



Australian Government

**National Land & Water Resources Audit**

*An initiative of the Australian Government*

# ESTUARINE, COASTAL AND MARINE HABITAT INTEGRITY

INDICATOR HEADING

## **Estuarine, coastal and marine habitat condition**

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INDICATOR GUIDELINE

### **Dissolved oxygen**

Dissolved oxygen

#### **Recommended by the Audit for further consideration**

This version of the guideline has been developed through the National Land and Water Resources Audit and was informed by expert review and broad consultation on national indicators via national coordination committees and their associates. Version 1 – June 2008 does not yet have the final endorsement of any jurisdiction. The document is for guidance only and is presented to provide a basis for on-going discussion. It may require further consideration by a jurisdictional based reference group before national endorsement.

# Status of indicator agreement

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The National Land & Water Resources Audit (the Audit) coordinates the collation of data to support reporting on natural resource condition required under the National NRM Monitoring and Evaluation Framework (National M&E Framework).

The National M&E Framework identifies three requirements for monitoring natural resource condition:

- a set of resource condition indicators to measure progress toward the agreed national outcomes on a medium and long term basis
- a set of indicators for monitoring community and social processes relevant to or affected by NRM programs, as well as measures of the adoption of sustainable development and production techniques
- contextual data pertinent to the indicator being considered.

The Audit Advisory Council has agreed to a process for achieving a practical set of indicators under the National Monitoring and Evaluation Framework.

This process is to:

- obtain on-going **recommendations** from the relevant **National Coordination Committees** for each thematic area (including “Matters for Target”) on appropriate indicators, protocols and information needs
- seek **endorsement** from the **Audit Advisory Council** that the indicators and protocols can be implemented at the national, state / territory and regional levels
- seek **agreement** from the Natural Resource Policies and Programs Committee (**NRPPC**) (or the Marine and Coastal Committee –**MACC**- for Estuarine, Coastal and Marine) that the indicators will be used and promoted by jurisdictions to underpin evaluations of NRM initiatives.

The NRPPC and MACC report to the Natural Resource Management Ministerial Council (NRMMC).

# Introduction

This suite of “indicator guidelines” is relevant to the Estuarine, Coastal and Marine Habitat Integrity Matter for Target.

Two indicator headings are identified:

1. Estuarine, coastal and marine habitat extent and distribution
2. Estuarine, coastal and marine habitat condition.

Initially, 31 potential indicators were developed to measure the effect of the stressors on ecosystem condition (physical/chemical and biological) and habitat extent (Scheltinga et al., 2004). These indicators were reviewed at a national workshop (Souter and McKenzie, 2006) and further refined to 19 nationally agreed indicators (Table 1).

Drawing on a series of state/territory trials and national consultations; the documentation for the indicators has been modified from a “protocol” format that sought to define both measurement standards and reporting (information) products to one that presents “guidelines” for the collection and storage of monitoring data.

These “indicator guidelines” should be used as standards for the collection, collation and storage of data in order to assist NRM service providers and community groups make observations that can potentially be pooled and re-used at a later date.

Ten ECM indicators were prioritised and guidelines have been developed through extensive consultation and reviewed by key experts in the field.

Table 1. Nationally agreed ECM Resource Condition Indicators. Indicators prioritised for documentation and included in this document are shown with an asterisk.

Indicator heading	Indicator
<b>Estuarine, coastal and marine habitat extent and distribution</b>	<ol style="list-style-type: none"> <li>1. Extent and distribution of key habitat types*</li> </ol>
<b>Estuarine, coastal and marine habitat condition</b>	<p>Biological condition</p> <ol style="list-style-type: none"> <li>2. Algal blooms</li> <li>3. Animal or plant species abundance*</li> <li>4. Chlorophyll a*</li> <li>5. Coral bleaching</li> <li>6. Mass mortality events</li> <li>7. Pest species (number, density, distribution)*</li> <li>8. Targeted pathogen counts</li> <li>9. Vertebrates impacted by human activities</li> </ol> <p>Physical/chemical condition</p> <ol style="list-style-type: none"> <li>10. Dissolved oxygen*</li> <li>11. Nutrients*</li> <li>12. pH</li> <li>13. Presence / extent of litter (marine debris)*</li> <li>14. Salinity (EC)</li> <li>15. Sedimentation/erosion rates*</li> <li>16. Shoreline position</li> <li>17. Temperature</li> <li>18. Toxicants (in water / sediments / biota)*</li> <li>19. Turbidity / water clarity*</li> </ol>

# Dissolved oxygen

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## Matter for target:

Estuarine, coastal and marine habitat integrity

## Indicator heading:

Estuarine, coastal and marine habitat condition

## Indicator name:

Dissolved oxygen

This document presents the recommended monitoring guidelines for collecting, collating and reporting information on the level of dissolved oxygen in water for national, state/territory and regional application.

## 1. Definition

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

AIM 1: To determine the daytime levels of dissolved oxygen in surface waters and to compare with local guidelines.

INDICATOR 1: Dissolved oxygen concentration in the surface water measured during the middle hours of the day and expressed as percent saturation.

AIM 2: To determine minimum dissolved oxygen concentrations following significant inflows from the catchment.

INDICATOR 2: Dissolved oxygen concentrations in surface waters measured just before daylight. Measurements should be collected daily for the two weeks after the inflow and the lowest of these values should be recorded as the final indicator value.

## 2. 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 (ie photosynthesis) and oxygen consumption (ie aerobic respiration, nitrification and chemical oxidation) in the water environment, and the exchange of oxygen with the atmosphere. Natural processes (eg 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, decrease the available habitat and limit animal movements. Low DO can also result in changed conditions in 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 determinants 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 factors influencing DO concentrations, the significance of DO levels and related information on anoxic and hypoxic events, see the OzCoast and OzEstuaries website ([http://www.ozcoasts.org.au/indicators/dissolved\\_oxygen.jsp](http://www.ozcoasts.org.au/indicators/dissolved_oxygen.jsp)).

### **3. Monitoring methodology**

The recommended condition indicator is dissolved oxygen (DO), measured as percent saturation. Where consistent point sources are the main concern, measurements can be taken at any time. The location of monitoring sites will be dictated by the likely spread of influence of organic matter and this may need to be assessed through pilot studies. In poorly mixed systems, measurements should be taken at a range of depths. In systems with high levels of primary production, it is desirable to take DO readings in the early morning when minimum values occur.

Where a catchment is the main source of oxygen-depleting substances, measurements need to be taken at least daily following a significant run-off event. Such events cause only short-term oxygen depletion but the effects may be very large. Therefore it is important to capture the DO minimums which commonly occur days or even a week or two after the main inflow has ceased. The exact time period depends on the size of the system and the size of the event.

#### **3.1 Monitoring locations**

Samples should be taken from sites within the mid estuary and, where possible, from the upper and lower reaches of an estuary. In estuaries where little or no monitoring has been done before, the initial samples should ideally be taken along the length of the estuary at intervals of 10% of the total length intervals (but not closer than every 3 km). This will allow the 'worst' areas to be identified and continually monitored. Areas near organic matter point source inputs should also be monitored. A similar logic should be used to select sites within coastal waters.

As bottom waters are more likely to have low DO they should be sampled, building a profile through different depths.

#### **3.2 Monitoring frequency required**

The direct monitoring of DO needs to be conducted on a monthly basis on the falling tide. If possible monitoring during the neap cycle (lowest tidal range) is preferred. Two measurements should be taken if possible: 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 mass mortality events (ie animal kills), they are generally not very useful as the diurnal range of DO is required for proper data interpretation. Sampling should occur for at least one year.

#### **3.3 Data measurement method**

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.

Monitoring equipment should be maintained appropriately and be inspected and **calibrated**

**before** each field trip.

DO concentrations (expressed as % saturation) are determined through in situ (water sample) measurement methods.

**Equipment required: [BT format]**

- DO probe.

**Site procedures (middle of estuary from boat):**

1. Prepare field recording sheets.
2. Calibrate probe prior to sampling.
3. Locate the site using a Global Positioning System.
4. While in a slow forward motion, cut the engine to prevent fouling.
5. Turn the meter on and place the probe in the water.
6. Allow the probes to stabilise for a minimum of 90 seconds for the initial site reading.
7. Record reading 0.2 m below the surface (to reduce the impact of surface slicks) on the field recording sheet.
8. Save the data in the hand-held data logger.
9. Repeat at 2 m intervals until the bottom is reached allowing a minimum of 30 seconds for the probes to stabilise at each depth. After the initial 30 seconds, confidence stability is attained by readings remaining constant for 10 seconds. If values fluctuate, continue measuring in 10 second increments until stability occurs.
10. Between sites, fill the PVC probe-holding tube with water from the previous site to maintain probe stability.

**Site procedures (shore-based procedures):**

1. Prepare field recording sheets.
2. Calibrate probe prior to sampling.
3. Locate the site using a Global Positioning System.
4. Rinse a clean 20 L plastic bucket three times and fill with sample water.
5. Place the probe in the bucket and allow to stabilise.
6. Before taking measurements, ensure the water sample is well mixed by continuously stirring the bucket with the probe.
7. Record information on the field recording sheet.

8. Save the data in the hand-held data logger.
9. Between sites, fill the PVC probe-holding tube with water from the previous site to maintain probe stability.

*Calibration of DO probe (eg YSI 610/650 multiprobe)*

The dissolved oxygen sensor is susceptible to drift outside acceptable limits in a short period of time. Dissolved oxygen levels are therefore determined by the Winkler Titration method before and after a survey.

1. Remove the sensor guard and check DO membrane for nicks, cuts and holes. Check that there are no air bubbles behind the membrane. Replace the sensor guard and plug the YSI 610/650 into the cable.
2. Turn the meter on and place the probe into a full 20 L bucket of tap water and mix using the probe.
3. Rinse the titration bottles and flask.
4. Rinse and fill a 300 mL bottle with water from the bucket, being careful to avoid rapid filling and production of air bubbles. Gently tap the outside of the bottle with stopper to remove air bubbles and insert stopper to ensure exact volume.
5. Ensure reagents are within use-by-date. Add 1.5 mL  $\text{MnSO}_4$  solution followed by 1.5 mL alkali-iodide-azide reagent and stopper carefully to remove all air bubbles.
6. Mix the contents of the bottle by inverting (20 inversions is recommended) until the floc dissolves to a homogenous burnt orange colouration.
7. Place contents into conical flask with a small quantity of vitex starch indicator and titrate with 0.025M  $\text{Na}_2\text{S}_2\text{O}_3$  until the solution goes clear (if the endpoint is overrun, the titration must be repeated). Discard remaining pipette volume (1 mL of 0.025M  $\text{Na}_2\text{S}_2\text{O}_3$  used in the titration equates to 1 mg/L dissolved oxygen in the bucket of water).
8. Fill out the appropriate field recording sheet detail and daily calibration documentation and record the pre-calibration DO value on the meter.
9. Choose the DO mg/L calibration function on the meter and swirl the probe in the bucket of tap water to maintain water flow adjacent to the membrane to avoid DO depletion.
10. Enter the value for DO from the Winkler titration.
11. Once the DO stabilises, calibrate the meter.
12. Go to the 'run' mode in the meter and record the post-calibration value on the field recording sheet detail and daily calibration documentation.
13. If the post-calibration value is +/- 0.3 mg/L outside the value obtained from the titration, the sensor must be fitted with a new membrane or be totally replaced before continuing with water sampling.

The Waterwatch Queensland (2003) 'Community Estuarine Monitoring Manual' CD includes an Excel spreadsheet designed to convert dissolved oxygen readings in mg/L to percent saturation.

### **3.4 Data collation / calculation method**

Data for a specific site should be collated over the study period and the median value calculated and compared against the relevant guidelines.

### **3.5 Data storage and management**

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.

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

When examining 'ambient' DO levels, data from at least one year should be used in the analysis. Median DO values should be compared with the relevant water quality guidelines. 'National' default trigger values have been listed in the 'Water Quality Guidelines' for coastal waterways in different geographic regions (ANZECC/ARMCANZ, 2000a); these trigger values are superseded in Queensland by the 'Queensland Water Quality Guidelines' (EPA, 2006). Local guidelines (which supersede both national and state/territory ones) may be available for some estuaries.

The solubility of oxygen in water is limited and DO levels usually range from 6 to 14 mg/L. Water bodies are defined as anoxic at oxygen concentrations near 0 mg/L and hypoxic at oxygen concentrations less than 2 mg/L.

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 (photosynthesis by plants and algae) during the day, net respiration at night, and 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 (eg from sewage treatment plants and industry, organic runoff or algal blooms) which leads to increased bacterial activity (decomposition by aerobic micro-organisms). 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 (ie 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 sulphate runoff may also affect DO, as the oxidation of iron sulphides can rapidly remove oxygen from the water.

### **3.7 Reliability, validity and quality assurance**

Quality assurance and control measures are important to minimise avoidable errors in the data and thus give more confidence in the data collected and conclusions made. Individuals collecting the data must have adequate training in sample collection. Instrument calibration

and/or laboratory quality assurance should be regularly examined and recorded.

### 3.8 Metadata

Metadata documentation should be completed for all datasets (see Appendix A). The metadata statement should be consistent with current ANZLIC standards, which now comply with ISO 19115.

See the following web site for the Metadata Profile:

[http://www.osdm.gov.au/ANZLIC\\_MetadataProfile\\_v1-1.pdf?ID=303](http://www.osdm.gov.au/ANZLIC_MetadataProfile_v1-1.pdf?ID=303)

For the Metadata Guidelines see:

[http://www.osdm.gov.au/ANZLIC\\_MetadataProfileGuidelines\\_v1-0.pdf?ID=397](http://www.osdm.gov.au/ANZLIC_MetadataProfileGuidelines_v1-0.pdf?ID=397)

## 4. Reporting / information products

### 4.1 Audiences

Regional natural resource managers will be the main audience for information on specific estuaries and coastal waters. State and federal managers will be more interested in the collation of information into regional summaries/reports.

### 4.2 Products

At the smallest reporting level (ie at the site scale) DO levels are 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 site. Box plots are an easy way to visually compare the data with reference data/guidelines. Once sufficient information on DO is available for a location, it will be possible to produce tables or graphs showing trends/change 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.

When reporting at an estuary or larger scale, the number of zones/sites in which annual median DO levels exceed the relevant guidelines should be reported (see Table 1 for scoring categories). Alternatively, if monitoring the minimum sustained DO values after an event, the condition scores in Table 2 should be used.

Table 1. Scoring categories and indicator values for ambient dissolved oxygen as an indicator of estuarine condition.

<i>Condition indicator: ambient dissolved oxygen</i>	
<b>Condition score</b>	<b>Indicator value: % of sites exceeding guidelines</b>
Excellent	0
Good	1-19
Fair	20-50
Poor	51-99
Very Poor	100

Table 2. Scoring categories and indicator values for the minimum sustained dissolved oxygen values during the days following an inflow event as an indicator of estuarine condition.

<i>Condition indicator: minimum sustained dissolved oxygen values during the days following an inflow event</i>	
<b>Condition score</b>	<b>Indicator value</b>

Excellent	>70% saturation at all times
Good	>50% saturation at all times
Fair	<50% saturation for periods of >24 hours
Poor	<35% saturation for periods of >24 hours
Very Poor	<20% saturation for periods of >24 hours

### 4.3 Confidentiality

Data confidentiality is the responsibility of the data custodian.

### 4.4 Data collation/calculation method

The development of regional summaries/reports for state and national managers will require the collation of local datasets. Scoring categories provided for local scoring (Tables 1 and 2) can also be used for scoring at a regional level.

### 4.5 Data analysis, integration and interpretation information

Any national/regional level information products (ie interpreted products) need to be linked to the regional/local information that was used to create it (ie to the relevant state/territory and regional databases/information systems). Any specific methodologies, assumptions, additional data and changes in confidence in the interpreted products need to be stated.

### 4.6 Data access and storage

National level products should be developed with the needs of the various stakeholders in mind. Data access and storage for national level products should be through a nationally known and recognised web site such as 'OzCoast and OzEstuaries'. Links should then be made to state/territory and regional web sites to access the underlying products/datasets.

### 4.7 Product definition statement

Each product should have a product definition statement. The product definition statement follows the same general format as the metadata statement referred to in 3.8.

## 5. Current national activities

There are no national activities related to DO monitoring.

## 6. Future development

More relevant (ie at least state/territory) DO guidelines need to be developed..

## 7. Links to other indicators

Animal or plant species abundance (indicator)

Nutrients (indicator)

Nutrients in aquatic environments (matters for targets)

## 8. Further information

ANZECC/ARMCANZ. 2000a, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

[http://www.mincos.gov.au/publications/australian\\_and\\_new\\_zealand\\_guidelines\\_for\\_fr](http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fr)

## esh and marine water quality

- ANZECC/ARMCANZ. 2000b, *Australian Guidelines for Water Quality Monitoring and Reporting*.  
[http://www.mincos.gov.au/publications/australian\\_guidelines\\_for\\_water\\_quality\\_monitoring\\_and\\_reporting](http://www.mincos.gov.au/publications/australian_guidelines_for_water_quality_monitoring_and_reporting)
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- 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.
- OzCoast and OzEstuaries*. 2007. Web site. <http://www.ozcoasts.org.au/index.jsp>.
- 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).

## **9. Glossary**

- Aerobic – In the presence of oxygen.
- Ambient – Prevailing (normal or typical) conditions.
- In-situ* – Latin term for 'in the original place'
- Microorganism – Microscopic animal or plant.
- Stratification – The layering of water due to differences in density.

## Appendix A: Metadata statement

<b>Monitoring program</b>	The name of the monitoring program
<b>Custodian of data/Contact</b>	The business name and address/contact details of the custodial organisation or responsible party
<b>Summary of program</b>	A brief narrative summary of the program
<b>Geographic extent</b>	The ordinary name(s) of the locations where the data was collected (ie study area)
<b>Indicators monitored</b>	List of all indicators monitored
<b>Method of data collection</b>	Summary of the methods used to collect the data
<b>Past/future sampling</b>	Description of when sampling started, how often it occurred, when it will finish
<b>Quality assurance</b>	Description of the quality control/assurance procedures used
<b>Data access</b>	1) Location: Where and how the data is stored. If it can be accessed remotely (ie from a website) 2) Format in which dataset is stored and available 3) Any restriction or legal prerequisites that may apply to access and use of the data
<b>Other comments</b>	Any other comments
<b>Information source(s)</b>	Where information on the program can be found (eg reports, literature, websites)
<b>Date metadata created</b>	Date when the metadata record was created