in relevant taxa (such as the Jervis Bay Baseline Studies; CSIRO 1994).

### **Data measurement methods**

"This indicator would be measured using refined field sampling and laboratory analysis protocols to be defined and developed for a specific SOP. It would probably be based on oysters, mussels and seagrass leaves, since there are existing baseline data on these taxa, they have overlapping distributions around the Australian coast, and they are widely and naturally available for field collection with minimum environmental impact." (Ward *et al.*, 1998).

The species collected for analysis should be a widespread and common species whose populations will not be affected by collection. The species used will also depend on the toxicant being tested for. "In the case of seabirds, the most efficient way to track exposure to lipophilic (fat-loving) residues such as pesticides is by analysis of the concentrations of these chemicals in their eggs. Overseas studies have found this a useful way to determine and monitor pesticide exposure in seabirds with minimum invasion of, and impacts on, populations (Coulson *et al.*, 1972; Barrett *et al.*, 1985; Wilson and Earley, 1986; Stronkhorst *et al.*, 1993). Also, fish-eating marine birds (shags) may accumulate, in their eggs, pesticides not accumulated by mussels (Allen and Thompson, 1996). Using eggs of seabirds as a monitoring tool has a number of advantages: the readings represent actual exposure of a top predator to the target contaminants; the eggs have a known affinity for pesticides and mercury; the eggs are easy to sample and analyse; and the sampling has a limited ecological impact on the bird population (Becker, 1989)." (Ward *et al.*, 1998).

The Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b) give formal guidance for appropriate analytical methods for water and sediment toxicants. Although there is no guidance for the toxicants in biota, chemicals which have the potential to bioaccumulate are identified.

### **Data analysis and interpretation**

*Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Many pollutants are synthetic chemicals (such as some pesticides) that do not normally exist in nature, while others are naturally occurring compounds or elements (such as hydrocarbons or trace metals) and become pollutants when they occur in higher than usual concentrations. However, as described under 6.1, for both synthetic and natural materials the precise level at which an effect can be expressed in the flora [plants] and fauna [animals] is difficult to define. So, rather than use concentration criteria to determine when levels are acceptable, we need to rely mainly on an assessment of trajectory to evaluate the level of stress imposed by contaminants. For synthetic chemicals, levels should be trending downwards, hopefully to near-zero, while for natural materials they should be close to natural background levels and not trending upwards. Locations that do not fit these objectives may be in most need of remedial action. Change can only be detected against a baseline of existing or historic data, and then only with many caveats about collection and analysis techniques. Laboratory techniques have become increasingly sophisticated in the last decade, and data from earlier times are usually highly questionable.

*Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Chronic effects of bioaccumulated toxicants in organisms include alterations of growth, reproductive success, competitive abilities and deformities such as imposex. Elevated

toxicant concentrations in organisms (e.g. fish and shellfish) may also pose health risks to consumers of those organisms (including humans). For this reason, toxicant concentrations in food are regulated.

There are still many challenges to understanding the fate, transport and interactions of contaminants in marine systems. In particular, more information is needed on contaminant concentrations and processes governing their distribution in Australian coastal environments. Section 8.5.3 of the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) lists several other deficiencies in knowledge.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of toxicant levels in biota is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on toxicant levels is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. At a higher level, the percentage of animals/plants containing detectable levels of toxicants could be reported against.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values).

The percentage of seafood which contains contaminant at concentrations that exceed the maximum recommended limits for consumption could be reported against.

### **Proposed responsibilities**

“Commonwealth and State agencies responsible for managing coastal ecosystems – typically environment, conservation, water and fisheries portfolios – have data on contaminants in relevant taxa. However, most relate to ‘hotspots’ of concern, or are limited to small spatial areas, and have been gathered for issue-specific purposes. Realistic data on background concentrations over regional areas and decadal periods are not available.” (Ward *et al.*, 1998).

State and Commonwealth health and fisheries agencies should be able to provide data on the maximum recommended limits for contaminants in biota (with respect to human consumption). They should also be able to provide data on the percentage of samples tested that exceed these limits, for a species, toxicant or location.

The regional body may or may not choose to monitor toxicants in biota themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal disease/lesions (indicator)  
Animal kills (indicator)  
Occurrence of imposex (indicator)  
Toxicants in the sediment (indicators)  
Water soluble toxicants in the water column (indicator)



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### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Bioaccumulation – the process by which chemical are accumulated in biota with levels increasing up the food chain (i.e. small animals and plants take up toxicants from the waters, and when they are eaten by other animals, the toxicants move up the food chain with higher concentrations being found in higher predators).

DBIRD – Department of Business, Industry and Resource Development.

DEC – Department of Environment and Conservation.

EPA – Environment Protection Agency.

Imposex – Development of male sex organs in females.

PIRVIC – DPI, Primary Industries Research Victoria.

Spatial – Pertaining to space or distance.

Taxa – A taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

TBT – Tributyltin. A toxic chemical used to prevent the fouling of ship hulls.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.



## Indicator: Toxicants in the sediment

### **Definition**

This indicator documents the levels of toxicants in the surface sediments of estuarine, coastal and marine systems.

### **Rationale**

Toxicants are chemicals that harm animals or plants. They can be natural (e.g. metals (zinc, copper) which are essential for life but become toxic at high concentrations) or unnatural (i.e. man-made substances). A list of potential toxicants is provided in the Water Quality Guidelines (ANZECC/ARMCANZ, 2000a).

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Pollutants commonly accumulate in sediments and are a starting point for contamination throughout the food chain, potentially damaging marine life and affecting human health. Measurement of sediment concentrations of contaminants is a useful way to track long-term trends in concentrations of most contaminants in marine and estuarine systems. These concentrations indicate the extent and magnitude of the pressure imposed by contaminants on the flora [plants] and fauna [animals] of the shallow-water ecosystems.

Most [toxicants] find their way into the surface sediments of contaminated waterways after various periods (sometimes brief) in the water column.

Areas with contaminated sediments may be harmful to humans, animals and plants.

Sediment toxicants (see 'sediment quality (contaminants)') is an important indicator for State of the Environment reporting (Ward *et al.*, 1998), and was used as one determinant of sediment quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

For further information on toxicants including a detailed explanation of what toxicants are, the sources of toxicants, environmental significance of toxicants, and coastal habitats susceptible to toxicants see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### **Key information**

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Toxicants	<\$100	Moderate	Moderate	AWQC (SA) DEC (NSW) EPA (QLD) EPA (VIC)

**Links to stressors**

This indicator is most likely to respond to the following stressor:

- Toxicants

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition indicator associated with the stressor (i.e. animal kills or occurrence of imposex).

**Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal kills and disease
- Biota (plants and animals) and habitat lost/disturbed
- Dredging/resuspension of toxicants from sediments
- Human health problems (skin irritations, disease, etc.)
- Point sources: industrial discharge, dumping of toxicants
- Poor water quality: toxicant levels
- Shellfish/fisheries closures
- Toxicant release: spills, oil spills, insect control chemicals, pesticides/herbicides, outboard motor emissions, etc.

**Monitoring method**

Detailed monitoring methods for toxicants in the sediment can be found in the Monitoring Guidelines (ANZECC/ARMCANZ, 2000a,b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b) give formal guidance for appropriate analytical methods for sediment toxicants.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

Information provided in OzEstuaries on 'pesticide hazard'

([http://www.ozestuaries.org/indicators/HA\\_pesticide\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_pesticide_hazard_f.html)), 'industrial point source hazard'

([http://www.ozestuaries.org/indicators/HA\\_industrial\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_industrial_hazard_f.html)) and 'wastewater discharges'

([http://www.ozestuaries.org/indicators/HA\\_stormwater\\_f.html](http://www.ozestuaries.org/indicators/HA_stormwater_f.html)) is useful for assessing toxicant risk from agricultural and/or urban and industrial sources.

**Monitoring locations and frequency**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

The indicator would be monitored annually (or as otherwise specified in the SOP [Standard Operating Procedure]) in a small number of carefully selected refuge/reference areas (possibly nature reserves/marine parks) and other randomly and explicitly selected sites.

Development of the detailed techniques for an SOP will need a specialised assessment and pilot study for each site and IMCRA [Interim Marine and Coastal

Regionalisation of Australia] subregion based on individual estuary catchments and an analysis of existing data derived from previous major programs that have determined baseline levels of contaminants in sediments (such as the Jervis Bay Baseline Studies; CSIRO 1994).

#### **Data measurement methods**

"This indicator would be measured using refined field sampling and laboratory analysis protocols to be defined and developed for a specific SOP." (Ward *et al.*, 1998).

*Excerpts from OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

It is recommended that sampling for toxicants be undertaken in accordance with the ANZECC/ARMCANZ Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b). Table 5.2 (pg 5-4) in the guidelines is a source of appropriate analytical methods. Decision tree frameworks for assessing toxicants in ambient waters are provided in Figures 3.4.1 (water pg. 3.4-14) and 3.5.1 (sediments pg. 3.5-6) of the ANZECC/ARMCANZ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a).

A new approach being used at Sydney University involves not only an assessment of sediment quality, but also a determination of the severity of impact and identification of contaminant sources and dispersion pathways

[\[http://www.ozestuaries.org/indicators/DEF\\_sediment\\_scheme.html\]](http://www.ozestuaries.org/indicators/DEF_sediment_scheme.html).

#### **Data analysis and interpretation**

*Excerpt from the guidelines for State of the Environment reporting* (Ward *et al.*, 1998):

Many pollutants are synthetic chemicals (such as some pesticides) that do not normally exist in nature, while others are naturally occurring compounds or elements (such as hydrocarbons or trace metals) and become pollutants when they occur in higher than usual concentrations. Most find their way into the surface sediments of contaminated waterways after various periods (sometimes brief) in the water column. However, for both synthetic and natural materials, the precise level at which an effect can be expressed in the accompanying or adjacent biological systems is very difficult to define (see, for example, Suchanek, 1994). So, rather than use concentration criteria to determine when levels are acceptable, we need to rely mainly on an assessment of trajectory to evaluate the level of stress imposed by contaminants. For synthetic chemicals, levels should be trending downwards, hopefully to near-zero, while for natural materials they should be close to natural background levels and not trending upwards. Locations that do not fit these objectives may be in most need of remedial action.

Change can only be detected against a baseline of existing or historic data, and then only with many caveats about collection and analysis techniques. Laboratory techniques have become increasingly sophisticated in the last decade, and data from earlier times are usually highly questionable. So full documentation of procedures, quality assurance and controls is critical if the currently collected data are to be useful in the next century.

*Excerpts from OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

Many toxicants reaching estuaries have a high affinity for fine-grained sediment. The concentrations of some toxicants are therefore controlled to a certain extent by processes governing sediment transport and deposition. In tide-dominated waterways (e.g. deltas, estuaries and tidal creeks), flanking environments are the main traps for fine sediments, and these include mangroves (Harbison, 1986), saltmarsh areas (Lee and Cundy, 2001) and intertidal flats (Lee and Cundy, 2001). Fine sediments also accumulate in mangroves, saltmarsh and intertidal flats in wave-dominated coastal waterways (e.g. estuaries and strandplains/coastal lagoons), but the central basin is usually the main sink. The baffling of water movement by seagrass leaves can also cause fine sediments and toxicants to deposit in seagrass meadows. Physical disturbance of these habitats (e.g. dredging, reclamation, erosion and re-suspension)

can remobilise toxicants from the sediments into the water column (Lee and Cundy, 2001).

DOM [dissolved organic matter] can enhance the solubilities of some organic pollutants and pesticides (Chiou *et al.*, 1986), and this might be important in areas where there is lots of decaying vegetation.

There are still many challenges to understanding the fate, transport and interactions of contaminants in marine systems. In particular, more information is needed on contaminant concentrations and processes governing their distribution in Australian coastal environments. Section 8.5.3 of the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) lists several other deficiencies in knowledge.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of toxicant levels in the sediment is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on toxicant levels is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The percentage of site in which toxicant concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

"Commonwealth and State agencies responsible for managing coastal ecosystems – typically environment, conservation, water and fisheries portfolios – have data on contaminants in sediments. However, most relate to 'hotspots' of concern, or are limited to small spatial areas, and have been gathered for issue-specific purposes. Realistic data on background concentrations over regional areas and decadal periods are not available." (Ward *et al.*, 1998). The National Land and Water Resources Audit compiled information on sediment toxicants as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor toxicants themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Animal kills (indicator)  
Occurrence of imposex (indicator)  
Toxicants in biota (indicators)  
Water soluble toxicants in the water column (indicator)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*.  
<http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

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OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']

Suchanek, T.H. 1994. Temperate coastal marine communities: biodiversity and threats. *American Zoologist* 34: 100–114.

Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>

## **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

EPA – Environment Protection Agency.

Imposex – Development of male sex organs in females.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

## Indicator: Turbidity/water clarity

See matter for target: Turbidity/suspended particulate matter in aquatic environments

### Definition

This indicator documents the level of turbidity in estuarine, coastal and marine waters.

### Rationale

"Turbidity is a measure of water clarity or murkiness. It is an optical property that expresses the degree to which light is scattered and absorbed by molecules and particles. Turbidity results from soluble coloured organic compounds and suspended particulate matter in the water column. Suspended particulate matter may include clay and silt (e.g. suspended sediment), and detritus and organisms. Degree of turbidity and changes in turbidity levels in coastal and estuarine waters are an indicator for State of the Environment reporting (Ward *et al.*, 1998)." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>). Turbidity was used as one determinant of ecosystem integrity in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

"Measurements of turbidity are very useful when the extent of transmission of light through water is the information sought, as in the case of estimation of the light available to photosynthetic organisms. Another strong point in favour of turbidity is that field measurement is straightforward and can be performed rapidly by relatively unskilled monitoring teams. Turbidity is a measurement included in Waterwatch programs nationally. Because of the simplicity of the technique and its widespread use, large volumes of turbidity data are becoming available for national evaluation and interpretation. The turbidity of Australian coastal waters is an important issue in relation to benthic productivity, since many highly valued seagrass and algal bed communities have evolved in, and depend on, conditions of high light penetration (low turbidity)." (Ward *et al.*, 1998).

For further information on turbidity and fine sediment loads including; a detailed explanation of what turbidity is, what causes turbidity, the significance of turbidity, coastal systems susceptible to turbidity, the impacts of fine sediment loads on coastal waterways and what biophysical parameters may indicate that a waterway is receiving excess sediment loads see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a **rough guide only**. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.



Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>†</sup> :
Aquatic sediments	<\$5 (Secchi/NTU) to <\$30 (TSS)	<\$30 (turbidity tube) to >\$1000 (turbidity meter)	Easy	Moderate	DEC, DIPNR (NSW) DIPE (NT) EPA (QLD) EPA, AWQC, SARDI (SA) EPA (VIC) GBRMPA Waterwatch WRC (WA)

### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Aquatic sediments

This indicator may also respond to the following stressors:

- Hydrodynamics
- Habitat removal/disturbance
- Freshwater flow regime

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of appropriate biological condition and habitat extent indicators associated with the stressor aquatic sediments (i.e. animal or plant species abundance and seagrass depth range).

### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Algal blooms
- Biodiversity decreased
- Biota (plants and animals) lost/disturbed (smothering, filter feeders, sessile benthic and grazing animals, physical abrasion of gills and behavioural changes, lower light availability for benthic plants)
- Diffuse sediment sources: catchment clearing, landuse and run-off (rural and urban)
- Dredging, trawling: resuspension of sediments, dumping of dredged material
- Environmental flows – water and frequency of floods from catchment water changed from natural by dams, barriers, water extraction, levees, impoundments and weirs, increased hard surfaces, land cover, decreased/increased water velocity
- Episodic and large scale events (drought, floods, storms, cyclones, bushfires)
- Erosion
- Eutrophication
- Habitat lost/disturbed (smothering)
- Light penetration decreased
- Poor water quality: turbidity
- Primary aquatic plant productivity (changed)
- Shipping movement through shallow waters
- Urban development and soil disturbance in coastal zone due to development
- Visual amenity decreased

### **Monitoring method**

Detailed monitoring methods for turbidity can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure

that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### **Monitoring locations and frequency**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Temporal scales: Like most other water quality indicators, turbidity is worth measuring over a wide range of time scales. Medium to long-term trends (monthly and longer) are to be favoured for national state of the environment reporting. Nevertheless, extremes resulting from floods or other exceptional events are important information in the Australian context because these events are responsible for most transport of suspended particulate matter to coastal waters.

Spatial scales: Turbidity values are often very low in marine waters. As a result, routine measurements of turbidity are often confined to rivers, streams and the upper reaches of estuaries (i.e. small spatial scales).

Since most of the suspended particulate matter entering coastal waters has a terrestrial source (phytoplankton blooms arising from incursions of nutrient-enriched marine waters are an exception), estuaries are an appropriate monitoring location for land run-off. They act both as a filter and as a channelling conduit between land and sea, and are thus sensitive to change.

A two-tiered monitoring scheme is proposed comprising: intermittent sampling together with other water quality indicators; and continuous sampling at a master station. Within each estuary, a sub-sampling approach could involve five sites sampled monthly. At each site, surface and bottom water samples would be collected and turbidity measured.

### **Data measurement methods**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Survey strategy: Turbidity measurement is well suited to field surveys, for the reasons given above [see rationale].

Turbidity sensors are well suited to automated monitoring systems. One of the five stations involved in the intermittent estuarine sampling should also be identified as the 'master' station, at which an automatic turbidity monitor (most likely coupled with automated measurement of temperature, conductivity and chlorophyll) is installed. It would sample continuously at the surface and near the bottom. Incorporation of this sampling program into existing estuarine surveys done by State agencies or other organisations would be advantageous. Turbidity is being evaluated as a parameter able to be measured by remote sensing; such an approach would have obvious appeal for SoE [State of the Environment] reporting and, supported by selective ground-truthing like that described above, would be suitable for a national approach.

It would also be advisable to pass a measured volume of water sample through a filter membrane (e.g. 0.45 µm or 0.22 µm pore size) to obtain the concentration of suspended particulate matter gravimetrically (the relatively new technique of field flow fractionation should be considered in the longer term as it gains wider acceptance and a need for greater characterisation of suspended particulate matter is recognised).

The detail of a monitoring program for SoE will need to be developed and defined in an appropriate SOP [Standard Operating Procedure].

*Excerpt from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

Turbidity is estimated either by nephelometry or by directly determining the mass of suspended particulate matter in given volume of sample. When 'turbidity' is directly determined (e.g. by filtration, drying and weighing) it is referred to as suspended particulate matter (or SPM). By comparison, nephelometry compares the intensity of light scattered by a sample with the intensity of light scattered by a standard reference suspension under the same conditions. It is recorded in nephelometric turbidity units



(NTU). Turbidimeters equipped with nephelometers are well suited to field measurement.

Measures of visual clarity or light penetration are more appropriate for coastal and estuarine waters when the goal is estimate the depth of light penetration (Monbet, 1992). This is because turbidity levels (measured as NTU's) may be low in surface waters but may be high at the intersection between freshwater and seawater in a stratified water column. Visual clarity can be simply assessed by lowering a black and white circular plate (Secchi disk) into the water column. The depth at which the plate is no longer visible is called the Secchi depth. A simple rule of thumb is that light can penetrate to ~2-3 times the Secchi depth. Light sensors can be used for a more accurate measure of euphotic depth (i.e. the depth at which photosynthetically-active radiation (PAR) is reduced to about 1%).

### **Data analysis and interpretation**

*Excerpts from the guidelines for State of the Environment reporting (Ward et al., 1998):*

Turbidity is an operationally determined parameter that is related to the 'murkiness' of water. Depending on the instrument used, it is quantified by light either scattered from, or absorbed by, suspended particles and colloidal material, with perhaps minor contributions also from coloured dissolved organic matter (e.g. humic substances). Reasons for measuring turbidity differ slightly from those for other water quality indicators. Although increases in turbidity are often related to deterioration in water quality, it does not follow that the severity of the contamination can be assessed. For example, severe clouding of water by clay minerals and humic substances from soil disturbance may be unsightly, but not toxic to fish or other aquatic creatures. However, a lesser loading of metal-rich particles from mine tailings discharge, or high-clarity waters loaded with aluminium arising from runoff from acid sulfate soils, can devastate biota.

High turbidity values are the data of interest, and change in waters from low to high values. A problem encountered is one shared with other water quality indicators — the need for national baseline data that make it possible to distinguish values and patterns that depart from the norm and may indicate environmental problems or anomalies.

Shifts in long-term patterns (in space and time) of turbidity in estuarine and coastal waters are of concern given the unique values of Australia's seagrass beds and algal assemblages, but these can only be determined by evaluation against a baseline of data. In general terms, a tendency to increasing turbidity, for longer periods or over greater areas, would usually be considered detrimental.

High turbidity levels can be the result of tidal current resuspending sediments, inputs from catchment/shoreline erosion, dredging, dissolved organic matter and/or algal blooms. For further information on the interpretation of turbidity data can be found at the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

Increased turbidity reduces the amount of light available for photosynthesis which may decrease the phytoplankton biomass and therefore result in increased dissolved nutrients in the water column. "Turbidity caused by suspended sediment can smother benthic organisms and habitats, and cause mechanical and abrasive impairment to the gills of fish and crustaceans (ANZECC/ARMCANZ, 2000b). Suspended sediment also transports contaminants (particulate nutrients, metals and other potential toxicants) (ANZECC/ARMCANZ, 2000b), promotes the growth of pathogens and waterborne diseases, makes marine pests difficult to detect (Neil, 2002) and can lead to dissolved oxygen depletion in the water column if it is caused by particulate organic matter. Overall, unnaturally high turbidity levels can lead to a reduction in the production and diversity of species." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Default trigger values for turbidity have been listed in the Water Quality Guidelines for coastal waterways in different regions (ANZECC/ARMCANZ, 2000a). The effect of total suspended solids on environmental conditions of waterways can be examined using the Simple Estuarine Response Model II (SERM II) (<http://www.per.marine.csiro.au/serm2/index.htm>).

The Department of the Environment and Heritage (Australian Government) provides water quality targets online (<http://www.deh.gov.au/water/quality/targets/>) for turbidity.

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of turbidity levels is probably most easily represented in tables, graphs (against time) or box plots showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on turbidity levels is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The number of times turbidity levels exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) and the turbidity levels associated with extreme events resulting in increased sediment transport (e.g. floods) could also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

### **Proposed responsibilities**

Due to the relative ease of measurement, large amounts of turbidity data exist for estuarine, coastal and marine waters from around Australia. State agencies, major research institutions, environmental consultants, community groups and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on turbidity as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor turbidity themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Algal blooms (indicator)  
Animal or plant species abundance (indicator)  
Seagrass depth range (indicator)  
Sedimentation/erosion rates (indicator)  
Turbidity/suspended particulate matter in aquatic environments (matters for targets)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

ANZECC/ARMCANZ, 2000b. *Australian Guidelines for Water Quality Monitoring and Reporting*. <http://www.deh.gov.au/water/quality/nwqms/monitoring.html>

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2003. *Simple Estuarine Response Model II*. <http://www.per.marine.csiro.au/serm2/index.htm>

Environment Protection Agency (EPA) (Queensland). 1999. *Water Quality Sampling Manual: for use in testing for compliance with the Environmental Protection Act 1994*. 3<sup>rd</sup> Edition. EPA, Queensland Government, Brisbane. <http://www.epa.qld.gov.au/publications?id=330>

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- Neil, K.M. 2002. The detection, response and challenges of a pest detection. *Proceedings of the annual conference of the Australian Marine Sciences Association*. 10-12 July 2002, Fremantle WA.
- NLWRA (National Land and Water Resources Audit). 2002. *Australian Catchment, River and Estuary Assessment 2002*. Volume 1, 192 pp. National Land and Water Resources Audit, Commonwealth of Australia, Canberra.
- (OzEstuaries). Radke, L.C., Smith, C.S., Ryan D.A., Brooke, B., Heggie, D. and contributors. 2003. Coastal Indicator Knowledge and Information System I: Biophysical Indicators. Web document. Canberra: Geoscience Australia. <http://www.ozestuaries.org/indicators/indicators.html>
- OzEstuaries website. 2001. Query database. <http://www.ozestuaries.org/frame1.html> [to query data for a specific estuary: enter the estuary name (press enter key); selected required estuary from list; select 'condition assessment (pdf)']
- Ward, T., Butler, E. and Hill, B. 1998. *Environmental indicators for national state of the environment reporting – Estuaries and the sea*. Australia: State of the Environment (Environmental Indicator Reports). 81 pp. Department of the Environment; Canberra. Website: <http://www.ea.gov.au/soe/coasts/pubs/estuaries-ind.pdf>
- Waterwatch Australia Steering Committee. 2002. *Waterwatch Australia National Technical Manual. Module 4 – physical and chemical parameters*. Environment Australia, Canberra.

## **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Benthic – On the bottom of a body of water or in the bottom sediments.

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

GBRMPA – Great Barrier Reef Marine Park Authority.

Ground-truthing – To confirm remotely obtained data by physically visiting a site.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

SARDI – South Australian Research and Development Institute.

Sessile – Plants or animals that are permanently attached to a surface.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## Indicator: Water-current patterns

### Definition

This indicator reports on the change in water-current patterns within estuarine, coastal and marine waters.

### Rationale

Estuarine, coastal and marine waters are constantly on the move. Ocean currents influence the environment of both aquatic and terrestrial ecosystems. Water flows in complex pattern of currents which are determined by the moon phase (tides), wind, salinity, temperature, bottom profile, riverine input, and the earth's rotation.

Currents are important in determining the bottom topography and nature of a waterway. Strong currents scour the bottom preventing plant growth. As currents weaken they deposit sediments, building banks and sandbars. In addition to the movement of sediments, water currents are important in moving animals (e.g. plankton) and plants (e.g. seeds), nutrients, toxicants and other pollutants, as well as essential elements. Currents help maintain the balance of a system through the exchange of waters, and its contents, with adjoining systems.

Human construction and actions, (e.g. bridges, piers, sea walls, canals, dredging, land reclamation, etc.), may cause a change in speed, gradient and direction of local current fields. This may have detrimental effects on the system (e.g. sea walls may halt the natural movement of sand, canals can reduce flushing rates of a system and result in eutrophication).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Hydrodynamics	<\$5 (current meter) to >\$100 (drifters)	>\$1000	Moderate	Moderate	Coastal Protection Board (SA) CSIRO DEC, DIPNR (NSW) DIPE (NT)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Hydrodynamics

This indicator may also respond to the following stressors:

- Freshwater flow regime
- Habitat removal/disturbance

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition indicator associated with the stressor hydrodynamics.

### ***Links to issues***

The following list contains the main NRM 'issues' associated with this indicator:

- Climate change (changed rainfall patterns, global warming)
- Entrance modification (seawalls, spits, canals, etc.), dredging, artificial opening or closing of estuary mouth
- Environmental flows – water flows and frequency of floods from catchment water changed by dams, barriers, water extraction, levees, impoundments and weirs, landuse (increased hard surfaces, land cover), increased/decreased water velocity
- Episodic and large scale events (drought, floods, storms, cyclones)
- Stratification of waters (change in mixing rates)

### ***Monitoring method***

Detailed monitoring methods for water-current patterns can be found in numerous scientific publications. The exact details of the monitoring method used will depend on the region and particular aspects of the study (e.g. estuarine, coastal or marine). Whenever possible, the methods used should be consistent with commonly used protocols. This will maintain consistency between regions and allow for comparison between regions. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

### ***Monitoring locations***

In general, the monitoring of this indicator will occur in estuarine and coastal areas where human induced changes to hydrodynamic are thought to be having detrimental impacts on the waterway.

### ***Monitoring frequency***

Annual monitoring, (covering the full tidal, etc. variation expected), would be sufficient for most studies. However, more frequent monitoring may be needed depending on the study and aspects of the management actions and NRM issues being monitored.

### ***Data measurement methods***

Water-current patterns can be monitored using a number of methods, including: moored conventional current meters, acoustics (sound), drifting buoys, or by tracing temperature or chemical properties of the water. The exact method used will depend on the aims of the monitoring study.

Current measurements may be taken at a fixed location, transects or over a wide area. Moored instruments are used to obtain measurements at particular sites over a long time. Whereas, ship or satellite methods can make observations along a transect or over a wide area at a particular time.

Conventional current meters measure current speed and direction via a rotor and vane. They can be moored in a fixed location and monitor continuously. Acoustic methods (e.g. Acoustic Doppler Current Profiler Systems (ADCP)), use echo sounders. These measure changes in the time it takes a sound pulse to travel through the seawater from floor to surface (or reverse) and return. Changes in the travel time are related to changes in density of the water, which are in turn related to changes in currents. Acoustic devices can be moored or attached to ships. Sea floor electrometers measure the average speed of an ocean current by sensing the electric field created by salty seawater moving through the Earth's magnetic field. Satellites can be used to monitor currents via drifter tracking, sea temperature or sea level. Satellite altimeters accurately measure the height of the sea surface. Because ocean currents cause the sea surface to slope (e.g. the sea surface is about a metre higher near Tasmania than it is near Antarctica), the altimeter provides a means of monitoring ocean currents from space (CSIRO, 2004; <http://www.marine.csiro.au/LeafletsFolder/10ocean/10.html>).

### ***Data analysis and interpretation***

Estuarine, coastal and marine waters are constantly moving. In general, due to the highly variable nature of water-current patterns both temporally and spatially, initially there will be no standard data

available to compare against. Results from initial studies will form the baseline data against which future results can be compared.

A change in water-current pattern may result in several changes to the natural processes occurring within the system (e.g. residence times/flushing rates, sedimentation/erosion rates, animal migration, etc.), and thus adversely affect the waterway. It is important to try and determine if any observed changes in current is natural or due to human impact. Changes in average air temperature (e.g. global warming) may affect water-current patterns at a regional scale.

#### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

#### **Monitoring and reporting products**

Reporting on the water-current patterns is probably most easily represented in maps showing current speed and direction. Tables or graphs of current velocity may be a useful way to report in some studies. Once sufficient information on water-current pattern is available for a location, it will be possible to produce maps, graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change.

#### **Proposed responsibilities**

Data on water-current patterns exist mainly for ocean waters around Australia, though some hydrodynamic modelling of estuaries and bays has also occurred. CSIRO has collected and stored most of the data. State agencies, major research institutions and universities have collected some data on water-current patterns within estuaries and bays.

The regional body may or may not choose to monitor water-current patterns themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Chlorophyll a (indicator)

Estuary mouth opening/closing (indicator)

Salinity (indicator)

#### **Further information and references**

CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2004. Southern Ocean and Antarctic Circumpolar Current. *CSIRO Marine Research, Media and Information: Information Sheets*. <http://www.marine.csiro.au/LeafletsFolder/10ocean/10.html>

#### **Glossary**

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

CSIRO – Commonwealth Science and Industry Research Organisation.

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Impoundment – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

Temporal – Pertaining to time.

Topography – Detailed study of the surface features of a region.



## Indicator: Water soluble toxicants in the water column

### Definition

This indicator documents the levels of water soluble toxicants in estuarine, coastal and marine waters.

### Rationale

Toxicants are chemicals that harm animals or plants. They can be natural (e.g. metals (zinc, copper) which are essential for life but become toxic at high concentrations) or unnatural (i.e. man-made substances). A list of potential toxicants is provided in the Water Quality Guidelines (ANZECC/ARMCANZ, 2000a).

Most toxicants “find their way into the surface sediments of contaminated waterways after various periods (sometimes brief) in the water column.” (Ward *et al.*, 1998).

Waters containing water soluble toxicants may be harmful to humans, animals and plants.

Heavy metals and ‘other toxicants (including pesticides)’ were used as two determinants of water quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

For further information on toxicants including a detailed explanation of what toxicants are, the sources of toxicants, environmental significance of toxicants, and coastal habitats susceptible to toxicants see the OzEstuaries website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. ‘Easy’ complexity would mean that a person with little experience could easily learn how to collect/interpret the data. ‘Moderate’ would require a person with a couple years experience, and ‘hard’ would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Toxicants	<\$100	Moderate	Moderate	AWQC (SA) DEC (NSW) EPA (VIC)

### Links to stressors

This indicator is most likely to respond to the following stressor:

- Toxicants

It is extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of an appropriate biological condition indicator associated with the stressor (i.e. animal kills or occurrence of imposex).



### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Animal kills and disease
- Biota (plants and animals) and habitat lost/disturbed
- Dredging/resuspension of toxicants from sediments
- Human health problems (skin irritations, disease, etc.)
- Point sources: industrial discharge, dumping of toxicants
- Poor water quality: toxicant levels
- Shellfish/fisheries closures
- Toxicant release: spills, oil spills, insect control chemicals, pesticides/herbicides, outboard motor emissions, etc.

### **Monitoring method**

Detailed monitoring methods for toxicants in the water column can be found in the Monitoring Guidelines (ANZECC/ARMCANZ, 2000a,b), scientific publications and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b) give formal guidance for appropriate analytical methods for toxicants.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

Information provided in OzEstuaries on 'pesticide hazard' ([http://www.ozestuaries.org/indicators/HA\\_pesticide\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_pesticide_hazard_f.html)), 'industrial point source hazard' ([http://www.ozestuaries.org/indicators/HA\\_industrial\\_hazard\\_f.html](http://www.ozestuaries.org/indicators/HA_industrial_hazard_f.html)) and 'wastewater discharges' ([http://www.ozestuaries.org/indicators/HA\\_stormwater\\_f.html](http://www.ozestuaries.org/indicators/HA_stormwater_f.html)) is useful for assessing toxicant risk from agricultural and/or urban and industrial sources.

### **Monitoring locations and frequency**

Levels of water soluble toxicants should be monitored annually in a number of sites where toxicants are thought to be a threat and control sites. However, the monitoring location will depend on aspects of the management actions and NRM issues being monitored.

Standard operating procedures will need to be developed for the toxicants to be monitored and may require specialised assessment and pilot study for each site.

### **Data measurement methods**

Field sampling and laboratory analysis protocols need to be defined and developed depending on the specific toxicant to be monitored.

Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):

It is recommended that sampling for toxicants be undertaken in accordance with the ANZECC/ARMCANZ Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b). Table 5.2 (pg 5-4) in the guidelines is a source of appropriate analytical methods. Decision tree frameworks for assessing toxicants in ambient waters are provided in Figures 3.4.1 (water pg. 3.4-14) and 3.5.1 (sediments pg. 3.5-6) of the ANZECC/ARMCANZ Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a).

### **Data analysis and interpretation**

Excerpt from the guidelines for State of the Environment reporting (Ward et al., 1998):

Many pollutants are synthetic chemicals (such as some pesticides) that do not normally exist in nature, while others are naturally occurring compounds or elements (such as hydrocarbons or trace metals) and become pollutants when they occur in

higher than usual concentrations. Most find their way into the surface sediments of contaminated waterways after various periods (sometimes brief) in the water column. However, for both synthetic and natural materials, the precise level at which an effect can be expressed in the accompanying or adjacent biological systems is very difficult to define (see, for example, Suchanek, 1994). So, rather than use concentration criteria to determine when levels are acceptable, we need to rely mainly on an assessment of trajectory to evaluate the level of stress imposed by contaminants. For synthetic chemicals, levels should be trending downwards, hopefully to near-zero, while for natural materials they should be close to natural background levels and not trending upwards. Locations that do not fit these objectives may be in most need of remedial action.

Change can only be detected against a baseline of existing or historic data, and then only with many caveats about collection and analysis techniques. Laboratory techniques have become increasingly sophisticated in the last decade, and data from earlier times are usually highly questionable. So full documentation of procedures, quality assurance and controls is critical if the currently collected data are to be useful in the next century.

*Excerpts from OzEstuaries (<http://www.ozestuaries.org/indicators/indicators.html>):*

DOM [dissolved organic matter] can enhance the solubilities of some organic pollutants and pesticides (Chiou *et al.*, 1986), and this might be important in areas where there is lots of decaying vegetation.

There are still many challenges to understanding the fate, transport and interactions of contaminants in marine systems. In particular, more information is needed on contaminant concentrations and processes governing their distribution in Australian coastal environments. Section 8.5.3 of the ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) lists several other deficiencies in knowledge.

#### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

#### **Monitoring and reporting products**

Reporting of toxicant levels in the water column is probably most easily represented in tables or graphs (against time) showing the median and 20<sup>th</sup> and 80<sup>th</sup> percentiles for the location. Once sufficient information on toxicant levels is available for a location, it will be possible to produce graphs or tables showing trends and their statistical significance. These trends can then be reported as an estimate of change. The percentage of sites in which toxicant concentrations exceed guidelines (e.g. Water Quality 'trigger' values – ANZECC/ARMCANZ, 2000a) should also be reported.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values, local guideline values or national trigger values).

#### **Proposed responsibilities**

Various amounts of data exist from around Australia on toxicant concentrations in estuarine, coastal and marine waters. This data is collected and stored by the State/Territory Government agencies and research organisations. Much of the data has been gathered for specific studies of small sites thought to be highly impacted on by toxicants. The National Land and Water Resources Audit compiled information on heavy metals and 'other toxicants (including pesticides)' as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor toxicants themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

#### **Links to other indicators and matters for targets**

Animal kills (indicator)  
Occurrence of imposex (indicator)  
Toxicants in biota (indicators)  
Toxicants in the sediments (indicator)

#### **Further information and references**

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#### **Glossary**

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

EPA – Environment Protection Agency.

Imposex – Development of male sex organs in females.

Spatial – Pertaining to space or distance.

Temporal – Pertaining to time.

## Indicator: Water temperature

### Definition

This indicator reports the temperature of estuarine, coastal and marine waters.

### Rationale

Excerpts from *OzEstuaries* (<http://www.ozestuaries.org/indicators/indicators.html>):

Water temperature regulates ecosystem functioning both directly through physiological effects on organisms, and indirectly, as a consequence of habitat loss (ANZECC/ARMCANZ, 2000b). Photosynthesis and aerobic respiration, and the growth, reproduction, metabolism and the mobility of organisms are all affected by changes in water temperature. Indeed, the rates of biochemical reactions usually double when temperature is increased by 10°C within the given tolerance range of an organism (ANZECC/ARMCANZ, 2000b). This is called the Q10 rule, and it also applies to microbial processes such as nitrogen fixation, nitrification and denitrification. If temperature goes too far above or below the tolerance range for a given taxon (e.g. fish, insects, zooplankton, phytoplankton, microbes), its ability to survive may be compromised. For example, coral species live within a relatively narrow temperature range, and positive or negative temperature anomalies of only a few degrees can induce bleaching (Hoegh-Guldberg, 1999).

Unnatural changes in water temperature are a suggested indicator of water quality in the ANZECC and ARMCANZ guidelines (ANZECC/ARMCANZ, 2000b). Changes in sea surface temperature in marine and coastal waters are also a suggested indicator for State of the Environment reporting (e.g. Indicator 8.2 in the *Estuaries and the Sea* volume) (Ward et al., 1998).

Changes in water temperature influence:

- oxygen and calcium carbonate solubility (e.g. dissolved oxygen levels)
- toxicant absorption
- toxicity of some chemicals (natural or man made)
- viral persistence
- density
- conductivity
- pH
- partial pressure of CO<sub>2</sub>
- saturation states of minerals

Water temperature was used as one determinant of water quality in the National Estuary Assessment (stage 2: modified estuaries) completed for the National Land and Water Resources Audit (NLWRA, 2002).

For further information on the effects of temperature on waterways including a detailed explanation of what causes water temperature to change, the significance of water temperature, and coastal waterways most susceptible to unnatural changes in water temperature see the *OzEstuaries* website (<http://www.ozestuaries.org/indicators/indicators.html>).

### Key information

The information provided in the table below is based on expert advice from CRC for Coastal Zone, Estuary and Waterway Management and State/Territory agency staff. <sup>†</sup>Costs provided are for comparison against other potential indicators and are a rough guide only. They are for the collection and analysis of samples, and the capital cost of the measuring device only. They do not include costs relating to personal salary/travel, maintenance/calibration of equipment, or the purchase of other equipment such as boats, trailers, scuba gear, etc. which may be needed for monitoring the indicator. The major cost for any monitoring study is usually personal salary costs. The costs given will change over time and by location, and should be thoroughly investigated and scrutinized before being used in any financial planning. <sup>‡</sup>A list of State/Territory agencies and other organisations that can supply information on the monitoring of the indicator is provided in the table. This list is a guide only as the roles (and names) of agencies regularly change. The agencies listed should be the first point of

contact, though many of the indicators are measured by others, particularly university researchers and community monitoring groups, from around Australia.

Information on the level of complexity needed to (1) collect the data, and (2) analyse and interpret the data are also provided in the table below. 'Easy' complexity would mean that a person with little experience could easily learn how to collect/interpret the data. 'Moderate' would require a person with a couple years experience, and 'hard' would require an expert with several years of experience.

Stressor this indicator is recommended for:	Cost <sup>†</sup> per sample	Capital cost <sup>†</sup>	Complexity – data collection	Complexity – data interpretation and analysis	Information relating to monitoring can be found at <sup>‡</sup> :
Water temperature	<\$5	<\$100 (thermometer) to <\$500 (temperature data logger)	Easy	Moderate	DIPE (NT) DIPNR, DEC (NSW) EPA (QLD) EPA (SA) EPA (VIC) Waterwatch WRC (WA)

#### **Links to stressors**

This indicator is most likely to respond to the following stressor:

- Water temperature

This indicator may also respond to the following stressors:

- Freshwater flow regime
- Hydrodynamics

It is therefore extremely beneficial for data interpretation, if the monitoring of this indicator is associated with the monitoring of physical-chemical condition indicators for these stressors. Data interpretation will also benefit from the monitoring of an appropriate biological condition indicator associated with the stressor water temperature (i.e. coral bleaching).

#### **Links to issues**

The following list contains the main NRM 'issues' associated with this indicator:

- Biota (plants and animals) lost/disturbed
- Climate change/global warming (increased air temperature)
- Coral bleaching
- Industrial, dam and municipal discharge (hot or cold water)
- Poor water quality: water temperature
- Water stratification (thermoclines; poor water column mixing)
- Water-current pattern (changed)

#### **Monitoring method**

Detailed monitoring methods for water temperature can be found in numerous publications including: the Monitoring Guidelines (ANZECC/ARMCANZ, 2000b), guidelines for State of the Environment reporting (Ward *et al.*, 1998), scientific publications, Waterwatch monitoring manuals and State/Territory Government Department (e.g. Environment Protection Agency or equivalent) monitoring manuals.

The exact details of the monitoring method used will depend on the region and particular aspects of the study. Whenever possible, the methods used should be consistent with national (ANZECC/ARMCANZ, 2000b) protocols. This will maintain consistency between regions and allow for comparison between regions nationally. However, expert local advice should be obtained to ensure that the monitoring of this indicator is conducted at an appropriate spatial and temporal scale to allow the resulting data to be statistically assessed so that demonstrated changes are verifiable.

#### **Monitoring locations**

Sites threatened by water temperature change should be monitored, however, the monitoring location will depend on aspects of the management actions and NRM issues being monitored. For example, if

monitoring for water temperature change resulting from climate change then monitoring will occur in all estuarine, coastal and marine waters to determine the annual variability of surface waters. If monitoring industrial sources then specific 'threatened' sites and controls will be selected. Different depths at a location may also need to be monitored.

### **Monitoring frequency**

The frequency of monitoring will depend on what management actions and NRM issues are being monitored. Water temperature can be monitored continuously or during/after specific events. Water temperature changes daily and seasonally. Therefore, continuous monitoring of water temperature using a moored, continuously recording thermometer is advisable. However, if this is not possible then water temperature should be measured at dawn and midday to allow for diurnal variation.

### **Data measurement methods**

"It is generally good practice to measure temperature when taking any physical, chemical or biological samples. Temperature measurements are usually made with a mercury thermometer with 0.1°C increments. Temperature loggers can also be deployed to measure and record temperatures at different depths and at specified time intervals." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Thermal satellite imaging can be used to examine the temperature of large areas of ocean which may have increased in temperature as a result of climate change.

### **Data analysis and interpretation**

"Water temperature in coastal areas changes naturally, as part of daily and seasonal cycles, with variations in air temperature, currents and local hydrodynamics. Long-term monitoring of water temperature provides insight into seasonal and inter-annual temperature cycles, as well as into temperature anomalies caused by human activities." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Changes to water temperature can result from the following (see OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>):

- Changes to freshwater flow and freshwater/marine water mixing by winds or tides;
- Industrial discharges ('cooling' waters from power plants); and,
- Changes in air temperature and currents in response to El Niño or global warming.

"Sudden or large changes in temperature are generally of concern in coastal areas. Large temperature differences between surface and bottom waters are indicative of stratification." (OzEstuaries, <http://www.ozestuaries.org/indicators/indicators.html>).

Default trigger values for water temperature are not given in the Water Quality Guidelines. They recommend the development of local objectives for upper and lower low-risk trigger values defined by the 20<sup>th</sup> percentile and 80<sup>th</sup> percentile of the reference distribution. However, the Water Quality Guidelines do report that to protect aquaculture species, water temperature should not change by more than 2.0°C in 1 hour (ANZECC/ARMCANZ, 2000a).

### **Data storage**

Data should be stored by State/Territory agencies and by the collectors (if different) of the data. If possible, the public should have access to the data (and report summaries) through a website hosted by State/Territory government.

### **Monitoring and reporting products**

Reporting of water temperature is probably most easily represented in tables or graphs (against time) showing the 20<sup>th</sup> and 80<sup>th</sup> percentiles for the site. Once sufficient information on water temperature is available for a site, it will be possible to produce tables or graphs showing trends and their statistical significance. These trends can then be reported as an estimate of change.

Box plots are an easy way to visually compare the data with reference data (i.e. baseline values or local guideline values).



### **Proposed responsibilities**

Due to the relative ease of measurement, large amounts of water temperature data exist for estuarine, coastal and marine waters from around Australia. State agencies, major research institutions, environmental consultants, community groups and universities have collected and stored most of the data. The National Land and Water Resources Audit compiled information on water temperature as part of its condition assessment of Australian estuaries. These data are available in the OzEstuaries website (<http://www.ozestuaries.org/frame1.html>).

The regional body may or may not choose to monitor water temperature themselves. However, if they do, then the incorporation of data from a regional sampling program into existing surveys is important for determining regional baseline data and later comparison to detect real change.

While consideration should be given to who is responsible for data collection, collation, analysis and interpretation, storage and management, and the generation of reporting products, it is most likely that where existing monitoring by State/Territory/Commonwealth agencies occurs, then it should be used by regional bodies as it is the most cost effective and efficient option, and has been subject to quality assurance.

### **Links to other indicators and matters for targets**

Coral bleaching (indicator)  
Dissolved oxygen (indicator)  
Extent/distribution of key habitat types (indicator)  
Salinity (indicator)

### **Further information and references**

ANZECC/ARMCANZ, 2000a. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. <http://www.deh.gov.au/water/quality/nwqms/volume1.html>

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**Glossary**

Aerobic – In the presence of oxygen.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

DEC – Department of Environment and Conservation.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

EPA – Environment Protection Agency.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

Temporal – Pertaining to time.

WRC – Water and Rivers Commission.

## **SECTION 5 INTEGRATED REPORTING**

The primary purpose of a monitoring program using indicators identified through the processes described in this document is to provide information about the impact and effectiveness of regional NRM actions on the condition of that region's natural resources. Therefore, reporting will be most relevant at the regional scale. Guidance for assessing and reporting of individual indicators is provided in the indicator profiles (Section 4).

The key method for reporting by an NRM region will be the progress made against the targets set. For example, if the target set is 'mean annual turbidity in the estuarine sites A, B, C of 10 NTU', and the starting level is 20 NTU, and the level after 2 years of on-ground management actions is 15 NTU, then the progress made is 50% achievement of the target. The region may also wish to report that the turbidity has been reduced by 25% (i.e. from 20 NTU to 15 NTU) regardless of the target. Or a region may want to report that x% of the sites have made y% progress towards the turbidity targets.

However, an NRM region may seek to provide an integrated regional report of regional natural resource condition. Such integrated reports have proven to be powerful communication products with the wider community.

The responsibility for state-wide or nation-wide reporting of environmental condition, using the indicator data produced by NRM regions is the responsibility of State/Territory and the Australian Government. Some of the comments provided here may be useful for this wider-scale reporting, but these agencies may devise alternate methods for integrated reporting.

For some other ecosystems (e.g. freshwater ecosystems), indices have been developed to integrate quantitative information from multiple indicators (e.g. Victorian Index of Stream Condition). Although such quantitative indices are presently being considered for estuarine, coastal and marine ecosystems, none are yet fully developed, tested or standardised.

One example of a quantitative method is that developed for the Moreton Bay Ecosystem Health Monitoring Program (EHMP, 2004; Pantus and Dennison, 2004). This method provides an integrated 'report grade' of the condition of natural resources (not an assessment of their change in response to specific management actions), based upon the spatial area of a region that complies with guidelines/objectives/targets.

Qualitative methods currently remain the most common method to integrate reporting of multiple indicators for estuarine, coastal and marine ecosystems. As for the quantitative method described above, most current methods integrate data on indicators for the purpose of providing an overall picture of the condition of the environment, rather than determining the change (improvement/deterioration) in the environment in response to management actions.

The assessment of the condition of estuaries for the National Land and Water Resources Audit ('Australian Catchment, River and Estuary Assessment 2002, volumes 1 and 2') used a qualitative method. A score of 1 to 4 was applied to each indicator based upon its comparison to a guideline/reference condition. The scores were then aggregated for different but related indicators into 'index' categories, e.g. water quality, or ecosystem integrity, or habitat condition, etc.

A similar approach could be applied to the indicators in this document. The scores could be applied to indicators depending upon either:

- how they compare to the guideline/reference or baseline value; or
- how much progress has been made towards the target.

The scores could then be aggregated for each of the indicators within each of the three indicator categories used in this document (physical-chemical condition; biological condition and habitat extent), resulting in an overall score/grade for each of the 3 indicator categories.

Specific advice on methods to integrate the indicators for your NRM region should be sought from experts, such as the State/Territory agencies listed in the indicator profiles.

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## GLOSSARY

Aerobic – In the presence of oxygen.

AHD – Australian Height Datum.

Anaerobic – In the absence of oxygen.

ANZECC/ARMCANZ – Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

AWQC – Australian Water Quality Centre.

Baseline data – Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed. ([nces.ed.gov/pubs2000/studenthb/glossary.asp](http://nces.ed.gov/pubs2000/studenthb/glossary.asp)).

Bathymetry – Measuring water depths to determine the topography of the sea floor.

Benthic – On the bottom of a body of water or in the bottom sediments.

Bioaccumulation – The process by which chemical are accumulated in biota with levels increasing up the food chain (i.e. small animals and plants take up toxicants from the waters, and when they are eaten by other animals, the toxicants move up the food chain with higher concentrations being found in higher predators).

Bioindicator – An organism and/or biological process whose change in numbers, structure, or function points to changes in the integrity or quality of the environment.

Biomass – The total weight of all living organisms in a biological community or of a particular species/group.

CALM – Department of Conservation and Land Management.

Condition – As used in this report, condition is defined as the state or health of individual animals or plants, communities or ecosystems. Condition indicators can be physical-chemical or biological and represent the condition of the ecosystem.

Cryptosporidiosis – A disease caused by the protozoan *Cryptosporidium*, which is most commonly transmitted to humans by contact with animal faeces.

CSIRO – Commonwealth Science and Industry Research Organisation.

Cyanobacteria – Photosynthetic bacteria previously called blue-green algae.

Cyanophytes – Photosynthetic bacteria of the class Cyanobacteria.

DBIRD – Department of Business, Industry and Resource Development.

DEC – Department of Environment and Conservation.

DEH – Department for the Environment and Heritage.

Diatom – Microscopic algae with cell walls made of silicon.

Dinoflagellate – Microorganisms with both plant-like and animal-like characteristics, usually classified as protozoans having two lash-like structures (flagella) used for locomotion.

DIPE – Department of Infrastructure, Planning and Environment.

DIPNR – Department of Infrastructure, Planning and Natural Resources.

DPI – Department of Primary Industries.

DPIWE – Department of Primary Industries, Water and Environment.

DSE – Department of Sustainability and Environment.

EHMP – Ecosystem Health Monitoring Program (Moreton Bay Waterways and Catchments Partnership).

Embayment – A large indentation of a shoreline, bigger than a cove but smaller than a gulf.

Enterococci – A group of bacteria found primarily in the intestinal tract of warm blooded animals.

EPA – Environment Protection Agency.

Epiphytes – Plants or animals that attach themselves to the stem or leaves of plants.

Epizootic ulcerative syndrome – Red spot disease of fish (caused by a fungus).

Eutrophication – The process of enrichment of water with nutrients that increase plant growth and the succeeding depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Extent – As used in this report, extent is defined as the area/distribution (usually hectares or km<sup>2</sup>) covered by a particular habitat type (e.g. seagrass).

GBR – Great Barrier Reef.

GBRMPA – Great Barrier Reef Marine Park Authority.

Genera – A taxonomic group of organisms, one level higher than species.

Giardiasis – Intestinal disease caused by an infestation with a *Giardia* protozoan.

Grazers – Animals which feed (graze) on small organic particles and algae.

Ground-truthed – To confirm remotely obtained data by physically visiting a site.

Humic acid – Acidic water derived from humus (decaying organic matter).

Hypersaline – Above normal levels of salinity.

Hyperspectral – Remote sensors which collect image data simultaneously in dozens or hundreds of narrow, adjacent spectral (wavelength) bands.

Hyposaline – Below normal levels of salinity.

Ichthyofauna – Fish fauna.

Imposex – Development of male sex organs in females.

Impoundments – An accumulation of water into ponds/dams by human-engineered blocking of natural drainage.

*In-situ* – Latin term for 'in the original place'.

Line transect – A straight line placed on the ground along which ecological measurements are taken.

Meningo-encephalitis – Inflammation of the brain and its membranes.

MEWG – Monitoring and Evaluation Working Group

Microorganism – Microscopic animal or plant.

Multispectral – Remote sensors produce images with a few relatively broad spectral (wavelength) bands.

NAP – National Action Plan for Salinity and Water Quality.

NHT2 – Natural Heritage Trust.

NIMPIS – National Introduced Marine Pest Information System.

Periphyton – Small epiphytic algae.

PIRSA – Department of Primary Industries and Resource, South Australia.

PIRVIC – DPI, Primary Industries Research Victoria.

Primary producers – Photosynthetic organisms that produce a 'food source' for the next level up the food chain

Primary production – Production of a 'food source' by photosynthetic organisms at the bottom of the food chain.

PSR – Pressure State Response.

Quadrats – An ecological sampling unit that consists of a square frame of a known area.

Raphidophyte – Microscopic algae capable of producing environment toxic which may bioaccumulate up the food chain.

Sabkha – Saltpan, salt scald or saltflat.

Salmonellosis – Infection caused by *Salmonella* (bacteria).

SARDI – South Australian Research and Development Institute.

SASQAP – South Australian Shellfish Quality Assurance Program.

Sessile – Plants or animals that are permanently attached to a surface.

SoE – State of the Environment.

SOP – Standard Operating Procedure.

Spatial – Pertaining to space or distance.

Stratification – The layering of water due to differences in density.

Streptococci – Spherical gram-positive bacteria.

TAFI – Tasmanian Aquaculture and Fisheries Institute.

TASQP – Tasmanian Shellfish Quality Assurance program.

Taxa – A taxonomic group of organisms (of any rank, e.g. species, genera, family) considered to be distinct from other such groups.

TBT – Tributyltin. A toxic chemical used to prevent the fouling of ship hulls.

Temporal – Pertaining to time.

Thermotolerant – Able to survive in a wide range of temperatures.

TN – Total Nitrogen.

Topography – Detailed study of the surface features of a region.

TP – Total Phosphorus.

TSS – Total Suspended Solids.

Univariate - Statistical tests for comparing two or more groups with only one variable.

WHO – World Health Organisation.

WRC – Water and Rivers Commission.

WWF – World Wildlife Fund.

Zooxanthellae – Microscopic algae that live in a symbiotic relationship with certain corals, clams, and some sponges.



## APPENDIX A: BACKGROUND TO NATIONAL NRM MONITORING

### What is the national monitoring and evaluation framework?

*Excerpt from the National Natural Resource Management Monitoring and Evaluation Framework (2003) (<http://www.deh.gov.au/nrm/monitoring/evaluation/index.html>):*

The monitoring and evaluation framework was approved by the NRM Ministerial Council in May 2002, and is aimed at assessing progress related to the:

- health of the nation's land, water, vegetation and biological resources; and
- performance of programs, strategies and policies that provide national approaches to the conservation, sustainable use and management of these resources.

The National Framework provides information on the health of the nation's resources and on the conservation, sustainable use and management of Australia's land, water, vegetation and biological resources. The health of the nation's natural resource will be monitored on an intermediate and long-term basis through a coordinated, comprehensive and independent resource condition assessment process. This periodic assessment of resource condition will be used to judge the appropriateness and effectiveness of national policies, strategies and programs may be judged. This will assist in better targeting of natural resource management strategies.

The National Framework establishes nationally agreed outcomes and measures to report on resource condition changes and associated institutional, social and economic matters. This process requires a primary set of resource condition indicators to provide information on resource condition trends, measures of community and social processes relevant to or affected by NRM programs and measures of the adoption of sustainable development and production techniques.

A core set of these indicators is required to measure progress towards the agreed outcomes on a medium and long-term basis.

### How will it be used?

*Excerpts from the Draft Users' Guide (Preamble) Monitoring and Reporting on Natural Resource Management (2003) (<http://www.deh.gov.au/nrm/monitoring/reporting/index.html#download>):*

Integrated natural resource management plans developed by regional groups are the main building blocks of the National Action Plan for Salinity and Water Quality (NAP), and the extension of the Natural Heritage Trust. The Commonwealth and the States and Territories will invest in these plans once they have been accredited using criteria agreed by the Commonwealth and the States/Territories through the Natural Resource Management Ministerial Council.

...one of the criteria for accreditation of a natural resource management plan is that it sets, or has commenced the process to set, targets for the resource condition outcomes that the plan aims to achieve. The plan (and its investment strategy) also needs to ensure that adequate provision is made for monitoring and evaluating progress in reaching these targets.

### What needs to be monitored? The Matters for Targets

*Excerpts from the Draft Users' Guide (Preamble) Monitoring and Reporting on Natural Resource Management (2003) (<http://www.deh.gov.au/nrm/monitoring/reporting/index.html#download>):*

...the Framework also identifies 10 matters for targets designed to help focus the natural resource planning and investment needed to deliver the outcomes. Regional bodies are required, in undertaking their natural resource management planning, to consider the matters for targets, and to set regional targets for those matters relevant to their region. They are not, of course, limited to this set of matters for targets.

To measure progress against the targets, a suite of related indicators has been developed under the National NRM Monitoring and Evaluation Framework. Once a region has identified the matters for targets relevant to its activities, it will be able to draw on the list of indicators to see which ones it should use, and how to use them.

The indicators that have been developed so far (this is a work in progress) fall into three categories: resource condition, management action and social and economic. The first two are relevant for monitoring regional investments. The socio-economic indicators, which are largely supported by national data collection processes, provide contextual information for regional planning. Regions do not need to set social and economic targets.

The indicators are presented as 'headings' as they may, over time, include more than one indicator, or a number of complementary ways of measuring the same outcome.

#### Monitoring of Resource Condition against Standards and Targets Framework

The National Framework utilises the national natural resource outcomes identified by the National Natural Resource Management Standards and Targets Framework. The national outcomes provide direction for catchment/regional communities to identify specific timebound and measurable targets for each region, which will move natural resource condition towards the achievement of the national outcomes. Relevant national outcomes and associated measures from the Standards and Targets Framework will be used to monitor changes in resource condition associated with each program, strategy or policy.

#### **Estuarine, coastal and marine habitat integrity (a resource condition Matter for Targets)**

'Estuarine, coastal and marine habitat integrity' has been identified through the National Framework for Natural Resource Management – Standards and Targets (2003, <http://www.deh.gov.au/nrm/monitoring/standards/pubs/standards.pdf>) as one of ten matters to be addressed by regional NRM groups.

This matter is not defined in any greater detail in the Standards and Targets document. For the purposes of identifying appropriate indicators for monitoring, we have considered this matter to encompass any natural resource management issue within estuarine, coastal and marine ecosystems. This geographic region is further defined in Section 2.

#### **Indicators of estuarine, coastal and marine habitat integrity**

Two indicator headings are identified in the Monitoring and Evaluation Framework relating to this matter for target:

- (1) Estuarine, coastal and marine habitat condition
- (2) Estuarine, coastal and marine habitat extent and distribution.

The purpose of these indicators is to assess the performance of programs, strategies and policies in terms of their achievements towards improved natural resource condition (see Figure A.1). Specifically, these indicators will: "be used to monitor changes in resource condition associated with each program, strategy or policy" (*National Natural Resource Management Monitoring and Evaluation Framework, 2003; <http://www.deh.gov.au/nrm/monitoring/evaluation/index.html>*).

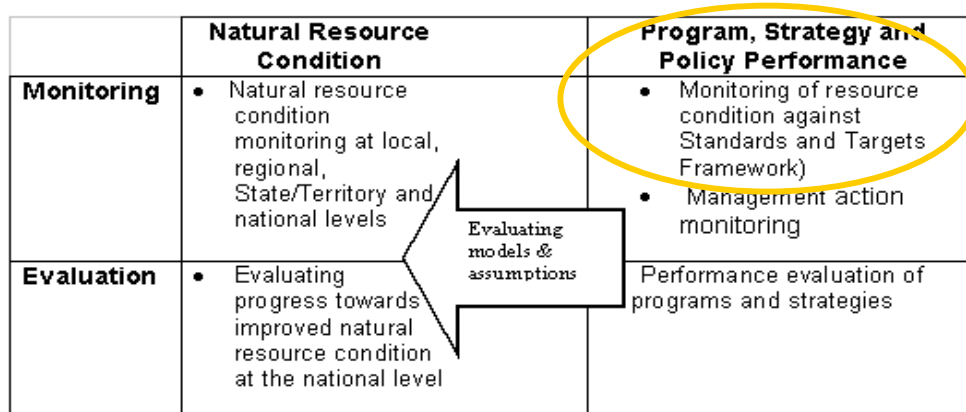


Figure A.1 Monitoring and Evaluation Framework (National Natural Resource Management Monitoring and Evaluation Framework, 2003; <http://www.deh.gov.au/nrm/monitoring/evaluation/index.html>)

These indicators are not designed for the other elements of the framework:

- management action monitoring;
- performance evaluation of programs and strategies;
- natural resource condition monitoring at local, regional, State/Territory and national levels (although some indicators identified herein may also be useful for this type of condition/health monitoring); and
- evaluating progress towards improved natural resource condition at the national level.

#### **Matters for Target:**

##### **List of indicators for resource condition matters for target developed to date (May 2004)**

Matters for Target	Indicator heading	Recommended indicators
Land Salinity	Area of Land threatened by shallow or rising water tables	<ul style="list-style-type: none"> <li>Depth to Ground water</li> <li>Groundwater salinity</li> <li>Location and size of salt affected areas</li> </ul>
Soil condition	Soil condition	For regionally significant soil condition issues that are the subject of targets in regional plans: <ul style="list-style-type: none"> <li>Soil acidification</li> <li>Soil erosion - water</li> <li>Soil erosion - wind</li> <li>Soil carbon content</li> <li>Soil physical condition</li> <li>Soil hydrophobicity</li> <li>Soil biota activity</li> </ul>
Native vegetation	Native vegetation extent and distribution	For regionally significant native vegetation that is the subject of targets in regional plans: <ul style="list-style-type: none"> <li>The extent of native vegetation by IBRA subregion measured in hectares.</li> <li>The extent of each present native vegetation type by IBRA subregion measured in hectares.</li> <li>The proportion remaining of each native vegetation type in each IBRA subregion measured as a percentage of the pre-European extent.</li> </ul>

	Native vegetation condition	<p>For regionally significant native vegetation types that are the subject of targets in regional plans:</p> <ul style="list-style-type: none"> <li>The proportion of each native vegetation type in each IBRA subregion that is estimated to be in specific condition classes based on a selected set of attributes.</li> </ul>
Inland aquatic ecosystems integrity	River condition	<p>For regionally significant reach based issues that is the subject of targets in regional plans, the indicators are:</p> <ul style="list-style-type: none"> <li>Benthic macro-invertebrate community assemblages</li> <li>Fish community assemblages</li> <li>Benthic diatom community assemblages</li> <li>Riparian vegetation community assemblages</li> <li>Riverine physical structure and in-stream habitat</li> <li>Water quality</li> <li>Hydrology</li> </ul> <p>If all or most of these indicators are measured, it may be possible to use monitoring data to develop an index of river condition.</p>
	Wetland ecosystem extent and distribution	<ul style="list-style-type: none"> <li>Extent of regionally significant wetlands</li> </ul>
	Wetland ecosystem condition	<ul style="list-style-type: none"> <li>Condition of regionally significant wetlands</li> </ul>
Estuarine, coastal and marine habitat integrity	Estuarine, coastal and marine habitat extent and distribution	<ul style="list-style-type: none"> <li>Area of each estuarine, coastal and marine habitat type measured in hectares</li> </ul>
	Estuarine, coastal and marine habitat condition	<ul style="list-style-type: none"> <li>Condition of habitat at significant sites of selected estuarine, coastal and marine habitats</li> </ul>
Nutrients in aquatic environments	Nitrogen in aquatic environments	<ul style="list-style-type: none"> <li>Total nitrogen + flow leaving sub-catchment or whole catchment</li> </ul>
	Phosphorus in aquatic environments	<ul style="list-style-type: none"> <li>Total phosphorus + flow leaving sub-catchment or whole catchment</li> </ul>
Turbidity/suspended particulate matter in aquatic environments	Turbidity/suspended solids	<ul style="list-style-type: none"> <li>Turbidity OR</li> <li>Total Suspended Solids (TSS) + flow</li> </ul>
Surface water salinity in freshwater aquatic environments	In-stream salinity	<ul style="list-style-type: none"> <li>Total Dissolved Solids (TDS) + flow OR</li> <li>Electrical conductivity (EC) + flow</li> </ul>
Significant native species and ecological communities	Selected significant native species and ecological communities extent and conservation status	<p>For significant species that are the subject of target in regional plans:</p> <ul style="list-style-type: none"> <li>Range area and location of each species: area</li> <li>Area, location and condition of key habitat of each species</li> <li>Relative abundance of each species</li> </ul> <p>For significant ecological communities that are subject of targets in regional plans:</p> <ul style="list-style-type: none"> <li>extent of each ecological community: estimated area (in hectares)</li> <li>condition of each ecological community</li> </ul>

Ecologically significant invasive species	Selected ecologically significant marine invasive species extent and impact	<ul style="list-style-type: none"> <li>• Presence/absence of known or new:                             <ul style="list-style-type: none"> <li>○ exotic marine pests and</li> <li>○ native pest marine species in commercial ports and boat harbours</li> </ul> </li> </ul>
	Selected ecologically significant vertebrate invasive species extent and impact	<ul style="list-style-type: none"> <li>• Reduction in impact of regionally significant invasive vertebrate pests (excluding fish)</li> </ul>
	Selected ecologically significant invasive vegetation species extent and impact	<ul style="list-style-type: none"> <li>• Reduction in impact of regionally significant invasive vertebrate pests (excluding fish)</li> </ul>

(Source: <http://www.deh.gov.au/nrm/monitoring/evaluation/attachment-c.html#recommended>).

## APPENDIX B: ENVIRONMENTAL STRESSORS

The following discussion on stressors is taken from the "Australian and New Zealand guidelines for fresh and marine water quality" (Section 3.3, Volume 1, 2000):

A number of naturally-occurring physical and chemical stressors can cause serious degradation of aquatic ecosystems when ambient values are too high and/or too low. Physical and chemical stressors can be classified broadly into two types depending on whether they have direct or indirect effects on the ecosystem.

### Direct effects

Two types of physical and chemical stressors that directly affect aquatic ecosystems can be distinguished: those that are directly toxic to biota, and those that, while not directly toxic, can result in adverse changes to the ecosystem (e.g. to its biological diversity or its usefulness to humans). Excessive amounts of direct-effect stressors cause problems, but some of the elements and compounds covered here are essential at low concentrations for the effective functioning of the biota – nutrients such as phosphorus and nitrogen, and heavy metals such as copper and zinc, for example.

Examples of non-toxic direct-effect stressors include:

- nutrients, that can result in excessive algal growth and cyanobacterial blooms;
- suspended particulate matter, that can reduce light penetration into a waterbody and result in reduced primary production, possible deleterious effects on phytoplankton, macrophytes and seagrasses, or smother benthic organisms and their habitats;
- organic matter decay processes, that can significantly reduce the dissolved oxygen concentration and cause death of aquatic organisms, particularly fish;
- water flow, which can significantly affect the amount and type of habitats present in a river or stream.

### Indirect effects

Indirect stressors (or factors) are those that, while not directly affecting the biota, can affect other stressors making them more or less toxic. For example, dissolved oxygen can influence redox conditions and influence the uptake or release of nutrients by sediments. Equally, pH, dissolved organic carbon (DOC) and suspended particulate matter can have a major effect on the bioavailable concentrations of most heavy metals.

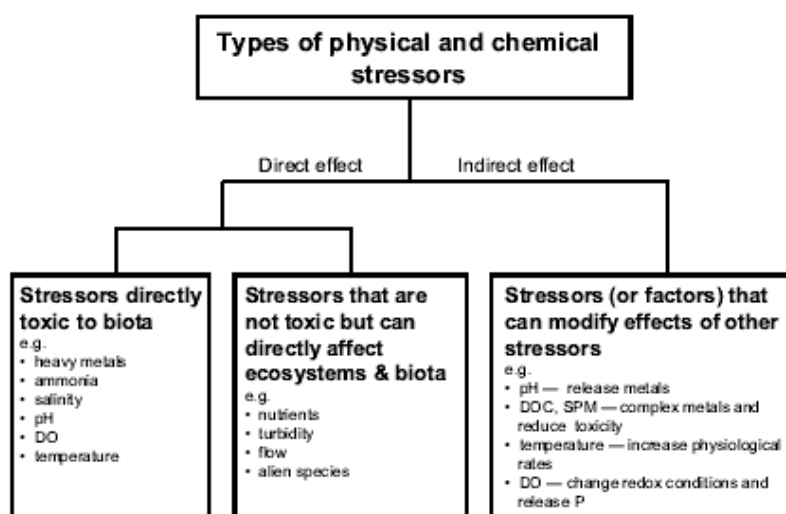


Figure B.1. Types of physical and chemical stressors (Australian and New Zealand guidelines for fresh and marine water quality, 2000).

## The Pressure-State-Response model for environmental reporting

Pressure-state-response (PSR) framework – this framework links pressures on the environment as a result of human activities, with changes in the state (condition) of the environment (land, air, water, etc.). Society then responds to these changes by instituting environmental and economic programmes and policies, which feed back to reduce or mitigate the pressures or repair the natural resource (OECD, 1993).

*Excerpt from OECD Environmental Indicators: Development, measurement and use (OECD, 2004)*  
(<http://www.oecd.org/dataoecd/7/47/24993546.pdf>):

The PSR model has initially been developed by the OECD to structure its work on environmental policies and reporting. It considers that: human activities exert pressures on the environment and affect its quality and the quantity of natural resources ("state"); society responds to these changes through environmental, general economic and sectoral policies and through changes in awareness and behaviour ("societal response").

- The PSR model highlights these cause-effect relationships, and helps decision makers and the public see environmental, economic, and other issues as interconnected. It thus provides a means of selecting and organising indicators (or state of the environment reports) in a way useful for decision-makers and the public, and of ensuring that nothing important has been overlooked.
- The PSR model has the advantage of being one of the easiest frameworks to understand and use, and of being neutral in the sense that it just says which linkages exist, and not whether these have negative or positive impacts. This should however not obscure the view of more complex relationships in ecosystems, and in environment-economy and environment-social interactions.
- Depending on the purpose for which the PSR model is to be used, it can easily be adjusted to account for greater details or for specific features. Examples of adjusted versions are the Driving force - State - Response (DSR) model formerly used by the UNCSD in its work on sustainable development indicators, the framework used for OECD sectoral environmental indicators and the Driving force-Pressure-State-Impact-Response (DPSIR) model used by the EEA.

**Environmental pressures** describe pressures from human activities exerted on the environment, including natural resources. "Pressures" here cover underlying or indirect pressures (i.e. human activities themselves and trends and patterns of environmental significance) as well as proximate or direct pressures (i.e. the use of resources and the discharge of pollutants and waste materials). Indicators of environmental pressures are closely related to production and consumption patterns; they often reflect emission or resource use intensities, along with related trends and changes over a given period. They can be used to show progress in decoupling economic activities from related environmental pressures, or in meeting national objectives and international commitments (e.g. emission reduction targets).

**Environmental conditions** relate to the quality of the environment and the quality and quantity of natural resources. As such they reflect the ultimate objective of environmental policies. Indicators of environmental conditions are designed to give an overview of the situation (i.e. the state) concerning the environment and its development over time. Examples of indicators of environmental conditions are: concentration of pollutants in environmental media, exceedance of critical loads, population exposure to certain levels of pollution or degraded environmental quality and related effects on health, the status of wildlife and ecosystems and of natural resource stocks. In practice, measuring environmental conditions can be difficult or very costly. Therefore, environmental pressures are often measured instead as a substitute.

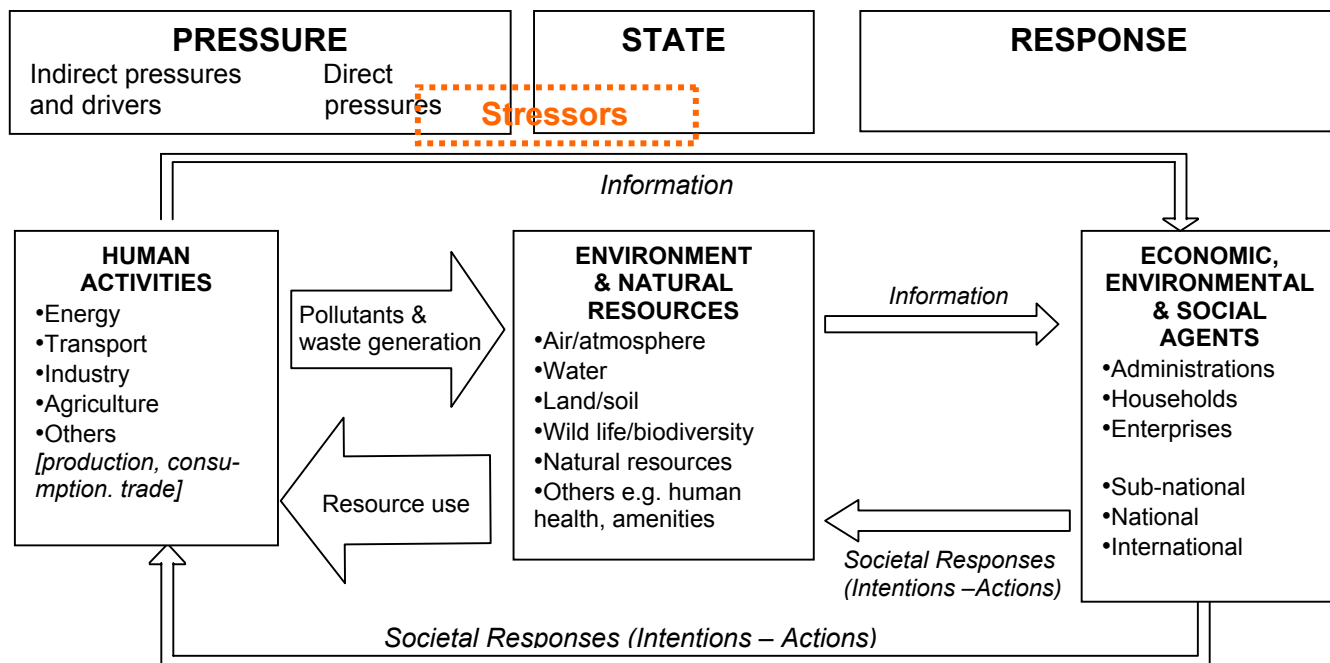
The condition of one aspect of the environment can equally represent a pressure on another aspect.



**Societal responses** show the extent to which society responds to environmental concerns. They refer to individual and collective actions and reactions, intended to:

- mitigate, adapt to or prevent human-induced negative effects on the environment;
- halt or reverse environmental damage already inflicted; and
- preserve and conserve nature and natural resources.

Examples of indicators of societal responses are environmental expenditure, environment-related taxes and subsidies, price structures, market shares of environmentally friendly goods and services, pollution abatement rates, waste recycling rates, enforcement and compliance activities. In practice, indicators mostly relate to abatement and control measures; those showing preventive and integrative measures and actions are more difficult to obtain.



#### Stressors and the PSR model

Physical, chemical and biological stressors are major components of the environment that, when changed by human or other activities, can result in degradation to natural resources.

With respect to pressures, states and responses, stressors may be either pressures or states, just as states may also be pressures and vice versa. For example, turbid water is an indicator of the state of an aquatic environment, but it is also a pressure in that it may cause the loss of benthic plant/algal communities by preventing light penetration through the water column. Turbid water is an indicator of the stressor 'aquatic sediments'.