ENVIRONMENT PROTECTION AUTHORITY

Community Estuarine Monitoring Manual



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Community Estuarine Monitoring Manual

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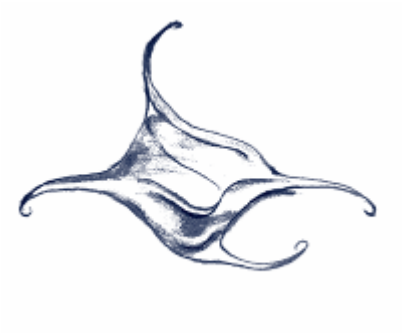
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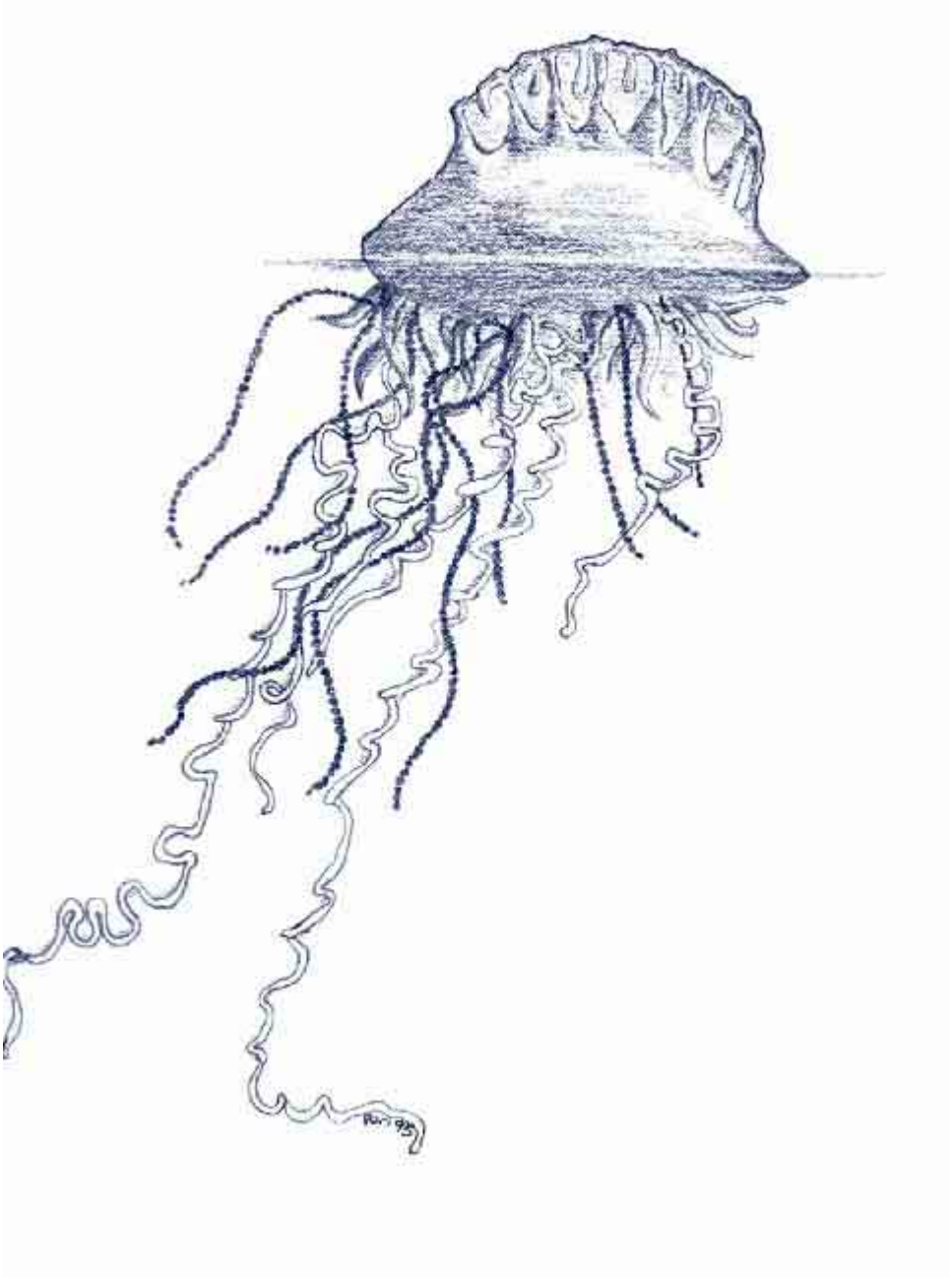
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Introduction



Meet the monitoring framework

Waterwatch Australia is a national community water-monitoring program that encourages all Australians to become involved with, and active in, the protection and management of their waterways and catchments.

Previously, Waterwatch concentrated on freshwater monitoring, but recently a number of community groups in estuarine areas have become interested in monitoring their estuaries. The interest stems from the maxim that 'estuaries are the report card of the catchment' (National Land and Water Audit, 2002).

In response to this interest, the EPA has developed an estuarine monitoring framework that is suitable for use by a wide range of community groups. The monitoring framework (Appendix 1) presents a range of activities that community groups may wish to explore. The activities are designed with the goals of:

- helping the community understand their estuary
- providing simple yet reliable data about the condition of the estuary.

The activities are broken into core and extension activities. Core activities may be:

- conducted by the widest range of people
- in the widest range of estuaries
- with basic equipment.

The core activities should result in a good level of understanding of estuarine processes while yielding reliable data on common estuarine parameters.

Extension activities are designed to be undertaken:

- by older groups
- by groups with a special interest in certain areas (for example the restoration of Mutton Cove)
- where there are certain types of habitat
- when parameters requiring processing back in a laboratory are being examined.

The extension activities should provide a deeper understanding of estuarine processes and yield a wider range of information about the functioning of the specific estuary being studied.

The following two lists summarise the core and extension activities suggested in this estuarine monitoring framework.

Core activities

Sampling site observations

- recording weather details
- reading time and tide height
- recording odours and odd things
- recording water depth
- recording surface water conditions
- recording water colour.

Understanding estuarine processes

- measuring water temperature
- measuring pH
- measuring water clarity
- measuring salinity.

Chemical assessments

- measuring dissolved oxygen
- measuring orthophosphate
- measuring ammonium
- measuring alkalinity.

Looking at the vegetation and habitat

- keeping a visual record of plankton blooms
- measuring beach litter.

Observing animal life

- tidal flats—counting crab burrows
- tidal flats—counting surface snails
- tidal flats—recording wading birds
- across the estuary—recording raptors
- across the estuary—recording invasive species.

Extension activities

Sampling site observations

- measuring flow rate.

Understanding estuarine processes

- mapping your estuary
- is your estuary positive or negative?
- classifying your estuary
- mapping the salinity gradient of your estuary
- mapping the salinity profile of your estuary
- mapping turbidity plumes
- where is the 'turbidity maximum' for your estuary?
- effect of tidal restrictions on wetlands.

Chemical assessments

- measuring sulphide
- measuring chlorophyll-a
- measuring total suspended solids
- estimating pollutant loads with mass balances
- measuring soil salinity and soil pH.

Looking at the vegetation and habitat

- getting to know phytoplankton with a net tow
- counting phytoplankton in a water sample
- monitoring a seaweed bed
- monitoring an intertidal SAM bed
- monitoring submerged SAM beds
- how continuous is the fringing vegetation?
- monitoring mangrove leaf/twig litter production
- monitoring mangrove expansion

- studying saltmarsh plants
- monitoring *Melaleuca* leaf/twig litter production
- using aerial photographs to map habitat change.

Observing animal life

- tidal flats—looking for benthic invertebrates
- rocky shore—counting grazing snails
- saltmarsh—looking for invertebrates in saltmarsh habitats
- saltmarsh—counting crabs and fish in saltmarsh creeks
- across the estuary—monitoring bacteria.

The framework recognises that different groups will want to do different things in their estuary. Some existing Waterwatch groups will be comfortable with the range of activities that they currently undertake, and may only wish to use equipment and methods that work over a wider range of salinities than currently catered for in Waterwatch kits.

Other groups may be attempting to understand or track down a pollution issue in their estuary, while still others may be engaged in restoration work in estuarine wetlands and may need guidance on how to monitor the progress of the restoration work.

The next section of these guidelines discusses how your group could select activities from the core and extension areas to build up a specific monitoring program that meets your groups' needs.

Definitions

The activity framework has a number of codes, abbreviations and symbols:

Age groups:

The age groups shown in the framework are the minimum recommended ages for each activity. The recommendation may be based on skill issues or safety.

Time requirements:

1 = less than 10 minutes

2 = 10 minutes to 1 hour

3 = 1–2 hours

4 = more than 2 hours

Activity symbols:

📖 = this activity is a desk–based activity

= this activity contains some field activities

In addition, there is a glossary at the end of these guidelines, to provide definitions for technical terms used in the framework and guidelines.



Understanding estuaries

Estuaries are where freshwater creeks, streams and rivers meet the ocean. They may be huge (like the Coorong) or tiny such as the small tidal creeks entering the two gulfs, Gulf St Vincent and Spencer Gulf. What happens in an estuary depends on the interactions between the amounts of freshwater flowing in (via rainfall, runoff, seepage and effluent outfalls), the amount of tidal exchange that occurs each day, the rate of evaporation and the size and frequency of waves.

The following definition of an estuary is used in this manual:

> An estuary is a narrow, semi-enclosed coastal body of water, which has a free connection with the open sea at least intermittently and within which the salinity of the water is measurably different from the salinity in the open ocean.

This is a wider definition than that of Cameron and Pritchard (1963), which assumed that all estuaries contained a measurable dilution of seawater. South Australian estuaries have very low flows of freshwater, and are therefore frequently **hypersaline** (more salty than the open ocean). In this aspect they are similar to many estuaries in areas such as Texas and parts of the Mediterranean Sea.

For the purposes of these guidelines, we will consider that the **head** of an estuary is the landward limit, or where you can no longer see any tidal variation, and the **mouth** is that part where either the salinity is indistinguishable from that of the sea, or there is some form of estuarine barrier or sandbar.

We can develop an understanding of the processes that affect an estuary by looking at two types of classification. We can examine the estuary and assess its salinity regime (positive or negative). We can also classify it according to the major forces (tides, river flows, evaporation and waves) that have shaped it. Understanding the type of estuary we are looking at allows us to understand what happens to water that enters it and where the different habitats will occur.

Positive and negative estuaries

The classical estuary has freshwater entering the head of the estuary, which gradually becomes saltier closer to the ocean. This is considered to be a 'positive' estuary. These estuaries require enough freshwater entering to not only dilute the seawater, but also to also make up for the effect of evaporation from the estuary surface itself. Positive estuaries are common in areas where there is high rainfall and low evaporation, but can exist in low-rainfall areas where a small river is fed from an extremely large catchment. In South Australia positive estuaries occur in the South East, on Kangaroo Island, and would have occurred in the past in parts of the River Murray estuary, in Lakes Alexandrina and Albert (Geddes and Hall, 1990).

South Australian estuaries are more commonly 'negative' estuaries, where the amount of freshwater entering the estuary as rain or runoff is less than the amount of freshwater lost as evaporation from the estuary surface. The salinity gradient in negative estuaries varies from hypersaline to **eusaline** (marine salinity). The Coorong is a well-known negative estuary.

The OzEstuaries classification

There are several different classification systems for estuaries. Most seek to classify the estuary on the basis of tidal influence (is there a large or small exchange of seawater daily?) and rainfall (is there a large river or rainfall input and what is the evaporation like?).

Geoscience Australia has produced a CD ROM about Australian estuaries, designed for educational use, that includes a classification system for estuaries (commonly called the OzEstuaries classification, developed by Heap *et al,* 2001). The system classifies estuaries into three major types, depending on whether they are dominated by the tides (mainly found in northern Australia where tides are large), by rivers (these are delta estuaries) or by waves (where a sandy barrier of some kind is formed by waves). Each of these groups can be subdivided, providing six subclasses: tide dominated deltas, wave dominated deltas, wave dominated estuaries, strand plains, and tide dominated estuaries and tidal flats.

A quick summary of these classes follows. If you wish to understand the classification method, you should obtain a copy of the CD ROM *Australian Estuaries and Coastal Waterways* from Geoscience Australia.

Tide dominated delta

Deltas are river dominated, so they can have strong freshwater influence. This may be only episodic, in the case of South Australian deltas. The large quantity of silt they carry to the sea is deposited around the mouth of the delta, causing the characteristic wedge- shaped delta to form (for example at the Light River, in Gulf St Vincent). The daily tidal influence in a tide-dominated delta rapidly mixes the salty and fresh water.

Wave dominated delta

Where waves are strong enough to deposit sediment in the main basin of old estuaries, wave dominated deltas may form. This type of estuary may be seen in South Australia at the Onkaparinga estuary. The influence of the tide is not large and so these deltas may become stratified, with a wedge of salt water underlying the fresher surface water.

Wave dominated estuary

Waves are strong movers of coarse sandy sediments, and where wave energies are strong enough they can produce a barrier near the mouth of an estuary. A well-known South Australian example is the Murray Mouth and Coorong. The sandy obstructions tend to attenuate the tide inside the estuary, resulting in stratification or partial mixing of the fresh and tidal water in the lagoon–like area behind the sand barrier.

Strand plain

Strand plain estuaries are tiny lagoons with minimal freshwater influence. The sand barrier is kept in place by the waves and there is so small a freshwater flow that the sand may close the opening completely. These estuaries may only be open to the sea for part of the year, during the period of highest freshwater flow. The salinity gradient in these small estuaries is spread over time, as well as space, as the water becomes more saline over summer, and less so over winter. The lack of wave, tidal or river flows in the lagoon can allow the water to develop salinity, temperature and dissolved oxygen stratifications.

Tide dominated estuary

Where freshwater flows are low, tide dominated estuaries may develop. The northern parts of Spencer Gulf and Gulf St Vincent may be considered to be essentially estuaries that drain the arid lands to the north. The tracks of old rivers (**paleorivers**) run into the northern gulfs, and show on the surface as chains of salt lakes. Freshwater drainage into the gulfs along these depressions is fairly rare. Tide dominated estuaries have obvious tides, well-mixed salinities and extensive mangrove systems.

Tidal flats

Small tidal flat estuaries are very common in South Australia, particularly in the two gulfs (First, Second and Third Creeks at Port Pirie, the Port River/Barker Inlet estuary, Gawler River and Port Broughton estuaries are a few). They are found in areas with high tidal influence and tend to drain right out at low tide. Their small size and the strong tidal influence tend to result in the salinity being well mixed. With the low rainfall and arid conditions, many of these estuaries are extremely negative, with salinities in the landward parts of the estuary frequently exceeding that of seawater. These small estuaries usually have a **riparian zone** of mangroves backed with saltmarsh.

Estuaries—values and impacts

Estuarine areas are nurseries for fish and larders for migratory birds. The varied estuarine habitats form natural filters and buffers between the land and the sea.

A typical pattern of habitats, identified first by Chapman (1960), is found in low energy coastal areas in Australia. The diagram below (Figure 1) is a simple way to visualise the habitats that may be found in the marine and brackish parts of an estuary, in wet or dry parts of Australia.

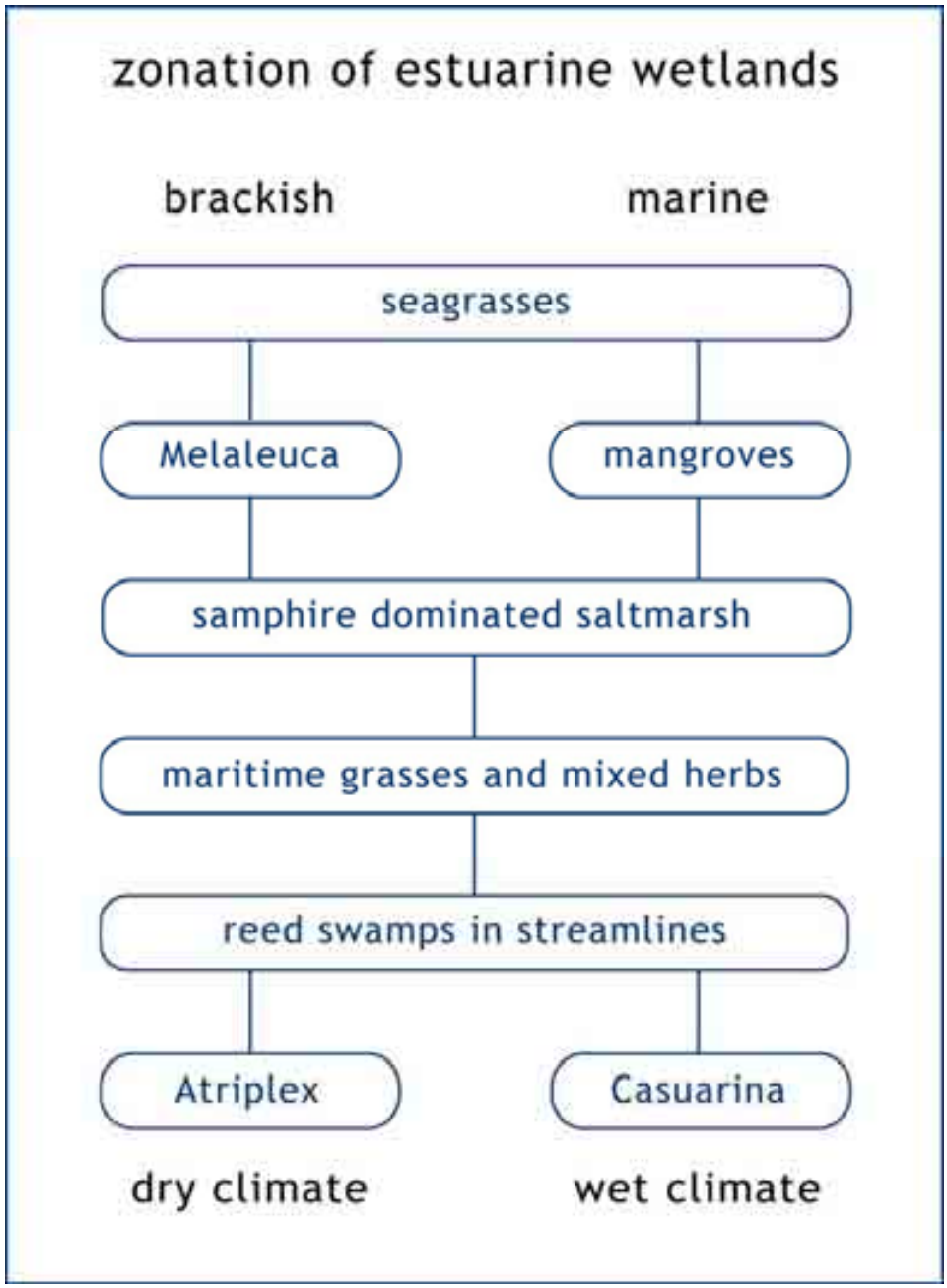


Figure 1—Habitat zones along estuaries

While each habitat may appear to be quite separate from the others, they are actually mutually dependant. For example, seagrasses require clear water, and mangroves and saltmarshes act as filters to clarify runoff from the land. At the same time, mangroves and saltmarshes will erode where water movement is high, and seagrass beds act as dampers to reduce water movement in the near shore area.

Therefore it is important to manage estuarine habitats as a whole, rather than concentrating on a single habitat.

Major pressure has been applied to the terrestrial estuarine habitats in the more urban parts of South Australia. For example, in Adelaide the **supratidal** areas have been almost entirely developed, the reed swamps from Hindmarsh to Port Adelaide are no longer in evidence, and much of the upper saltmarsh has been converted to industrial land in the Wingfield district. Even some of the mangrove areas in the North Arm area have been impounded and developed.

Apart from development pressures, estuarine habitats come under pressure from polluting effluent outfalls, sedimentation as a result of over clearing in upper catchments, the overfishing of fish and invertebrate stocks, and the changes to hydrology that come with sealing surfaces, damming rivers, diverting flows, and building dikes and seawalls.



Working in the field—safety & environment

Safety is the most important consideration in conducting fieldwork. Most safety issues can be addressed with a modicum of forethought. Group leaders need to visit sites before taking groups into the field, to assess any possible risks. Group leaders should discuss the area, the activities and any safety requirements with the rest of the group before taking them out to the site. Special training (such as how to handle broken glass or treat a spill of reagents) should be rehearsed before field activities are attempted.

The details of what training is required will depend on the activities being undertaken, and the skill and age of the participants. Each group leader needs to assess their group's particular needs. Some basic fieldwork safety and environmental care rules are presented below. They revolve around these principles:

- ensuring you do not find yourself in strife with no help available
- dressing appropriately
- being aware of dangerous situations
- treating yourself and others with consideration
- leaving as little evidence as possible behind you.

Ensure help is available

- work with at least one other person
- let somebody know where you are going and what time you expect to return
- carry a mobile phone, or radio (if out of mobile reception zones)
- carry a first aid kit.

Dress appropriately

- wear appropriate clothing and footwear to suit the area you are monitoring; for example, your footwear may need to withstand immersion, have good grip, and protect against sharp objects
- long sleeves, sunscreen and a hat will prevent sunburn
- insect repellent may be necessary at certain times of the year
- use gloves for handling litter.

Be aware of dangerous situations

- check the tide timetable before going into wet areas, or you may be trapped by the tide
- bridge-based activities may be dangerous—the water may be deep and passing traffic may also be a hazard. Safety jackets ensure you can be seen
- a seaworthy boat is one where the running gear is in good order, there is appropriate safety equipment and there are life jackets for each passenger. Never leave shore with anything less
- follow boating safety codes
- **mangals** and saltmarshes have uneven terrain, dense growth and ill-defined waterways. Always use established paths where possible. Dress brightly, so that you can be found more easily if you fall or become lost. Avoid muddy patches in mangals and 'rotten spots' in saltmarshes. Wear tight-fitting wetsuit bootees rather than wellingtons in muddy areas, as you are less likely to lose them.

Treat yourself, and others, with consideration

- never push someone who is tired or cold to continue working
- carry water, and drink frequently.

Leave as little evidence as possible behind you

- transect and other markers should only be placed where they cannot cause damage to boat propellers, and should be made of wood, not steel
- remove any rubbish that you have created
- used sample reagents should be poured into a lidded bucket that has kitty litter in it. Seal it and take it home with you to put out with the solid waste.

Working in the field—permits & politeness

There are other aspects to consider when working in the field. You may need a permit to conduct monitoring activities in a number of situations.

Native vegetation is protected outside the immediate Adelaide area, and on all Crown Lands. Any activities where living or dead plant matter is removed (for identification or for measurement) may require a permit under the *Native Vegetation Act 1991*, which is administered by the National Parks and Wildlife Service (NPWS). Additionally; this authority is responsible for administering all conservation reserves in the state, most of which have restrictions on the types of activities that may take place within them.

Advice on whether a permit is required for a specific activity under the Native Vegetation Act, or the *National Parks and Wildlife Act 1973*, may be obtained from the NPWS on (08) 8204 8776.

Mangrove plants are additionally protected under the *Fisheries Act 1982*. This Act also provides protection for many marine and estuarine areas such as Aquatic Reserves. Intertidal areas that are part of Aquatic Reserves may have other restrictions on taking invertebrates or other animals. The activities that can be conducted in these areas are defined in the Fisheries Act Regulations, and on boards erected at boat ramps in aquatic reserves. Advice on permits that may be required under the Fisheries Act may be obtained from Primary Industries and Resources SA (PIRSA) on (08) 8226 0222.

Groundwater piezometers less than 2.5 metres deep do not require a permit under the *Water Resources Act 1997*; however, deeper monitoring bores do. Shallow piezometers put in place for monitoring groundwater changes in saltmarshes are quite likely to be located on Crown land, so although no permit may be required under the Water Resources Act, permission may still be required from the NPWS.

Politeness is a basic requirement for establishing a monitoring program that is well supported by the community. Many people use estuaries. Some people depend on local estuaries to make a living, (adjacent landowners, commercial fishermen) and other people enjoy recreational activities in estuaries. The following advice will ensure that groups conducting monitoring do not cause offence to other estuary users.

- always obtain permission from landowners before entering their land
- leave gates exactly the way you found them
- do not litter the monitoring site
- be aware that untended markers are just another form of litter—remove temporary markers as soon as the activity is finished. Permanent markers for inter-annual comparison studies should be well maintained, marked with a contact label, and placed so they are not hazardous to other users
- many areas around estuaries are owned by the Crown, but managed by different authorities (local government, Coast Protection Board, NWPS or PIRSA). To set up a monitoring program on these areas, discuss what you would like to do with the managing authority
- be aware that the natural variation that occurs in many habitats from one year to another can be large, and it may take several years of monitoring before it is possible to identify whether a particular event has a natural or man-induced cause. You may wish to seek expert advice when interpreting your results
- if private bodies such as industries or researchers provide you with information to help you understand your estuary, never provide that information to others without asking permission from the people who gave it to you.

Designing your monitoring program

The range of activities provided by the framework is large so as to allow as many community groups as possible to become involved in monitoring their estuarine areas. Not all the activities will be suitable for your group, or for the habitats that occur in your specific estuary.

Before doing anything, it is important to develop a **monitoring program** that your group will be able to undertake. It needs to contain sufficient activities to provide the group with answers to their questions about their estuary while maintaining interest, but also must take up only the time that you have available. The decisions you will need to make include:

- deciding what you wish to know about your estuary
- choosing which activities are suitable for your group and your estuary
- deciding how much time you have available to monitor your estuary
- deciding on how frequently you will monitor each parameter you have chosen (monthly? quarterly? annually?)
- determining in what order to undertake the activities you have chosen
- understanding what level of data quality you wish to strive for.

Choosing activities

In general, it is advisable to select activities from each of the groups provided in the monitoring framework. The core activities from the sections *Sampling site observations* and *Understanding estuarine processes* are the basic activities that all monitoring programs could ideally be built on. Then, if water quality is an interest, consider the core activities from the *Chemical assessments* section of the framework.

At this point, consider whether your group would like to understand estuarine processes and water quality in more detail. If so, there are extension activities available in those sections that will deepen your understanding of these aspects of your estuary.

The biological sections of the framework have fewer core activities, and more extension activities. This is because many of these activities reflect habitats that may, or may not, be present in your estuary. The activities your group chooses should be based on the habitats in your estuary, or in the part of your estuary that you are sampling. Many of these activities require more time to conduct, more complex equipment, or a higher skill level.

The core activities described in *Looking at vegetation and habitat* and in *Observing animal life* may be conducted by people from a wide range of age and skill levels. These core activities are also suitable for most estuaries.

Which activity first?

When conducting fieldwork, timing and the order of activities matter. Try to monitor at the same time of day, and also attempt to monitor at the same part of the tidal cycle. The latter is not always possible, but at least keep a record of the state of the tide.

To observe some aspects of water quality, such as dissolved oxygen, which change over the period of a day, you may consider a one-off sampling event that monitors that parameter on an hourly (or even more frequent) basis, so that you may see the **diurnal variation** that occurs in your estuary.

When monitoring, it is important that the result of undertaking one activity does not influence the next activity. For example, water depth testing using a Secchi disk or measuring staff stirs up sediment, making the location unsuitable for testing water clarity (Secchi depth) or for collecting samples for measuring suspended solids. As a general rule, on arriving at a site, undertake the observational activities first (weather, surface water conditions, etc). Then collect any clear water samples that you will need for measuring water chemistry. Finally, undertake those activities that may disturb the benthic sediments.

Data quality

> Credibility doesn't mean having the most exacting techniques. It means delivering on your promises, no matter how small or large they are.
>
> Meg Kerr, RI River Rescue

Good results require cleanly collected samples, well-maintained equipment and careful methods. Comparative studies of Waterwatch community-collected data and professionally-collected data in Victoria (Nicholson *et al.,* 2002) and Tasmania (Otley, 2000) have shown that despite differences in the level of scientific training, data sets collected by the two groups were comparable for the parameters of electrical conductivity (salinity) and pH. The Tasmanian study found that the two groups could produce similar results in a whole-of-catchment survey for a wide range of parameters. In Victoria, turbidity and phosphorus data collected by community groups was less consistent and had a coarser resolution than data collected by professional groups.

Groups collect data for different reasons. Some groups may be monitoring an area to detect long-term trends, others may be trying to track down a point-source pollutant, and still others may be using their monitoring as part of an overall education program. The level of confidence that each group will require in any single measurement will therefore be different. It is important to decide what level of data confidence your group requires and is capable of producing, and then design the **quality plan** section of your group's monitoring program to meet that level.

Waterwatch SA has developed a range of data quality categories for community water monitoring that groups may choose to aim for. These levels are:

1 **Advanced Known Quality Data**—where test methods are chosen that are comparable in resolution to methods used by other water data users, where sampling frequency is at least six times annually, where equipment is calibrated for each event, results are reported directly from the equipment and reporting units are recorded, data on sampling conditions are reported, duplicates are tested, group training occurs annually and 'mystery solutions' are attempted twice annually. These data may be made available to external users, with the provision of the tolerance limits (the method resolution) for each parameter.

2 **Standard Known Quality Data**—where test methods are chosen that are comparable in resolution to methods used by other water data users, where sampling frequency is at least four times annually, where equipment is calibrated for each event, results are reported directly from the equipment and reporting units are recorded, data on sampling conditions are reported, and group training and 'mystery solutions' are attempted once annually. The data may be made available to external users for trend monitoring purposes, with the provision of wider tolerance limits (± twice the method resolution) for each parameter.

3 **Unknown Quality Data**—where test methods are chosen that are of coarser resolution than other water users may require, initial group training has been attended, data sheets are filled in to the best of the group's ability but may not be complete, and where sampling frequency is at least once annually. These data are of excellent value in the classroom situation where the measurements may be incorporated into parts of the mathematics, science, and society and environment curricula.

Sample collecting

How samples are collected and handled may influence your results. The following points will help you to collect samples that are representative of the water body you are examining:

- sample before undertaking activities that will disturb any sediment in the water body.
- to collect samples for immediate testing use clean polyethylene or PET bottles. Ensure there are no detergent residues if using cleaned bottles. For samples to be analysed by a laboratory, discuss what bottles, cleaning protocols and sampling methods are required with the laboratory. Label any bottles you are sending to a laboratory prior to sampling with a sample number, the location, date and analyses required.

- sample directly into the sampling bottle or jar unless a mixed sample is necessary, in which case ensure that the larger mixing container has been prepared in the same manner as the sampling container.
- you should rinse the sampling container in the sample stream several times, unless the bottle has been prepared for sending to a laboratory. In which case, the bottle may contain preservative that must be retained, so should not be rinsed in the sample stream.
- when sampling, submerge the bottle carefully. The mouth of the bottle should be held below the body of the bottle and plunged into the water before being tipped up to allow water to enter. The mouth should remain at least 200 mm below the surface. A sampling dipper simplifies obtaining a clean sub-surface sample.
- in flowing water, always ensure that your hand is downstream of the collecting bottle's mouth and that the mouth of the bottle is facing into the current.
- it is necessary that the person taking the samples use their discretion while collecting, so as not to take a non-representative sample. When sampling, avoid dislodging benthic algal mats, scraping against the estuary floor or jetty or bridge pylons, or otherwise disturbing the sediment. Care should be taken so that no larger animals or algae mats are included in the sample, unless that is what you wish to sample.
- when sampling waters, flowing or well-mixed water is preferable, but this may not always be available, particularly when very still conditions cause stratification in estuaries. In this case, attempt to collect three equally sized samples, from the surface, midzone and deeper waters, mix them together and sub-sample the mixture, or collect several separate samples if you wish to determine a profile.
- where possible, sample in the middle of the estuary, or at least in deeper water.
- once collected, measure the parameters you are interested in immediately. Leaving the water standing in a small container will allow some parameters to change (temperature & dissolved oxygen, for example).
- if collecting from a boat, shut off the motor before arriving at the site and drift the last few metres to reduce disturbance at the sample site. Always sample upstream from the motor, in case any hydrocarbons have escaped (this is particularly the case with older water-cooled two-stroke engines).

Equipment calibration

The old saying that a workman is only as good as his tools applies equally to measuring water quality as it does to any other activity. To ensure the information you collect is as accurate as possible, look after your equipment and calibrate it regularly. Advice on different types of equipment is given below:

- calibrate and maintain your equipment before going out to a sampling site and use an equipment checklist. The middle of the estuary is no place to discover something won't work properly or that you have left something at home.
- if you are using a meter, refer to the instruction manual that came with the meter to discover how to calibrate it. You will most likely need to use buffer solutions of known conductivity and pH.
- check what type of battery the meter uses, and carry a spare one in the meter's carry case.
- coil, don't kink, meter cables.
- treat your meter with respect. It is a delicate instrument. Always carry a meter in a carry case or box. Do not let it rattle around loose in the bottom of your sampling tub or boat.
- rinse the probes of your meter in fresh water after sampling in the estuary, and store them as recommended in the meter's manual.
- check the expiry dates on all test kit reagents before taking them out in the field. Old reagents may give inaccurate results.
- if you are using pH papers, be aware that they may become inaccurate if they are old, or may take longer to react. Before going out to the sampling site, try a few papers in pH buffer solutions

of 4 or 10, to check their accuracy and how long they take to react. If they are unacceptable, throw the pack away and open a new pack.

- thermometers and hydrometers require checking once a year against a certified instrument (return them to your Waterwatch coordinator). Being glass, these instruments usually break very obviously, but occasionally one may develop a visually undetectable crack that interferes with its accuracy.
- treat your glass items of equipment with respect. Carry them in a padded box and handle them gently. Broken instruments should be placed in a sharps container for disposal.
- refractometers may be calibrated using distilled water and a standard salt solution.
- refractometers have a glass prism and these may be damaged easily. The prism may break, or may be jolted out of alignment. Should this happen, the instrument may need replacing, or repairing at an optical specialist.
- the distance–marked cords on Secchi disks may stretch or shrink with use and repeated wetting and drying. Before going out into the field, check the accuracy of the markings on the cord using a metal tape.

Methods, records and quality plans

Raw data may be very misleading. To use information correctly, you need to know how it was collected, what exactly was being measured and the precision with which it was measured, amongst other things. A **data quality plan** is the document that provides end users of your data with information on those items.

The usual data quality plan contains a map showing your sampling site, a sampling timetable, a list of equipment and test methods that you use, details of the method ranges and resolutions, details of the reporting units for each method, details on how you check for data quality (calibration of equipment, duplicate samples, etc) and details on the training your group has received. The document does not need to be long, and your Waterwatch coordinator can assist you in developing it.

The other records you need to maintain are the sampling records. Always attempt to fill in the site records with as much detail as you can at the time of sampling. Keep them in a file or folder, so that you do not mislay them as you build up a collection of sheets. Remember to send in copies of your site records to your Waterwatch coordinator if you wish the data to be available for others to use.

Finally, consider what you are trying to determine, and use methods that are appropriate. It is not usually necessary to measure locations on a 50–m transect to the millimetre. It is pointless trying to measure nutrients that occur in the range of 0–0.5 mg/L using tests with measuring steps of 1 mg/L.



Selecting your monitoring sites

The sites that you sample will depend on whether you are attempting to monitor an entire estuary (a huge project in a large estuary, but feasible for a single group that is monitoring a small estuarine creek, or when doing specific activities such as mapping the salinity gradient), or whether your group is responsible for monitoring just one site as part of many groups monitoring an estuary.

Bearing in mind that water samples taken at the shallow edges of an estuary are likely to be unrepresentative, select sites where there is safe access to deeper water. In long estuaries in urban areas, a series of bridges may provide useful platforms, and allow you to gain samples from both sides and the middle of each span. Jetties and wharfs are other options that should be considered.

Should you be monitoring an entire estuary (such as small estuarine tidal creeks), attempt to have sampling sites that cover the spectrum of salinities found in the estuary.

If your group has a specific interest, your sampling locations may reflect that. For example, some groups may be interested in remediation of tidal wetlands, and these groups may sample the wetland they are working on. Other groups may wish to monitor the effects of stormwater or effluent outfalls (by mapping turbidity plumes, for example).



Sampling site observations



Recording weather details

Weather affects the estuarine environment itself and your ability to record accurate information about the estuary.

Hot weather may reduce the ability of estuarine waters to hold dissolved oxygen, windy conditions may stir up sediment, and heavy rain may introduce plumes of turbid runoff. Additionally, it may be difficult to obtain accurate Secchi disk measurements in strong glare or when the surface of the water is choppy.

In general, calm conditions are best for monitoring. Avoid monitoring in strong storms, as there are monitoring representativeness as well as safety issues to consider.

Activity: Core

Age: All

Time: 1

Why? The weather affects many other parameters being measured in a monitoring program, so should be included to aid interpretation of the collected data.

What you may need:

- site record form
- Beaufort scale
- thermometer
- weather records for previous few days from the Bureau of Meteorology (BOM) website <www.bom.gov.au>.

What to do:

On your site record form, record the weather at the time you are visiting your sampling site.

You may record whether it is sunny or cloudy, and estimate how much of the sky is covered by cloud. If it is raining, record this, and also record whether it has rained earlier that day.

You may use the same thermometer that you use for measuring water temperature to measure air temperature. Place the thermometer in a shaded dry place and allow it to equilibrate for five minutes, then read the temperature. Wet thermometers or those in the sun will give erroneous readings.

A version of Admiral Beaufort's wind speed scale has been provided in Appendix 2, to allow you to estimate wind speed. The version used in this manual is the one that includes indicators that one may see on land, and is more suitable for use in estuaries than the versions that are used on the open sea.

If you can obtain the weather records for the previous few days from the BOM website, attach these behind your site record sheet. The weather leading up to your sampling event may have a bearing on what you discover on site. For example, a series of hot, humid nights can result in very low oxygen levels just before sunrise and can sometimes cause fish deaths.



Recording time and tide height

What you may need:

- site record form
- timepiece
- tide timetable.

What to do:

On your site record form, record the time you visit your sampling site. Look up the tide timetable for the nearest tide station to your monitoring site and decide what stage the tide is at. Is it high tide, low tide, ebb (falling) tide, or flood (rising) tide?

Also record the time and height of the tide that occurred immediately before your visit, and the time and height of the next tide that will occur.

Activity: Core

Age: All

Time: 1

Why? The state of the tide affects many other parameters being measured in a monitoring program, so should be included to aid interpretation of the collected data.

Recording odours and odd things

Activity: Core

Age: All

Time: 1

Why? Algal blooms, some effluents and anoxic conditions all produce various odours.

What you may need:

- site record form.

What to do:

If your site smells, record this on your site record, along with a description of the smell. Does it smell like fish, sewage, new-cut grass, rotten eggs, over-ripe fruit or fuel?

As well as smell, take a note of anything else unusual—are new pipes discharging near the site? Is there an oil slick on the water? Oil slicks from pollution are usually brightly coloured, but sometimes in summer, the faintest slick of rainbow colours on the water surface may be from the oil in mangrove leaves.

The presence of dead fish and crabs is an indicator that should be recorded, as well as the presence of scum or foam on the water, rust-coloured ooze from the soil next to the water, the presence of lots of floating rubbish, or unusually turbid (muddy) water.



Recording water depth

What you may need:

- Secchi disk or depth staff (directions for making a Secchi disk are included in Appendix 6)
- site record form.

Activity: Core

Age: All

Time: 1

Why? The depth of water may affect other parameters being measured, such as temperature and dissolved oxygen.

Safety: Deep water may be dangerous.

To ensure good results:

As measuring the water depth may disturb the sediment, this measurement should be made after all other measurements have been taken.

The marked cord on a Secchi disk may stretch or shrink over time, so it should be checked against a metal rule before using it in the field.

What to do:

Gently lower the Secchi disk into the water until it just touches the bottom of the waterway. Read the water depth from the cord.

In shallow water, a measuring staff may be used instead of a Secchi disk. To prevent the staff digging into any soft sediment, the staff should have a footplate fitted.

Recording surface water conditions

Winds across the surface of the estuary helps mix the fresher surface water with the saltier water below. Stratification (layering) of salinity, temperature and dissolved oxygen may occur in very calm conditions. Large wind-driven waves indicate that much mixing will be occurring, along with additional oxygen incorporation.

Activity: Core

Age: All

Time: 1

Why? The water surface conditions indicate how much mixing is occurring in the estuary.

Safety: Deep water may be dangerous. Avoid monitoring in rough conditions.

What you may need:

- site record form.

What to do:

Observe the water surface. Does it look:

- calm like a mirror?
- ruffled or covered with small scale-like ripples?
- covered with short wavelets that do not have crests?
- moderately rough with longer waves with occasional white glassy foam crests?
- quite rough with waves with 'white horses' of foam where their crests are breaking?

Record the water surface condition on the site record form.



Recording water colour

Water often has a slight degree of colour, and this can indicate the chemicals dissolved in it, organic materials such as peat, blooms of **phytoplankton**, and soil erosion. Field measurements of colour tend to be subjective, and a wide range of colour scales have been developed for measuring colour in water, ranging from the platinum scale, to the Forel–Ule scale and the Borger and Munsell colour systems.

Laboratories use spectrophotometers to determine the hue, saturation and luminance of coloured water, thereby obtaining a quantitative result. In the field, one observes the apparent colour of water reflected from the white quadrants of a Secchi disk, and compares the colour to an arbitrary colour chart, set of coloured glass standards, or set of coloured water vials.

A useful set of colour definitions has recently evolved with the advent of the internet. To define colours used on HTML–coded web pages that will be displayed on TV and PC monitors, an RGB (red, green, blue) colour code is used. This allows people working all over the world to define colours the same way.

The colour chart provided in Appendix 3 uses the HTML-RGB codes, and has a similar range of colours to the Forel–Ule colour scale that is commonly used in estuarine studies.

Activity: Core

Age: All

Time: 1

Why? Water colour can indicate dissolved matter, the colour of the substrate, the presence of muddy sediments, floating oils or the presence of an algal bloom.

Safety: Deep water can be dangerous.

What you may need:

- Secchi disk (directions for making a Secchi disk are included in Appendix 6)
- site record form
- water colour chart.

To ensure good results:

The marked cord on a Secchi disk may stretch or shrink over time, so the markings on the cord should be checked against a metal rule before using the Secchi disk in the field.

If you reprint the colour chart, check the colour values against the printed chart in Appendix 3 of this manual to ensure they have reproduced correctly.

Submerge the Secchi disk in a shady area (shady side of boat, jetty or bridge) if possible, to reduce the effect of glare.

What to do:

Gently lower the Secchi disk into the water until the disk is one metre below the surface. Look at the colour reflecting back from the white quadrant of the disk.

Compare this colour with your colour chart and record the colour code that is closest to the water colour reflecting back from the Secchi disk.

Measuring flow rate

Flows in estuaries are very complex. Recording flow rate can help you determine whether erosion or accretion of the shoreline is likely to occur, whether an area is likely to host certain types of aquatic vegetation, and (if the flow rate is taken in a stormwater drain, effluent outfall or creek that is joining the estuary) the load of pollutants that is entering the estuary.

Flow rate may affect turbidity or water clarity, dissolved oxygen concentration and stratification. When examining fringing wetlands it is important to record flow rate to help determine whether tidal restrictions are occurring in these vulnerable areas.

The rate of flow may be multiplied by the cross–sectional area of the waterway being measured to determine the volume of water passing a given point over a period of time. Details for calculating this are contained in the book *Waterwatch Australia National Technical Manual, Volume 4–Physical and Chemical Parameters* (Waterwatch Australia Steering Committee, 2002).

Activity: Extension

Age: All

Time: 2

Why? The speed that water moves provides an indicator of the volume of stormwater, riverine or tidal flows in an estuary. Different habitats occur in areas of different flow rates.

Safety: Fast flowing, or deep, water may be dangerous.

What you may need:

- activity record form
- several oranges
- a net on a pole
- a 50-m measuring tape
- a stopwatch.

To ensure good results:

The longer the distance you time your orange over, the more likely you are to obtain an accurate result, so use a minimum distance of 10 metres, but preferably use a 50-m distance. Choose an area where there are no structures or rocky outcrops jutting into the flow, as these will modify the flow around them.

What to do:

Use your tape to mark the distance you will measure the flow rate over. Place a person at the beginning and end of the distance. The person at the start of the distance should have a stopwatch. The person at the end of the distance should have a net on a pole for catching the oranges.

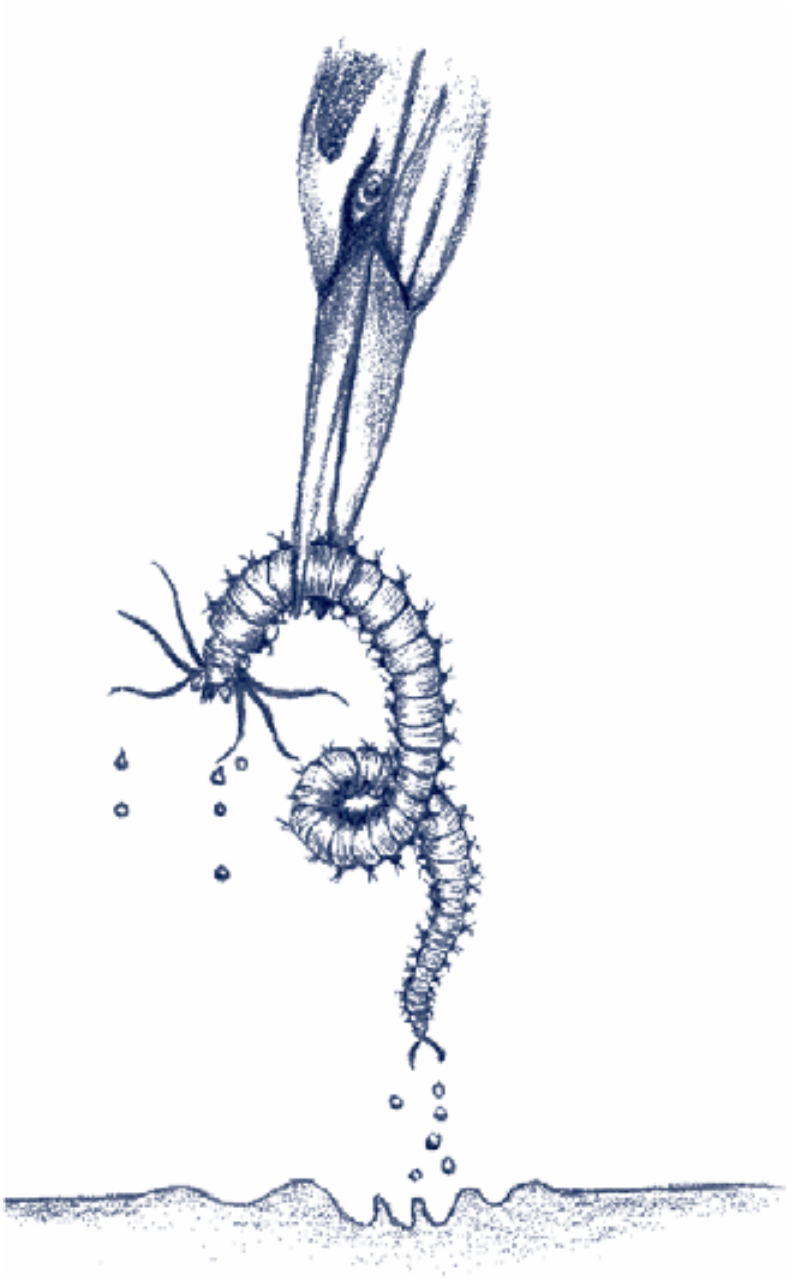
Place an orange in the water upstream of the first person. As the orange passes the first person, they should start timing. As the orange passes the second person they should call out loudly, then attempt to net the orange. The first person should stop the watch as soon as they hear the second person call out. Repeat this at least three times. Try to use the same orange, but as the orange is biodegradable, losing the odd one (if the flow is fast, for example) is not significant.

Take an average of the readings, and use this as the time in the following calculation:

$$\text{Flow rate (m/sec)} = \frac{\text{distance travelled}}{\text{time taken} \times 0.9}$$

where 0.9 is the correction factor because velocity varies between the middle and edge of a channel

Understanding estuarine processes



Measuring the water temperature

Activity: Core

Age: All

Time: 1

Why? Temperature plays an important role in determining the amount of oxygen that can remain in the water, as well as affecting the reproductive status of many organisms.

Warmer or cooler water than usual for an area may allow invasive species to gain a foothold.

Temperature also controls the rate of many of the chemical processes that occur in an estuary.

Safety: Use alcohol thermometers, not mercury ones. Glass thermometers may break. Handle gently. Broken pieces should be placed in a sharps container.

Water temperature is important for the functioning of estuaries and the ecosystems within them. It also influences a number of chemical and physical parameters, so should be measured whenever a water quality program is run in an estuarine environment.

Higher water temperatures decrease the ability of water to hold oxygen, reduce the density of the water (how heavy it is) and may also increase the chance of an algal bloom. Rapid temperature shifts affect the health of many species of aquatic animals, and may stress them considerably.

Long–term temperature changes may have a considerable impact on estuarine ecosystems. Warmer water temperatures encourage rapid growth of heat-tolerant organisms, which often include introduced species brought in by ships from tropical ports. As an example, Pacific Oysters, introduced for aquaculture, will often reproduce in the warm sheltered waters of estuaries, where they settle on rocky shores and reduce the space available for native species.

Low temperatures slow down growth and decrease food availability to fish and other grazing animals.

Factors that influence water temperature include time of day, season, depth of water, flow rate, tidal influence, nearby cooling water outfalls and the location and depth of the sampling point. Recording these other factors when taking your temperature reading will help ensure that your data is more useful for the management of your estuary.

There are several methods used to measure water temperature. The most common methods use a glass or electronic thermometer. A glass thermometer is the cheaper. An accurate electronic thermometer is quite expensive in comparison. Accurate electronic temperature sensors are commonly found in multi-sensor CTP meters, where conductivity, temperature and pH are measured together.

Temperature readings are used to interpret other parameters. Higher water temperature influences the ability of water to hold oxygen, and may influence salinity readings. Refer to the activities *Measuring salinity* and *Measuring dissolved oxygen* for more details.

What you may need:

- site record form
- red spirit thermometer
- collection bottle attached to a pole for sampling.

To ensure good results:

The thermometer should be calibrated yearly against a certified thermometer.

Thermometers should be checked prior to every use for bubbles in the red spirit or cracks in the glass. If bubbles or gaps are found in the red spirit, the thermometer should be 'shaken down' until the bubbles or gaps disappear. If cracks are found the thermometer should be replaced.

What to do:

Collect a water sample from at least a metre out from the shore (preferably further out) and from approximately 200–mm below the surface.

Place the thermometer into the water sample as soon as it is collected and leave the thermometer in the water until the reading stabilises (this may take up to two minutes).

Record the reading on the site record form as degrees Celsius (°C)



Measuring pH

pH is technically the hydrogen potential of a liquid. In common language it is a measure of the acidity or alkalinity.

pH ranges from 1 to 14. When a liquid has a pH of 7 it is considered neutral. A pH of less than 7 is acidic and more than 7 is alkaline or basic.

The pH value of water is critical to the survival of many aquatic plants and animals, thus monitoring of pH is an important part of all water quality monitoring programs. pH values of water in the environment may vary considerably. Pure water is neutral. Freshwater streams often have a pH of between 6.5 and 8.0. Estuarine waters usually have a pH of between 6.5 and 9.2 (EPA, 2003).

pH readings may rise with rising salinity, as many of the salts found in Australian streams are alkaline. High pH readings may also indicate the presence of an algal bloom.

Areas with large amounts of peat or organic litter in the water can have very low (< 5) pH readings as a result of humic acids released from the rotting organic matter.

Pollution may raise or lower pH values outside their normal limits. Adelaide has large areas of potential, and actual, acid sulphate soils that are the result of diking areas of saltmarsh away from the sea. These areas are leaching and generating very acid groundwater (often less than 4), which then enter our estuaries. Some industrial wastes, particularly from caustic plants, can be highly alkaline, and these are regularly discharged into estuarine environments.

Activity: Core

Age: All

Time: 2

Why? The pH of water controls the solubility of many metals such as iron and copper. Low pH may indicate acid rain events or acid soil drainage. Values outside the range 5-10 indicate industrial pollution or cataclysmic events. Estuaries are normally between 6.5 and 8.5 (lower in their freshwater end, higher at the marine end).

Safety: Dispose of all reagent/sample mixes appropriately. If water is suspected to be strongly acidic or alkaline avoid skin contact when handling samples.

pH may be measured using pH strips (with a resolution of 0.5 pH units), pH liquid test kits (with a resolution of 0.2 units) or with a probe and multi-purpose meter (with a resolution of less than 0.1 pH units). The pH strips are the cheapest and most rugged option but are less precise than the other two methods. Some types of strip are affected by salinity.

To detect smaller significant variations in pH, some knowledge of the estuary being monitored and its normal pH values is required. Extreme readings will be immediately obvious, however some estuaries may naturally be low in pH, while other estuaries, possibly with more sea influence, will be considerably higher. The natural pH range of most estuarine or marine areas in the state should be between 6.5 and 9.2 pH units. Values outside this range would indicate some form of past or present human interference

What you may need:

- site record form
- a box of pH strips that are suitable for seawater, or alternatively a meter
- a pH buffer solution with a value of 4 or 10
- sample dipper mounted to a pole for water sampling.

To ensure good results

pH strips may become inaccurate or not react at all as they age, or if they are exposed to water. If your packet of strips becomes wet please dispose of them.

Test your pH strips before each monitoring event to make sure that they provide an accurate reading in a reasonable length of time. This is done by immersing one of the strips into a fresh solution of known pH, checking that the strip provides the correct reading, and then disposing of the used strip. Should your test strip not perform adequately, please dispose of the entire pack and open a new one.

Estuaries generally have a basic pH, so the most appropriate pH buffer for estuarine monitoring would be the pH10 buffer. Using a pH7 buffer is not recommended as the unreacted colour of most pH strips is in the neutral range.

If you are using a pH meter or combined CTP meter, ensure it is calibrated prior to going out into the field.

What to do:

Collect a water sample from at least a metre out from the shore (preferably further out) and from approximately 200 mm below the surface.

Place a pH strip in the water sample and leave it in the water until no further colour change occurs (up to five minutes).

Remove pH strip from sample and immediately compare the colours on the strip with those on the packet.

Record the reading on the site record form.

Should you be using a meter, gently place the probes into the sample and allow them to equilibrate with the sample temperature. Once the reading has stabilised, record it on the site record form.



Measuring water clarity

Activity: Core

Age: All

Time: 2

Why? Water clarity controls the depths at which submerged plants can grow. The turbidity (cloudiness) of water may indicate erosion or algal blooms and is a useful measure for mapping stormwater plumes. EPA guidelines for estuaries suggest that 1 NTU or less is good, while more than 10 NTU is poor.

Safety: Secchi disks are deployed in deep water (eg from bridges, jetties, wharfs and boats).

Water clarity is an indirect measure of the amount of suspended solids in the water. As the amount of suspended solids increases, the depth that light can penetrate is reduced. There is no direct correlation between the weight of solids present in the water and water clarity. This is due to the effects of particle size–many smaller particles reflect more light than a few big particles.

Water clarity (measured with a Secchi disk) is frequently used as an alternative to turbidity measurement. However, the relationship between turbidity (measured in nephelometric turbidity units or NTUs) and clarity (measured in depth) is not perfect. An approximate correlation is given in the data interpretation section, as this is common practice in clear waters.

Water clarity may be naturally low (turbid) during or just after flooding. Lower water clarity can also be an indication of unsound land use management in the estuary's catchment. Higher levels of erosion in the catchment will result in lower water clarity in the estuary for a longer period of time.

Reduced water clarity can affect marine plant growth and reduces the depth range and extent of seagrass and **macrophyte** beds. The fine particles may deter some fish species or clog the feeding apparatus of filter feeding animals. A wide range of toxic or harmful pollutants can attach themselves to fine sediment, so low water clarity may also indicate high levels of other pollutants.

Common methods for measuring water clarity include the Secchi disk, the turbidity meter and the turbidity tube. Estuaries often have very high water clarity readings compared to freshwater rivers and streams, so Secchi disks are recommended for estuarine areas. Turbidity meters are available for the turbidity ranges found in estuaries, and they give a useful and often more accurate measure of light availability to benthic plants. However, they are considerably more costly, less robust and require calibration using formazine standards, which are toxic. Turbidity tubes are not sufficiently sensitive for clear marine waters.

What you may need:

- site record form
- Secchi disk (directions for making a Secchi disk are included in Appendix 1)
- tape measure (if Secchi disk cord is not marked with millimetres).

To ensure good results:

Secchi depth readings should ideally not be taken within two hours of sunset or sunrise, they should be done with a clear sky, calm water and without wearing sunglasses.

You may find you obtain more consistency in the readings if you take them from the shady side of the boat or jetty.

Use a minimal stretch nylon rope, or other shrink resistant line, for the Secchi disk. Check the length of the rope every six months to ensure that it has not stretched or shrunk. Rinse the disk off after use so that salt does not build up on the cord or disk.

What to do:

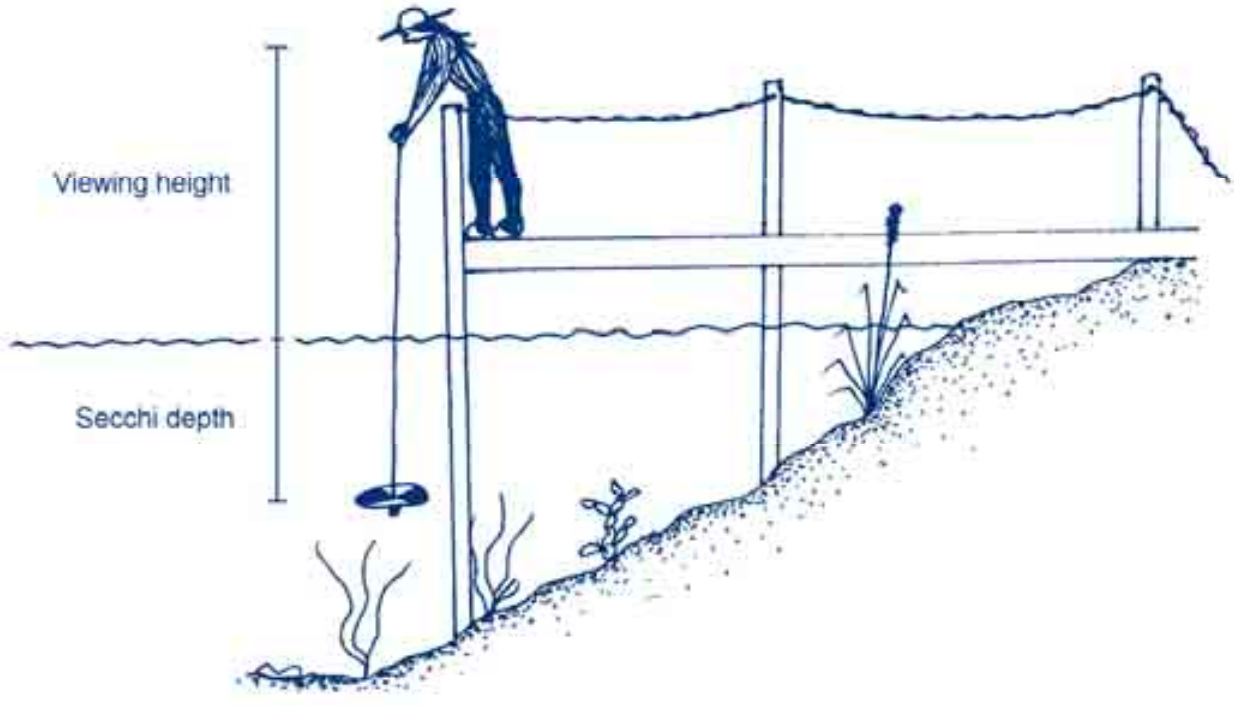


Figure 2—Taking a Secchi depth reading

A Secchi disk is a special disk marked with black and white quarters. Slowly lower the Secchi disk into the water until the black and white disk just disappears from sight. Note this depth.

When the disk disappears, raise the disk slowly until it just becomes visible again. You need to be able to distinguish between the black and white sections of the disk. Note this depth.

The Secchi depth is the average between the two readings. Most Secchi disks have a marked cord, which makes recording these depths easy, providing you are not too high above the water. If the disk reaches the bottom of the estuary and can still be seen then record the depth as 'greater than' and the depth of the water at that point.

Record the Secchi depth, measurement site, viewing distance from observer to water line and anything else you think may have an effect on the result, on your site record form.

The conversion between turbidity and water clarity varies, however a rough 'rule of thumb' for South Australian estuaries (developed by the EPA) is included below (Table 1).

Table 1—Secchi depth and turbidity relationship

2 NTU	10 m
5 NTU	4 m
10 NTU	2 m
25 NTU	0.9 m
100 NTU	0.2 m

Measuring salinity

Salinity is a measure of the amount of dissolved salts in a given unit of water. The salinity of seawater is normally around 3–4%. Estuaries have a salinity gradient, which means that the salinity at one end of the estuary will differ from that at the other.

Each estuary has its own salinity regime. Human activities, such as using water for irrigation or stormwater discharge, have altered these salinity regimes significantly in many estuaries. Taking regular salinity readings gives you an indication of what kind of salinity regime occurs in your estuary and therefore what you may expect from other parameters.

The salinity range is wide in South Australian estuaries and this makes finding instruments to measure salinity difficult. One method is to measure the change in conductivity that occurs when salts are dissolved in water. Common pocket conductivity meters have a range from freshwater to about half that of seawater. Some estuaries in South Australia have salinities of up to three or four times that of seawater. Conductivity meters that measure these sorts of salinities cost a considerable amount and require regular calibration specifically for the salinity ranges that are most commonly encountered in the area where they are used. Finally, the conversion of conductivity to salinity as total dissolved solids (TDS) in g/L, although a well-known relationship, is not a simple line in the range of salinities found in estuaries.

The change in the way light refracts through salty water is the basis for another method that uses a refractometer to measure salinity. Refractometers are both relatively fragile and have a very small scale, making reading these instruments a little difficult for novice users.

Activity: Core

Age: All

Time: 2

Why? Salinity is the dissolved salt content of water. Salinity and temperature are the primary controllers of stratification in estuaries. Salinity affects the amount of oxygen that can remain dissolved in water, and has an impact on the flocculation rate of suspended particles. Plants and animals are distributed in estuaries according to their salinity preferences.

Safety: If using glass instruments, handle carefully. Keep a sharps container on hand for broken glass.

The use of hydrometers to measure specific gravity (which correlates well to TDS as g/L) is recommended in this program, as they are available in a wide selection of salinity ranges, are economical and can be purchased with a quality certification.

Hydrometers consist of a blown glass tube, sealed at both ends, with a bubble of air in the middle and a weight at the bottom. Hydrometers work on the principle that the more salt the water contains the heavier or denser it becomes and the better it is at floating things. This is why it is easier to swim in salt water than in freshwater.

A litre of pure water weighs approximately one kg and has a hydrometer reading, or specific gravity, of 1.000 at 15.6°C. If you dissolved 20 grams of salt into that water, its volume would be similar (well, a smidgin more), but it would weigh 20 grams more, and the hydrometer reading would go up accordingly.

A table has been included in this section that allows you to convert the hydrometer reading of your estuary water into TDS g/L. As water changes volume depending on temperature, all hydrometer readings need to be corrected to reflect the temperature of the water as well, and the table includes this correction.

What you may need:

- site record form
- hydrometer in the SG range 1.000–1.050
- sampling container attached to a pole
- thermometer.

To ensure good results:

Use a hydrometer that has been checked against a known standard (usually recorded on the box or on a certificate accompanying the hydrometer. If the hydrometer is cracked or broken it needs to be replaced with a new one. These are available from most scientific supply houses.

Spinning the hydrometer in the water a little as it is placed into the sample will break the surface tension of the water and ensure a more accurate result.

Care must be taken that the hydrometer is suspended in the water without touching the sides of the sampling container to ensure a true result is obtained.

Water in a narrow container or surrounding a vertical tube forms a slightly curved surface, called a 'meniscus'. The water level is read at the bottom of the meniscus.

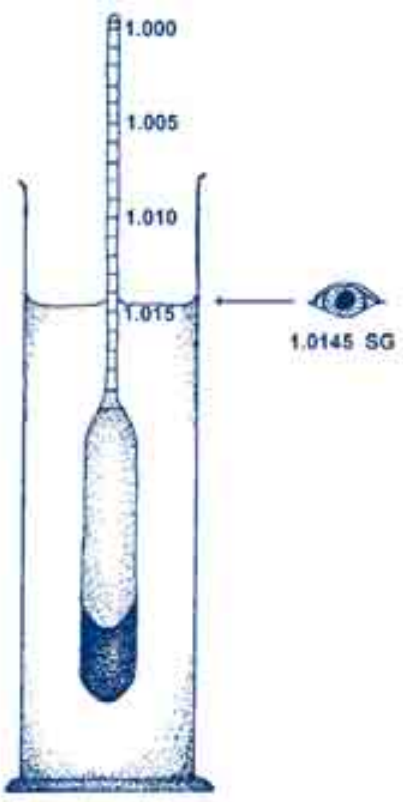


Figure 3—Reading a hydrometer

What to do:

Collect a water sample from at least a metre out from the shore (or further) and approximately 200 mm below the surface.

Measure the temperature according to the water temperature guideline. Record this on the site record form.

Place the hydrometer in the water sample. Leave it until it settles. Read off the number that is nearest to the base of the meniscus (see Figure 3).

Record the uncorrected reading on datasheet. Measure the temperature of the water and record it. The g/L TDS may then be calculated in the field, or later, and recorded.

The salinity of water may be stated in a variety of ways. If trying to compare salinity readings with the results of another group or survey, it is important that the salinity unit is known. A conversion chart between some of the more common types of salinity readings is provided in Table 3.

Should you be using a conductivity meter to measure salinity, be sure to follow the manufacturer's instructions. Many conductivity meters and probes have temperature compensation, which automatically compensates the reading to an EC value at 25°C. You will need to refer to the owner's manual to find out if the meter you are using has this feature, and make a note on the datasheet.

If there is no automatic temperature compensation on your meter, then your EC readings will need to be modified using the formula below:

$$K_{25}\ (\text{conductivity at } 25\ ^\circ\text{C}) = \frac{\text{conductivity}}{1 + 0.019\ (\text{water temperature} - 25)}$$

Table 2—Obtaining TDS g/L from SG and temperature

	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0
1.000					0.0	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.8	1.1	1.4	1.6	1.9	2.1	2.5	2.9	3.2	3.6	4.0	4.4	4.8	5.1
1.001	0.2	0.2	0.2	0.2	0.5	0.5	0.6	0.6	0.7	0.8	1.0	1.2	1.5	1.6	1.9	2.1	2.4	2.5	2.8	3.1	3.4	3.8	4.2	4.5	4.9	5.1	5.5	5.9	6.4
1.002	1.5	1.5	1.6	1.6	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.8	2.9	3.2	3.4	3.7	4.0	4.2	4.6	4.9	5.1	5.5	5.9	6.3	6.6	7.0	7.5	7.9
1.003	2.8	2.8	2.8	2.9	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.1	4.2	4.5	4.8	5.0	5.3	5.5	5.9	6.2	6.6	6.8	7.2	7.6	8.0	8.4	8.8	9.2
1.004	4.1	4.1	4.1	4.2	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.4	5.5	5.8	6.1	6.3	6.6	7.0	7.2	7.5	7.9	8.3	8.5	8.9	9.3	9.7	10.1	10.5
1.005	5.3	5.4	5.4	5.4	5.5	5.5	5.7	5.8	5.9	6.2	6.3	6.6	6.7	7.0	7.1	7.4	7.6	7.9	8.3	8.5	8.9	9.2	9.6	10.0	10.2	10.6	11.1	11.5	11.9
1.006	6.6	6.6	6.7	6.7	6.8	6.8	7.0	7.1	7.2	7.5	7.6	7.9	8.0	8.3	8.5	8.8	9.1	9.3	9.6	9.8	10.2	10.5	10.9	11.3	11.6	12.0	12.4	12.8	13.2
1.007	7.9	7.9	7.9	8.0	8.1	8.1	8.3	8.4	8.5	8.8	8.9	9.2	9.3	9.6	9.8	10.1	10.4	10.6	10.9	11.3	11.5	11.9	12.2	12.6	13.0	13.4	13.8	14.2	14.6
1.008	9.2	9.2	9.2	9.3	9.3	9.4	9.6	9.7	9.8	10.0	10.2	10.5	10.6	10.9	11.1	11.4	11.7	11.9	12.2	12.6	12.8	13.2	13.6	13.9	14.3	14.7	15.1	15.5	15.9
1.009	10.4	10.5	10.5	10.6	10.6	10.7	10.9	11.0	11.1	11.3	11.5	11.8	11.9	12.2	12.4	12.7	13.0	13.2	13.6	13.9	14.1	14.5	14.9	15.3	15.7	16.1	16.5	16.9	17.3
1.010	11.7	11.7	11.8	11.8	11.9	12.0	12.2	12.3	12.4	12.6	12.8	13.1	13.2	13.5	13.7	14.0	14.3	14.5	14.9	15.2	15.6	15.8	16.2	16.6	17.0	17.4	17.8	18.2	18.7
1.011	13.0	13.0	13.1	13.1	13.2	13.4	13.5	13.6	13.7	13.9	14.1	14.4	14.5	14.8	15.0	15.3	15.6	16.0	16.2	16.5	16.9	17.3	17.5	17.9	18.3	18.8	19.2	19.6	20.0
1.012	14.1	14.3	14.3	14.4	14.5	14.7	14.8	14.9	15.0	15.2	15.4	15.7	15.8	16.1	16.3	16.6	17.0	17.3	17.5	17.9	18.2	18.6	19.0	19.3	19.6	20.1	20.5	20.9	21.4
1.013	15.4	15.4	15.6	15.7	15.8	15.8	16.0	16.2	16.3	16.5	16.7	17.0	17.1	17.4	17.7	17.9	18.3	18.6	18.8	19.2	19.5	19.9	20.3	20.6	21.0	21.4	21.9	22.3	22.7
1.014	16.7	16.7	16.9	17.0	17.0	17.1	17.3	17.5	17.7	17.8	18.0	18.3	18.6	18.7	19.0	19.3	19.6	19.9	20.1	20.5	20.9	21.2	21.6	22.0	22.3	22.7	23.2	23.6	24.0
1.015	17.9	18.0	18.0	18.2	18.3	18.4	18.6	18.8	19.0	19.1	19.3	19.6	19.9	20.0	20.4	20.6	20.9	21.2	21.6	21.8	22.2	22.5	22.9	23.3	23.6	24.0	24.6	25.0	25.3
1.016	19.2	19.3	19.3	19.5	19.6	19.7	19.9	20.1	20.3	20.4	20.6	20.9	21.2	21.3	21.7	22.0	22.2	22.5	22.9	23.3	23.5	23.9	24.3	24.7	25.1	25.5	25.9	26.3	26.8
1.017	20.5	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.6	21.7	22.0	22.2	22.5	22.7	23.0	23.3	23.5	23.8	24.2	24.6	24.8	25.2	25.6	26.0	26.4	26.9	27.3	27.7	28.1
1.018	21.7	21.8	22.0	22.1	22.2	22.3	22.5	22.6	22.9	23.0	23.3	23.5	23.8	24.0	24.3	24.6	24.8	25.2	25.5	25.9	26.1	26.5	26.9	27.3	27.7	28.3	28.7	29.0	29.4
1.019	23.0	23.1	23.3	23.4	23.5	23.6	23.8	23.9	24.2	24.3	24.6	24.8	25.1	25.3	25.6	25.9	26.1	26.5	26.8	27.2	27.6	27.8	28.2	28.6	29.0	29.5	30.0	30.4	30.8
1.020	24.3	24.3	24.4	24.6	24.7	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.4	26.6	26.9	27.2	27.4	27.8	28.2	28.5	28.9	29.2	29.6	30.0	30.4	30.9	31.2	31.6	32.1
1.021	25.6	25.6	25.7	25.9	26.0	26.1	26.4	26.5	26.8	26.9	27.2	27.4	27.7	27.9	28.2	28.5	28.9	29.1	29.5	29.8	30.2	30.6	30.9	31.3	31.7	32.2	32.5	33.0	33.4
1.022	26.8	26.9	27.0	27.2	27.3	27.4	27.7	27.8	28.1	28.2	28.5	28.7	29.0	29.2	29.5	29.8	30.2	30.4	30.8	31.2	31.5	31.9	32.2	32.6	33.0	33.5	33.9	34.3	34.8
1.023	28.1	28.2	28.3	28.5	28.6	28.7	28.9	29.1	29.4	29.5	29.8	30.0	30.3	30.6	30.8	31.2	31.5	31.7	32.1	32.5	32.8	33.2	33.5	33.9	34.4	34.9	35.2	35.6	36.2
1.024	29.4	29.5	29.5	29.8	29.9	30.0	30.2	30.4	30.6	30.8	31.1	31.3	31.6	31.9	32.1	32.5	32.8	33.2	33.4	33.8	34.2	34.5	35.0	35.4	35.7	36.2	36.5	37.1	37.5
1.025	30.6	30.7	30.8	30.9	31.1	31.3	31.5	31.7	31.9	32.1	32.4	32.6	32.9	33.2	33.4	33.8	34.1	34.5	34.7	35.1	35.5	35.9	36.3	36.7	37.1	37.5	37.8	38.4	38.8
1.026	31.9	32.0	32.1	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.7	33.9	34.2	34.5	34.7	35.1	35.4	35.8	36.0	36.4	36.8	37.2	37.6	38.0	38.4	38.8	39.3	39.7	40.2
1.027	33.2	33.3	33.4	33.5	33.7	33.9	34.1	34.3	34.5	34.7	35.0	35.2	35.5	35.8	36.2	36.4	36.7	37.1	37.5	37.7	38.1	38.5	38.9	39.3	39.8	40.2	40.6	41.0	41.5
1.028	34.5	34.5	34.7	34.8	35.0	35.1	35.4	35.6	35.8	36.0	36.3	36.5	36.8	37.1	37.5	37.7	38.1	38.4	38.8	39.1	39.4	39.9	40.2	40.7	41.1	41.5	41.9	42.5	42.9
1.029	35.6	35.8	35.9	36.2	36.3	36.4	36.7	36.8	37.1	37.3	37.6	37.8	38.1	38.4	38.8	39.0	39.4	39.7	40.1	40.5	40.8	41.2	41.6	42.0	42.4	42.8	43.3	43.8	44.2
1.030	36.9	37.1	37.2	37.3	37.6	37.7	38.0	38.1	38.4	38.6	38.9	39.1	39.4	39.7	40.1	40.3	40.7	41.0	41.4	41.7	42.1	42.6	42.9	43.3	43.8	44.2	44.6	45.1	45.6
1.031	38.2	38.4	38.5	38.6	38.9	39.0	39.3	39.4	39.7	39.9	40.2	40.5	40.7	41.0	41.4	41.8	42.0	42.3	42.7	43.1	43.4	43.9	44.3	44.7	45.1	45.5	45.9	46.5	46.9
1.032	39.5	39.6	39.8	39.9	40.1	40.3	40.6	40.7	41.0	41.2	41.5	41.7	42.0	42.4	42.7	43.0	43.3	43.7	44.1	44.4	44.8	45.2	45.6	46.0	46.5	46.8	47.3	47.8	48.3
1.033	40.8	40.9	41.0	41.2	41.4	41.6	41.9	42.0	42.3	42.5	42.8	43.0	43.3	43.7	44.1	44.3	44.7	45.0	45.4	45.7	46.2	46.6	46.9	47.3	47.8	48.2	48.6	49.2	49.6
1.034	42.0	42.2	42.3	42.4	42.7	42.9	43.2	43.3	43.6	43.8	44.1	44.3	44.6	45.0	45.4	45.6	46.0	46.3	46.7	47.0	47.5	47.9	48.3	48.7	49.2	49.5	50.0	50.5	51.0
1.035	43.3	43.4	43.6	43.8	44.0	44.1	44.4	44.6	44.9	45.1	45.4	45.7	46.0	46.3	46.7	47.0	47.3	47.6	48.0	48.4	48.8	49.2	49.6	50.0	50.5	50.9	51.3	51.9	52.3
1.036	44.5	44.7	44.8	45.0	45.3	45.4	45.7	45.9	46.2	46.4	46.7	47.0	47.3	47.6	48.0	48.3	48.6	49.0	49.4	49.7	50.1	50.6	50.9	51.4	51.8	52.3	52.7	53.2	53.7
1.037	45.8	46.0	46.1	46.3	46.6	46.7	47.0	47.2	47.5	47.7	48.1	48.3	48.6	48.9	49.4	49.6	49.9	50.3	50.7	51.0	51.5	51.9	52.3	52.7	53.2	53.6	54.0	54.6	55.0
1.038	47.1	47.2	47.4	47.6	47.8	48.0	48.3	48.5	48.8	49.0	49.4	49.6	49.9	50.2	50.7	50.9	51.3	51.6	52.0	52.3	52.8	53.2	53.6	54.0	54.5	54.9	55.4	55.9	56.4
1.039	48.3	48.5	48.7	48.9	49.1	49.3	49.6	49.8	50.1	50.3	50.7	50.9	51.2	51.6	52.0	52.2	52.6	52.9	53.3	53.7	54.1	54.6	54.9	55.4	55.9	56.3	56.7	57.2	57.7
1.040	49.6	49.8	49.9	50.1	50.4	50.5	50.9	51.1	51.4	51.6	52.0	52.2	52.5	52.9	53.3	53.5	53.9	54.3	54.7	55.0	55.5	55.9	56.3	56.7	57.2	57.6	58.0	58.6	59.0
1.041	50.9	51.0	51.2	51.4	51.7	51.8	52.2	52.3	52.7	52.9	53.3	53.5	53.8	54.2	54.7	54.9	55.2	55.6	56.0	56.3	56.8	57.2	57.6	58.0	58.5	59.0	59.4	59.9	60.4
1.042	52.1	52.3	52.5	52.7	53.0	53.1	53.5	53.6	54.0	54.2	54.6	54.8	55.1	55.5	56.0	56.2	56.5	56.9	57.3	57.6	58.1	58.6	58.9	59.4	59.9	60.3	60.7	61.3	61.7
1.043	53.4	53.6	53.8	54.0	54.2	54.4	54.7	54.9	55.3	55.5	55.9	56.1	56.4	56.8	57.3	57.5	57.8	58.2	58.6	59.0	59.4	59.9	60.3	60.7	61.2	61.6	62.1	62.6	63.1
1.044	54.7	54.9	55.0	55.3	55.5	55.7	56.0	56.2	56.6	56.8	57.2	57.4	57.7	58.1	58.6	58.8	59.2	59.5	60.0	60.3	60.8	61.2	61.6	62.1	62.6	63.0	63.4	64.0	64.4
1.045	55.9	56.1	56.3	56.5	56.8	57.0	57.3	57.5	57.9	58.1	58.5	58.7	59.1	59.4	60.0	60.1	60.5	60.9	61.3	61.6	62.1	62.6	62.9	63.4	63.9	64.3	64.8	65.3	65.8
1.046	57.2	57.4	57.6	57.8	58.1	58.2	58.6	58.8	59.2	59.4	59.8	60.0	60.4	60.7	61.3	61.4	61.8	62.2	62.6	62.9	63.4	63.9	64.3	64.7	65.2	65.7	66.1	66.7	67.1
1.047	58.5	58.7	58.8	59.1	59.4	59.5	59.9	60.1	60.5	60.7	61.1	61.3	61.7	62.1	62.6	62.8	63.1	63.5	63.9	64.3	64.8	65.2	65.6	66.1	66.6	67.0	67.4	68.0	68.5
1.048	59.7	59.9	60.1	60.4	60.7	60.8	61.2	61.4	61.8	62.0	62.4	62.6	63.0	63.4	63.9	64.1	64.4	64.8	65.3	65.6	66.1	66.6	66.9	67.4	67.9	68.3	68.8	69.4	69.8
1.049	61.0	61.2	61.4	61.6	61.9	62.1	62.5	62.7	63.1	63.3	63.7	63.9	64.3	64.7	65.3	65.4	65.8	66.2	66.6	66.9	67.4	67.9	68.3	68.7	69.3	69.7	70.1	70.7	71.2
1.050	62.2	62.5	62.7	62.9	63.2	63.4	63.8	64.0	64.4	64.6	65.0	65.2	65.6	66.0	66.6	66.7	67.1	67.5	67.9	68.2	68.8	69.2	69.6	70.1	70.6	71.0	71.5	72.1	72.5

The table below is based on one developed by Professor Bill Williams of Adelaide University, and presented at the 6th International Symposium on Saline Lake Research, Beijing, 1994. It is for brine between 22°C and 25°C. The table may be used to convert between various salinity measurements.

Table 3—William's salinity conversion table

Specific gravity	Brinometer degrees	Baume degrees	% salinity (% NaCl in brine)	Seawater salinity % scale	TDS (g/L or ppt w/v)	TDS (g/kg or ppt w/w)	EC (mS/cm)
1.0000	0	0.0	0.000	0	0.0	0	0.0
1.0040	2	0.6	0.528	16	6.6	6	9.0
1.0050	3	0.7	0.704	20	8.2	7	11.0
1.0070	4	1.0	1.056	29	10.9	10	16.0
1.0100	5	1.4	1.452	40	14.9	14	21.8
1.0107	6	1.5	1.544	43	15.1	15	23.2
1.0110	6	1.6	1.584	44	15.5	15	23.8
1.0140	8	2.0	2.020	57	20.2	20	30.2
1.0150	8	2.1	2.112	60	21.8	21	31.6
1.0180	9	2.5	2.482	71	25.4	25	37.1
1.0190	10	2.7	2.640	76	27.1	27	39.0
1.0200	10	2.8	2.772	80	28.6	28	41.0
1.0214	11	3.0	2.956	86	30.6	30	44.0
1.0230	12	3.3	3.167	92	32.9	32	47.0
1.0250	13	3.5	3.540	100	35.8	35	50.7
1.0260	14	3.7	3.695		37.3	36	52.5
1.0286	15	4.0	4.038		41.1	40	57.3
1.0300	16	4.2	4.223		42.4	42	59.8
1.0322	17	4.5	4.513		46.4	45	63.8
1.0340	18	4.8	4.750		49.0	47	66.9
1.0359	19	5.0	5.001		51.7	50	70.1
1.0380	20	5.3	5.279		54.1	53	73.7
1.0395	21	5.5	5.477		55.8	55	76.3
1.0400	21	5.6	5.543		56.4	56	77.0
1.0420	22	5.8	5.807		60.3	58	81.0
1.0431	23	6.0	5.952		62.5	60	82.4
1.0460	24	6.4	6.335		66.7	64	87.0
1.0468	24	6.5	6.441		67.9	65	88.3
1.0500	26	6.9	6.863		70.6		



Mapping your estuary

Understanding the mixing processes in your estuary requires an understanding of the geography of the estuary. Saltwater and freshwater mix differently depending on the shape of the 'container' they are in.

To demonstrate this, mixing patterns in a 250–mL measuring cylinder may be compared with mixing patterns in a wide shallow bowl. Simply pour 100–mL of thick oil into the two containers, then 100–mL of very thin oil on top. Gentle swirling of the shallow bowl will cause considerable mixing, while gentle swirling of the deep, narrow measuring cylinder will have little effect at all.

Examination of maps of your estuary may help to explain some of the readings you obtain in the field. Mapping also allows you to measure shoreline changes such as erosion, or the development of sandbanks that may change flow patterns within the estuary.

A wide variety of maps is available. Standard references for your estuary should include at least one large–scale topographic map. As you deepen your understanding of your estuary, you may wish to add bathymetric maps (that map the underwater features), aerial photography, **orthophoto** maps (aerial photographs that have been **georectified** and have topographic details superimposed on them), and satellite imagery.

Activity: Extension

Age: High school

Time: Variable

Why? The width-to-length-to-depth ratio of an estuary has an influence on the mixing of the fresh and saline waters within it. Mapping shoreline changes over time may allow any changes in the quantity of flow, or the effects of riparian clearing, to be noted.

Safety: This is a desk-based activity.

Maps may be purchased as paper products, or digitally, on CD ROM. In South Australia, Mapland provides a wide range of mapping products for areas within the state, and a smaller range for other parts of Australia.

What you may need:

- large scale maps or aerial photos of your estuary (try to get a map that includes your estuary on one sheet—if you have a really large estuary, choose the scale that shows you the most detail, and paste as many maps together as you require)
- tide books
- measuring tools such as callipers, rulers and compasses.

What to do:

If you need help interpreting topographic maps, Mapland stock a range of books that may assist. Two Australian books on map reading are:

Armstrong, P (1987), *Reading and Interpretation of Australian and New Zealand Maps*, 2nd edition, Longman Cheshire, Melbourne.

State Emergency Service (1991), *Map Reading Handbook*, 2nd edition, TASMAP, Dept of Environment and Planning, Tasmania.

Using the scale on your map as a guide, work out how **long** your estuary is. It may be tricky determining where the head of the estuary is—it is usually considered to be the point farthest upstream that still has a rise and fall in tide. This may not be marked on your map and you may need to make some field observations.

Take several measurements across the **width** of the estuary. What is the average width of your estuary? Does it vary much? A very wide estuary may sometimes be subject to **Coriolis forces**, which push the

denser seawater to one side of the estuary, and the freshwater to the other. Does this happen in your estuary?

Now try to calculate the **area** of your estuary. You will need this information to determine whether your estuary is negative or positive (see the guideline *Is your estuary positive or negative?*). Measuring area on maps that have a grid drawn on them is not difficult, but it may be harder on aerial photographs. See the guideline *Using aerial photographs to map habitat change* for details on working out areas.

Depth is an important measure. It may be available from bathymetric maps, or from your harbour master. Is your estuary deep with steep sides, or wide and shallow with deeper channels?

Once you know the average depth, you can calculate the **volume** of water in your estuary. For a very rough estimate, multiply the square metres of area by the metres of depth. Each resulting cubic metre is a kilolitre of water. To get a more accurate measure, divide your estuary up into different zones, and calculate the area and volume for each zone.

Each day the **tide** comes in and out of your estuary. When the moon is full, the spring tides bring in huge amounts of water, while the neap tides of half-moon have the smallest tidal exchange. By looking at the difference in height between high and low tide at neaps and springs, and then looking at your topographic and bathymetric maps, you may be able to gain a rough idea of the volume of water that moves in and out with the tide. This water, the **tidal exchange**, has a major influence of how long it takes for pollutants to disperse in your estuary. An estuary with a small tidal exchange retains the pollutants for considerably longer than a similar estuary with more exchange.

You may gain quite a lot of information about shoreline deposits, erosional areas and sand bars from your maps. Besides using that information in your fieldwork, note any changes you observe. Large changes in the shoreline or in deposition areas such as sandbanks may reflect land management practices in the catchment.

The information that you gather in this activity will be very useful in the activities that follow in the next few pages.

If your group becomes very interested in mapping, you may be prepared to spend the time to learn the use of a computerised geographic information system (GIS). These packages simplify the **georectification** and scaling of aerial photographs, and allow you to overlay your field measurements onto topographic and other base maps. They provide a very sophisticated analysis. Free public domain GIS packages are available for those interested in exploring this technology. More information (and the software) can be found at the following web addresses:

- <www.microimages.com> is the site for free TNTlite software (size limited version of TNTmips)
- <grass.baylor.edu> is the site for free, open source GRASS software developed by the US military
- <http://www.esri.com/software/arcexplorer/> is a very basic free GIS from the makers of ArcInfo
- <www.tiem.utk.edu/~sada/> is the free Spatial Analysis and Decision Assistance software page
- <www.mapmaker.com> is the site to download Mapmaker Gratis.



Is your estuary positive or negative?

Positive estuaries are those where the amount of freshwater that naturally enters the estuary exceeds the amount of freshwater lost to the air as evaporation (see Figure 4). Such an estuary will have a salinity gradient that is fresh at its head and will gradually increase to marine at its mouth.

In contrast, a negative estuary loses more freshwater to evaporation each day than enters the estuary. This type of estuary will have **hypersaline** (very salty water) at its head, and the salinity decreases to that of seawater at the mouth. Negative estuaries are very slow at dispersing pollutants–and this may be even more noticeable if tidal exchange is low.

In South Australia many of our estuaries are negative. This is the result of a combination of factors: the overall aridity (high evaporation and low rainfall), and the size of our river catchments. Only one of our rivers (the Murray) has a catchment that extends into wetter parts of Australia.

Activity: Extension

Age: High school

Time: 3

Why? This factor determines the types of salinity patterns in your estuary.

Safety: This is a desk-based activity.

What you may need:

- the area of your estuary
- the gross annual evaporation for your district
- the annual rainfall for your district
- a topographic map or catchment map for your estuary
- alternatively, gauging station data for the river upstream from the estuary can be used to determine water input from upstream.

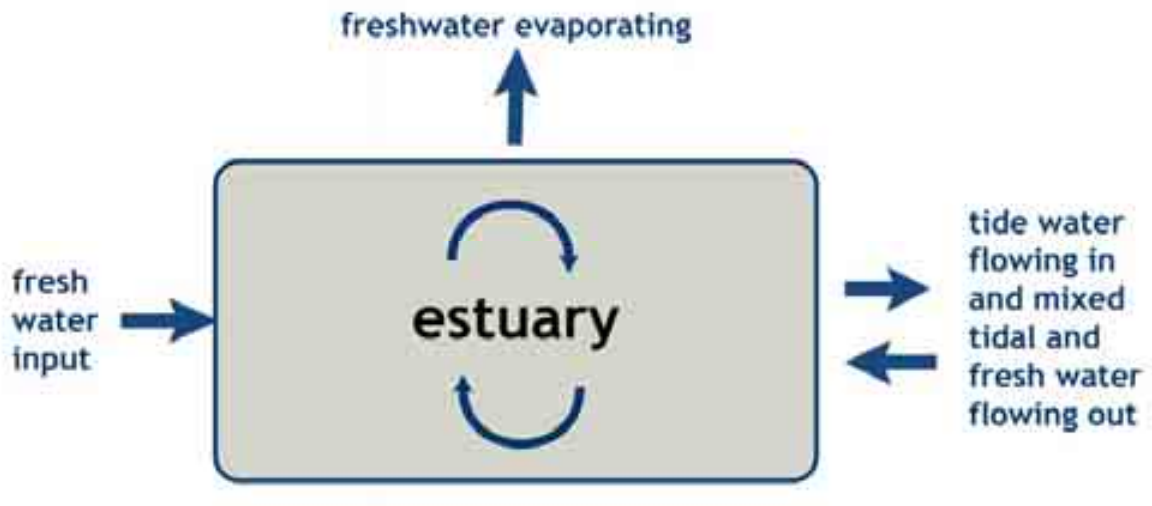


Figure 4—Water movements in an estuary

What to do:

For a small catchment: Take your topographic or catchment map and determine what catchment area is covered with urban development and what area is vegetated or farmed. Record these areas as '**urban area**' and '**rural area**'.

To work out the volume of rain that may run off into the river (and estuary) each year from the land, multiply each area (in m^2) by the annual rainfall (in metres), then by a **runoff coefficient**. While very accurate runoff coefficients have been developed for all types of development, for this purpose two very approximate factors are used. The runoff coefficient for urban areas in this calculation is 0.65, and the runoff coefficient for rural areas is 0.12. Record the cubic metres of water that run into your estuary for the year as **input volume**. Each cubic metre is equal to a kilolitre of water, and 1000 cubic metres equal a megalitre.

Now calculate the amount of water that will evaporate from the water surface of your estuary. For this you need to obtain the evaporation data for your area from the BOM website. The evaporation that the BOM provides is usually in the form of **gross evaporation**, rather than **pan** or **net evaporation**. Subtract the annual rainfall (in mm) from the gross evaporation (in mm) to obtain pan evaporation. Convert this figure from millimetres to metres, then multiply it by the area of your estuary (in m^2). Record the result (in cubic metres) as **evaporation volume**.

Which of these figures is the larger? If the input volume is largest, your estuary is a positive estuary. If the evaporation volume is the larger, your estuary is a negative estuary.

For a large catchment: In rivers such as the Murray, there are many sub-catchments that cover huge areas that have different annual rainfall and evaporation. If your estuary is this type of estuary, you can still calculate the evaporation volume as specified above.

To calculate the input volume, you will require **gauging data** from weirs on your river, as close to the estuary as possible. This will tell you the volume of water that passed over the weir in a year. The data may be in kilolitres or megalitres.

Traps for the unwary: Inter-basin water transfer (for example, from the River Murray to the Torrens and Onkaparinga rivers) may provide an unnatural source of freshwater to your estuary. If your calculations based on runoff show that your estuary would normally be a negative estuary, but your field data shows it to be a positive estuary, you may need to consider where the extra freshwater is coming from. Inter-basin transfers are not always obvious. For example, the outfall from a sewage works is mainly water that originally entered your house as mains water. Are you on a piped water scheme? Many townships in SA obtain their piped water from the River Murray.

Reuse: Pastures and forests have much lower runoff rates than urban areas, which have sealed roads and roofs. What (approximately) would be the runoff from your catchment, if there were no urban areas? Is it very different from the current runoff?

The calculations above are extremely simplified forms of the complex models that natural resource management (NRM) boards may use to determine how much urban stormwater runoff they may responsibly harvest and store in underground aquifers for reuse. Are there any aquifer storage projects in your area? How much water is being injected into the aquifer in those projects? Don't forget to subtract that amount from your input volume!



Classifying your estuary

Geoscience Australia has produced a CD ROM about Australian estuaries, designed for educational use, that includes a classification system for estuaries (commonly called the OzEstuaries classification, developed by Heap *et al,* 2001). The system classifies estuaries into three major types, depending on whether they are dominated by the tide (mainly found in northern Australia where tides are large), by rivers (these are delta estuaries) or by waves (where a sandy barrier of some kind is formed by waves). Each of these groups can be subdivided, providing six subclasses: tide dominated deltas, wave dominated deltas, wave dominated estuaries, strand plains, tide dominated estuaries and tidal flats.

Activity: Extension

Age: High school

Time: 2

Why? Different types of estuaries are very different in their mixing regimes and in how pollution is distributed. Understanding what type of estuary you are studying will help you in understanding why things happen the way they do in your estuary.

Safety: This is a desk-based activity.

What you may need:

- Geoscience Australia (2002) *Australian Estuaries and Coastal Waterways*, a CD ROM produced for the National Land and Water Resources Audit (NLWRA), AGSO GeoScience Australia, Canberra
- a good topographic map of your estuary
- a tide book
- annual rainfall and evaporation totals
- access to the internet to explore the OzEstuaries database on the NLWRA website at <www.ozestuaries.org>.

What to do:

First explore the CD ROM. Can you understand the method the NLWRA use in their classification of estuaries? Looking at your estuary's shape on your topographic map, the range of your tide on your tide book, and your weather details, what type of estuary do you think you may be studying?

Visit the OzEstuaries website. Is your estuary listed on the site? If it is, did the NLWRA come to the same classification as you did? The NLWRA only examined fairly large estuaries, so yours may be part of an 'amalgamated' estuary. If your estuary is listed, pull up some of the detailed data that is entered on the website. If your estuary was too small to be included, look at the data on a similar estuary in the vicinity of yours. Does it have much in common with your estuary?

The data on this site may provide you with lots of information about your estuary, and this may help you in deciding what aspects of your estuary you wish to study further.



Mapping the salinity gradient of your estuary

Activity: Extension

Age: High school

Time: 4

Why? Estuaries vary in salinity from their head to their mouth.

Safety: Salinity gradient mapping may require working over deep water.

Many water quality monitoring programs are based on taking a water sample regularly at the same location each time. This monitoring is a valid method of ensuring replicable sample results, although the samples may not tell you much about the rest of your estuary.

Estuaries have a gradient of salinity along them, starting with either freshwater (in **positive estuaries**) or **hypersaline** water (in **negative estuaries**) at the head of the estuary, and either increasing or decreasing in salinity until at the mouth of the estuary the salinity is that of seawater (**eusaline**).

To look at the salinity gradient in your estuary, multiple samples need to be taken along the estuary–along the edges of the estuary and as close to midstream as you can get (usually from a bridge, or from a jetty or boat).

What you may need:

- salinity profile and gradient record form
- a sampling tube on a pole
- equipment to measure salinity and temperature
- GPS to determine your location if using a boat, or good topographic map if measuring from a jetty or bridge
- sampling platform (seaworthy boat, bridge, jetty).

To ensure good results:

Check your equipment prior to going out into the field. See the method guidelines *Measuring salinity* and *Measuring temperature* for details.

What to do:

Identify your sample location and get there. Record site details such as location coordinates if sampling from a boat. Often a series of several low-level bridges are ideal for this activity, as you may sample on both edges of the estuary and the middle, at several locations along the estuary.

Sample water from about 200–mm below the surface. Once samples are collected, test them for salinity and temperature. See the method guidelines *Measuring salinity* and *Measuring temperature* for details. Record the results for each location.

On return to base, plot the results on a map of the estuary.

This type of information is very useful when making management or monitoring decisions about an estuary (or any coastal water body). More suitable locations for discharging stormwater or clean saltwater effluents (for example from industrial evaporative air conditioning plants, water softening plants, and reverse osmosis plants) may be selected based on the salinity gradient of your estuary.

Mapping the salinity profile of your estuary

Many water quality monitoring programs are based on taking a water sample regularly at the same location and at the same depth each time. This monitoring is a valid method of ensuring replicable sample results, but may not give a representative result in stratified estuaries.

Stratification, or layering, of different salinity waters often occurs in estuaries, particularly in the negative estuaries that are so common in South Australia. Highly saline water is heavier than seawater, so when the tide comes in or a stormwater discharge occurs, the fresher water flows over the top of the more saline water. Stratification can result in reduced dissolved oxygen levels in the deeper layers.

To get a representative sample in a stratified estuary, multiple samples need to be taken at a range of depths as close to midstream as you can get, usually from a bridge, or from a jetty or boat. This method is called profiling.

Activity: Extension

Age: High school

Time: 3

Why? Stratified estuaries have quite different water quality at different depths. To determine how a pollutant will be distributed in an estuary it is necessary to understand the stratification pattern.

Safety: Salinity profiling is conducted in deep water.

A common range of sampling depths would include: 200 mm below the surface, one metre, two metres and then every two metres after that, until the bottom of the water body is reached. If your estuary is particularly shallow, you may like to make the sampling depths closer together. Optimally you would take at least three samples (bottom, middle and near surface) from each location. Salinity, dissolved oxygen (DO), pH and temperature readings are taken for each sample.

Profiles are usually made at a number of locations to produce a salinity stratification map of the estuary, which aids in selecting the most representative site for regular sampling.

What you may need:

- salinity profile and gradient record form
- depth sampling device, marked with 500-mm intervals–these may be purchased or homemade (see Appendix 6 for useful designs)
- multiple sample bottles with lids
- equipment to measure salinity and temperature (DO and pH are optional)
- alternatively you could replace the last two items with a multi-parameter probe that reads EC, DO, pH and temperature with a six-metre cable
- GPS to determine your location if using a boat, or good topographic map if measuring from a jetty or bridge
- sampling platform (seaworthy boat, bridge, jetty).

To ensure good results:

Try to reach your sampling location without disturbing the water unduly. Disturbing the water may mix the stratification layers.

Check your equipment prior to going out into the field. See the method pages *Measuring temperature, Measuring pH, Measuring salinity* and *Measuring dissolved oxygen* for details.

What to do:

Identify your sample location and get there. Record location details such as coordinates, if sampling from a boat.

Use your sampling device to collect water samples at several depths. Most samplers work by removing the lid of the bottles after reaching predetermined depths. Samplers may test several depths at once or may sample single bottles at a time. In the latter case, repeat the collection process until a sample has been collected at each desired depth. When taking repeated samples, collect the shallowest samples first, so as not to disturb the stratification.

Once samples are collected, remove them from the water and test the samples for the desired water quality parameters (salinity, temperature, and maybe pH and DO).

The results will reveal if there are any stratified layers in the water column at your sampling location. If there are no obvious layers, it shows that your estuary has good mixing at that location, on that day. Differences in temperature of only 2°C or salinity changes of a couple of grams per litre may be sufficient to produce a stratification layer.

Low oxygen levels in the deeper samples are a good indicator of slow vertical mixing. This means that the animals and plants on the floor of the estuary will be those that require little oxygen or those that reduce sulphur compounds to extract oxygen.

This type of information is very useful when making management or monitoring decisions about an estuary (or any type of coastal water body). Stratification is more likely to occur in areas that have small tidal ranges, which explains why stratification is so common in South Australian estuaries. Inflows of freshwater may also cause temporary stratification layers.



Mapping turbidity plumes

Mapping turbidity plumes is an event-based monitoring activity. Event-based monitoring is an important, but labour intensive and time sensitive. For successful turbidity plume mapping, people need to respond rapidly and be available at a moment's notice. This type of monitoring is designed to capture the effects of runoff events (particularly the first large event in a wet season) on the estuarine receiving waters.

Mapping of a turbidity plume is done immediately after or during the first major runoff event for the season. A boat is used to go out and map the extent of a turbidity plume from a stormwater discharge point or tributary. The major discharge point for your estuary needs to be identified prior to the event.

Water clarity measurements taken with a Secchi disk, or turbidity measured with a meter are the only parameters required in this activity. However, pH, salinity, dissolved oxygen and nutrients, particularly of the discharge, could also be measured if you have the time.

Turbidity maps are very important when trying to manage an estuary and its associated catchment. These maps measure the immediate decrease in water clarity from a runoff event. In catchments with good land management practices this impact is generally fairly small. The bigger the impact, the worse the land management practices in the catchment generally are.

The fine sediments that cause the decreased water clarity generally bring other pollutants with them. These can include nutrients, heavy metals and hydrocarbons. The first flush of floodwaters is generally the worst, but is often the hardest to capture with monitoring. Other effects of stormwater can be alkaline or acid runoff, chemical pollutants that deplete oxygen concentrations and faecal bacteria. By mapping the turbidity, it is possible to estimate how other pollutants from the event will disperse into the estuary.

Another turbidity map can be created a couple of days after the event to give an idea of how fast the plume, with its associated pollutants, disperses into the ecosystem.

Activity: Extension

Age: High school

Time: 4

Why? Turbidity plumes reveal where the impacts of stormwater pollution are likely to be found.

Safety: This activity is completed either during rain events or when storm water is flowing. Floodwaters can be dangerous.

Never stand in water above knee-height if it is flowing at any speed. Always use some form of sampling device if trying to take a sample in fast-flowing water, as you can let go of it if the flow tries to pull you in. Sample from bridges or other structures rather than a boat if the flows are too great.

Do not go out in lightning storms, when visibility is bad or when there is a heavy weather warning out for boats in coastal areas. Check the BOM website to make sure. **IF IN DOUBT—DON'T GO OUT.** Find some other way to gather the data, or wait until some other runoff event.

What you may need:

- event monitoring form
- Secchi disk
- sample bottles and test equipment for any other parameters being tested
- seaworthy boat and all necessary safety equipment
- GPS for locating sites
- at least two people in the boat and a couple on the shore
- a good topographic map or a bathymetric map of the estuary.

To ensure good results:

Identify the main stormwater drains entering your estuary. Your local council may be able to help you.

Check your test equipment, prior to going out on site. See the method page *Measuring water clarity.*

What to do:

Collect all of your gear together and ensure all your test and safety equipment is stored in the boat. Wait for a rain event. If water is running down the nearby stormwater drains, it will only be a matter of minutes or a couple of hours at most before it starts to enter the estuary. Once water is seen running into the nearby drains in any quantity, gather the monitoring group together and go check your major stormwater discharge location.

Once all safety issues are assessed and addressed, and stormwater is coming out of the stormwater drain, launch your boat and go to the discharge point. Take Secchi disk readings and collect a sample (if required) at the discharge point.

Using your GPS as a guide, move directly out from the discharge point and take another Secchi depth or turbidity reading. Continue away from the discharge point, taking Secchi depths and recording them with your GPS location until the Secchi depth stops increasing. This is the extent of the plume.

Use a similar procedure to work out the width of the plume, taking water samples if you wish to do chemical analyses of them on the boat or later.

The depth of a plume in very stratified estuaries may be estimated by using a multi-parameter probe on a long cable, that records pH, EC, DO and turbidity. To gauge the depth of a plume more accurately, sample the water for suspended solids using a depth-sampling device. See *Mapping the salinity profile of your estuary* for more details on sampling stratified estuaries.

Data from event-based water clarity or turbidity mapping can be compared with data collected during normal monthly sampling. This information will identify the extent that the values of different parameters may be expected to change between normal and storm events.



Where is the 'turbidity maximum'?

In estuaries the water in the upriver part of the estuary and the water in the marine part of the estuary are usually fairly clear (except where very turbid water is coming from a river, such as the Darling River flows in the Murray–Darling system). Within the main part of the estuary, however, the water is often very turbid, highly charged with suspended sediment.

This is known as the **turbidity maximum**. The sediment moves up and down the estuary with the daily tide. It may become diluted during high flood events or disappear during strong tidal flow, but may reform during **neap** tidal cycles.

The phenomenon occurs because very fine particles that are carried in river water come into contact with seawater that contains salts such as carbonates. These help the fine particles to aggregate, forming large, soft flocs. The flocs are heavier than the fine particles were, and they start to settle to the bottom of the estuary. However, they do not form solid sediments on the base of the estuary, and so may be resuspended with the next incoming tide. Thus the zone receives a continuous new supply of new sediment, while resuspending some of the sediment already present.

Activity: Extension

Age: High school

Time: 4

Why? The turbidity maximum in an estuary is the zone where much of the sediment from the river is settled out. The zone forms an important part of many estuarine food chains, but may also be the location where accumulations of toxic metals may occur.

Safety: This may involve work in deep water.

The turbidity maximum for a given estuary is the area where most soft sediments are deposited, and this is the area where metals, etc, in the river water will precipitate. Thus the turbidity maxima of estuaries perform an essential cleaning function of the river water before it enters the sea. The zone is also a rich feeding zone for small macro invertebrates, and therefore provides the basis of many estuarine food chains.

What you may need:

- event monitoring form
- Secchi disk
- seaworthy boat and all necessary safety equipment
- GPS for locating sites
- at least two people in the boat and a couple on the shore
- a good topographic map or a bathymetric map of the estuary, and possibly an aerial photograph.

To ensure good results:

Only conduct this activity in calm conditions with low tidal flows (neap tides). At this time, the turbidity maximum will be more pronounced and easier to detect.

Check your test equipment, prior to going out on site.

What to do:

Review your topographic maps, bathymetric maps and aerial photographs. You may be able to pick the rough location of the turbidity maximum from turbidity visible in the aerial photograph. Use your other maps to look for areas of deposition (sandbanks on the bathymetric maps, in-stream sandy islands on the topographic maps), and the channels around these areas.

Collect all of your gear and ensure all your test and safety equipment is stored in the boat. Wait for calm weather and a neap tide. Once you are sure the conditions are stable, gather the monitoring group and go out into the estuary.

Start from the marine end of the estuary, or at least well on the marine side of the area that you have decided may contain your turbidity maximum. Take Secchi disk readings at regular intervals as you progress upstream, recording each location using your GPS. The guideline *Measuring water clarity* contains details about using the Secchi disk.

The turbidity maximum will be revealed as a series of low clarity readings.

Identifying the location of your estuary's turbidity maximum assists environmental managers who may be studying pollutant accumulation in the estuary. The complex flocs that are formed in this zone are a mixture of organic and inorganic materials, and so this zone may also contain a large population of macro invertebrates. Students working on estuarine macro invertebrates may find that knowing the location of estuarine turbidity maxima provides them with further understanding about the distributions of certain species within estuaries.



Effect of tidal restrictions on wetlands

Studying the effect of tidal restrictions on the wetlands that surround your estuary is a fascinating way of discovering estuarine processes. Estuarine wetlands develop their character from the hydrological regime of the estuary. Monitoring the ground and surface water quality and quantity can provide an insight into the health and long-term changes in these wetlands.

Tidal restrictions may cause a wide range of biological, ecological, chemical and physical effects. Areas with natural or anthropogenic restrictions on tidal movement often have higher salinities or salinity ranges than areas that have free tidal flushing. If there is a large regular freshwater input to a tidally restricted area the lack of tidal flushing may result in reduced salinity. When salinity levels fall below 20 g/L or 2%, opportunistic brackish plants such as *Phragmites australis* (common reed) may start to take over the samphire areas. Many historic developments in South Australia did not consider the impacts of tidal restriction.

Tide restrictions may block the passage of estuarine invertebrates and fish into the upper estuary. Restricted areas may also suffer from a concentration of sediments, organic matter and water pollutants in the marshes, so they become anoxic and smelly.

Sediments that were once regularly submerged in sulphate-rich seawater may sink rapidly when the seawater is drained off and the sediments are exposed to air. This is because many marine sediments contain large quantities of shell grit (calcium carbonate). Sulphate compounds left behind by the seawater are converted to hydrogen sulphide by sulphur-reducing bacteria. Hydrogen sulphide may convert to sulphuric acid in contact with the air, and this rapidly reacts with the calcium carbonate in the shell grit. This results in carbon dioxide off-gassing from the soil and calcium sulphate entering the groundwater, effectively removing solid matter from the soil.

Knowledge of tide restrictions, their type and potential effects is essential for comprehensive saltmarsh monitoring and assessment. Tidal influence is an important parameter to measure, along with tidal range and salinity. These three attributes can provide a very good understanding of the effect of tide restrictions on the physical and chemical nature of saltmarshes.

This activity outlines the basic methods used to monitor tidal restrictions. It is envisaged that community groups undertaking restoration or recovery programs in affected estuaries will find the methods useful is assessing the progress of their projects.

Activity: Extension

Age: High school

Time: 4 (initially, then 2 to monitor)

Why? Estuarine wetlands develop their character (saltmarsh, melaleuca wetland, mangrove, or freshwater-tidal wetland) from the hydrological regime. Monitoring the ground and surface water quantity and quality can provide insight into the health of, and reasons for long-term change in, these wetlands.

Safety: Saltmarshes contain rough terrain and ill-defined waterways. Participants should wear sturdy shoes, long pants and a hat. Participants should take care when walking so that they do not fall down undercut embankments or slide over in muddy sections. Working in pairs will help avoid and deal with any injuries that may occur in saltmarshes.

Areas where tidal movement is restricted may have strong currents passing through channels or culverts. Care should be taken to avoid these, and avoid wading in fast flowing water.

The methods used in this activity measure the area of tidal influence, average tidal ranges, salinity concentrations and pH changes in areas that have been affected by tidal restrictions. This is done by installing depth gauges in samphire ponds and in the unrestricted waterway, as well as piezometers in the samphire uplands (high marsh).

Staff gauges are essentially large rulers staked in a fixed position, and are used to measure water levels. You can construct staff gauges from a variety of materials, and the only requirements are that they be durable, rustproof and appropriate for the site location, budget, and needs of the investigators.

Groundwater is sampled from vertically installed one-metre long PVC pipes known as **piezometers**. These are used for monitoring the depth, salinity and pH of the **groundwater table**. Groundwater in saltmarshes is usually monitored only during dry periods, although sampling during wet periods may be interesting from a salinity and pH perspective. During wet periods the groundwater will usually be at, or near, the surface.

The average tidal range is estimated by taking regular observations of a surveyed depth or staff gauge over a tidal period (approximately six hours) at least once a year during a spring tide. Monitoring several times a year is preferable.

The area of tidal influence is measured by observing several depth gauges over a tidal period to determine how far the tide moves into the saltmarsh. The tidal influence on ground water can also be measured by taking several depth observations down piezometers over a tidal period or over a day.

Excellent reference books on tidal marsh restoration are:

Coultas, CL & Hsieh, Y (eds) (1997), *Ecology and Management of Tidal Marshes—A Model from the Gulf of Mexico*, St Lucie Press, Delray Beach, Florida.

Packham, JR & Willis, AJ (1997), *Ecology of Dunes, Saltmarsh and Shingle*. Chapman and Hall, London.

Purinton, TA & Mountain, DC (1997), *Tidal Crossing Handbook—A Volunteer Guide to Assessing Tidal Restrictions*, Parker River Clean Water Association, Massachesetts. This book may be downloaded from the Internet from <www.parker-river.org>.

Zedler, JB(ed) (2001), *Handbook for Restoring Tidal Wetlands*, CRC Press, Boca Raton, Florida.

What you may need:

For installing staff gauges

- between two and seven staff gauges
- a surveyor or surveying equipment
- large sledgehammer or mallet.

For monitoring surface tidal movement

- installed staff gauges
- hydrology field datasheets and pencils
- clock or watch with stopwatch
- clipboard.

For constructing and installing piezometers

- tape measure
- 50–75 mm PVC pipe (one metre per piezometer)
- small garden stake with flag or bright paint
- drill with a 0.5 to 10–mm drill bit
- two end-caps per piezometer to fit the PVC pipe
- some knee-high stockings (two per piezometer)
- GPS and/or a detailed topographic map
- augur or post–hole digger for boring a hole greater than 100–mm
- bucket of coarse sand or gravel & bucket of bentonite
- small amount of quickset concrete.

For groundwater monitoring work

- plopper or beeper (instructions for making these are in Appendix 6), or a thin straight dry wooden stake longer than 1.3 m for each piezometer
- sample flask & test equipment and guidelines for measuring for pH and salinity
- baler or petrol siphon with foot–valve for removing water from the well
- distilled water to clean baler(s)
- measuring tape.

What to do:

Installing staff gauges

Staff gauges are graduated, meaning that units (metres) are clearly written on the staff so that the water level can be recorded by simply looking at the gauge (Figure 5). These gauges should be constructed of rustproof materials that can withstand wind and water currents.



Figure 5—Staff gauge

It is common to use PVC pipe to construct gauges, with units marked by etching the pipe then filling the etchings with paint. Another method is to use a sheet of plastic or melamine with black and white layers, so that the marks may be etched into the white side so that the black layer shows through. These are best for installing directly onto a culvert or fence post, and they withstand damage from vandals.

Finding a suitable location for the staff gauges is sometimes a challenge. Visiting the study site at different tidal stages will assist you. Place the gauges where there is usually only a small amount of water, but where you can easily read them when the tide is high. A suggested set of locations for staff gauges is illustrated in the example site plan below (Figure 6).

To gauge a restriction, you should install staff gauges no further than 15 m from the tidal restriction on both sides of the restriction (eg on the restricted side and the unrestricted side). Other, additional, gauges may be placed in a tidal marsh to map the area of inundation.



Figure 6—Staff gauge locations and piezometer transects

Gauges on freestanding posts should not be placed where strong currents occur as they may wash away. Also, it is difficult to read the water level if the current is creating large eddies around the post. In areas subject to frequent vandalism, attach gauges to pre-existing immovable objects where possible, for example culverts or rock embankments.

If you are installing freestanding gauges, two people may be necessary to install the gauges–one to hold the gauge post while the other pounds it into the substrate with a sledgehammer or mallet. To be sure you accurately place the gauge, install the post, then attach the staff marking plate. Be sure to position the staff gauge so that the height marks are readily visible by the observer.

Your local council may be prepared to assist you survey staff gauge locations and install them, as a surveyor (or at least their equipment) is required to place the markers at a known height relative to AHD (Australian Height Datum). Gauges should be installed at least a day or two before the sampling date to ensure they are in a suitable location.

Measuring tidal movement using staff gauges

The next step is to collect the tidal range data. The staffs are measured by recording the level the water reaches on the staff. A torch or pair of binoculars may be needed to help you see the marks on the staff.

This monitoring requires someone to be on site to record water levels (tidal height in AHD) on all the staff gauges every 15 to 30 minutes, over the period of one or several tides. The regular readings are noted, along with the time of each measurement, on the field datasheet. The monitoring is usually done over a period of at least six hours so that both a high and low tide is covered for the event. Names of investigators, date of sampling, and time of high tide will also need to be recorded. This activity should be conducted at that time of the month where the tidal variation is greatest—the monthly spring tides. Additional sampling at the neap tides (the period mid-month when the range is the smallest) may also be useful, but is not essential.

Working in shifts with different people to take the readings may reduce the time resources required from each person.

Less intense monitoring may be done by going out on site only at high and low tides, or at set times each day, and taking these readings over a longer period of time, perhaps six readings over 12 hours or two readings a day for a week or month. The intensity of the monitoring program depends entirely on the aims of the program, and this will need to be decided by your resource limitations and in consultation with your Waterwatch coordinator.

Installing piezometers

Prior to going out into the field to install your piezometers, it is important that you determine how many piezometers you will require, roughly where they will go and what the surveyed ground levels are for those sites.

Site selection is best done during dry periods when the wetland is most accessible. Selecting sites at a moderate high tide will give you an idea of where the tide comes to in your saltmarsh, and all piezometers should be placed above this mark.

Using an aerial photograph, determine two or three transect lines running from the high tide mark through to the highest point in your saltmarsh. They should form a straight line perpendicular to the tide line, as this will help show tidal influences on groundwater and the zonation of plants. It may be worthwhile placing a couple of piezometers in a reference site, which is similar in habitat or geography, but does not have tidal restrictions.

Placing the transects at different distances from the tidal restriction, for example 50 m and 100 m, will give you an idea of the effects of tidal restriction further into the saltmarsh. Placing your piezometers in different saltmarsh habitats will also give you some interesting and useful data.

Place your two to four piezometer sites along each transect with at least one at each end, with any others spaced in between. Examples of suitable piezometer sites are shown in the example site plan provided in the staff gauge section above.

It may be advisable to dig a test hole at the highest and lowest points to work out how long your piezometers will need to be, so that they are in a zone of groundwater flow. This is determined by digging a small hole with a shovel or posthole digger until you reach a point where the soil is saturated and the bottom of the hole starts to gather water. A maximum depth of one metre below the ground, with 300 mm of pipe above ground level is advised, as piezometers longer than this (1.3 m) become difficult to handle.

A surveyor or surveying equipment will be needed to determine the height of the ground at each of your selected piezometer sites. Once each point has been surveyed, mark each site with a garden stake and take a GPS location to ensure that the site can be found again. The piezometers should then be made and installed as soon as possible, to minimise the chance that a location will be lost.

The piezometers are made by cutting the required lengths of pipe so that at least 100–mm of the pipe will be in the saturated zone of the soil. The pipe will need to be long enough so that it sticks out of the soil by approximately 300 mm so that the piezometers may be seen from a distance, without being overly obvious.

For a standard piezometer, the construction method is outlined below.

- cut a one-metre section of PVC pipe
- drill small holes (5 mm) approximately 20 mm apart into the lower third of the pipe
- alternatively a handsaw could be used to cut slots across the pipe instead, if drilling is too time consuming
- drill a vent hole 100 mm from the top of the pipe
- fit an end-cap over the top opening of the pipe, being careful not to cover the vent hole
- fit an end-cap with a few holes drilled into it over the bottom opening of the pipe
- pull at least two stockings over the lower end of the pipe, including the opening and all of the drill holes
- — secure the stocking fabric with duct tape.

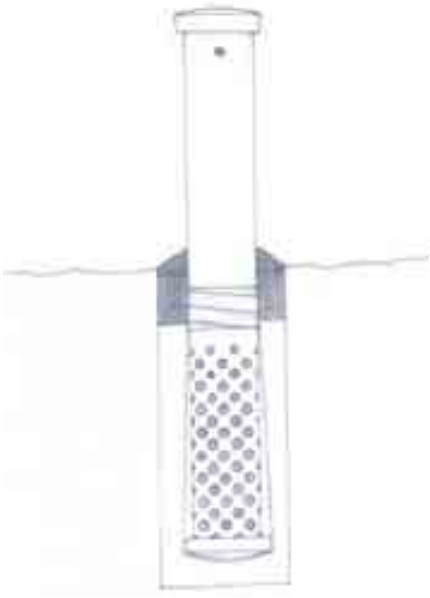


Figure 7—Installing a piezometer

Installation is a simple procedure once the sites have been identified and surveyed (Figure 7). A posthole auger is used to dig a small hole at least 100 mm across and 50 mm deeper than the intended depth of the piezometer.

This hole is filled with approximately 50–mm of coarse gravel or sand, then the piezometer is placed into the hole and the space around it packed with further coarse gravel or sand to just above the drill holes. The space above the drill holes is then packed tight with bentonite, or native clay, and capped with a small amount of quickset concrete (if available).

These small groundwater monitoring stations need to be left to settle for at least a week before the monitoring commences. The depth of each piezometer from the top of the ***standpipe****, the height of each standpipe above the ground surface and the ground level at each site needs to be recorded on your field datasheet. These will be used later to help calculate the groundwater level and will help you repair your piezometers if any are damaged.*

Measuring groundwater level

The first parameter to be measured when doing groundwater monitoring is the **Standing Water Level** (SWL) of the piezometer. This may be determined using a variety of equipment.

The simplest (and cheapest) way is by gently inserting (so as not to damage the bottom of the well) a thin dry wooden or bamboo stake into the pipe until it can go no further. Once it is withdrawn the depth of water from the bottom of the well may be measured as the wet section of the stake, or the distance the wet area is from the top of the standpipe may be measured. This method has its drawbacks–it can be difficult and potentially dangerous carrying large numbers of long stakes, and if it rains on them or they become wet in some other way there is no way of determining where the water levels are.

Professional groundwater monitoring groups use either a **plopper** or **beeper**, depending on the depth of the wells that they are monitoring and the financial resources of the group. Instructions for making ploppers and beepers are included in Appendix 6.

A plopper is simply a cup-shaped tin object, which is attached to a string and lowered face down into the pipe. When the cup hits the water, the force makes a 'plop' sound. This can be done several times and the average point where this sound is made can be marked on the string, and the groundwater depth is calculated as the depth from the top of the standpipe, minus the height of the standpipe above the ground.

A beeper is the easiest to use and most accurate method, particularly for deep piezometers or where the piezometers require a long walk through the samphires. It comprises a small electronic circuit, which is attached to a long, two-cored electrical cable with both the wires exposed at one end. The circuit is normally an open circuit as there is nothing joining the two cores of the cable. When the cable is lowered down a groundwater well it eventually comes into contact with water. Water conducts electricity so it completes the circuit. This allows electricity to flow between the two wires and the buzzer (held in your hand) beeps and a light comes on. The wire can be jiggled up and down to identify the exact water level from the top of the standpipe.



Figure 8—Assorted groundwater monitoring equipment

The next step in groundwater monitoring is measuring the pH and salinity. To do this the contents of the well need to be completely removed, preferably to twice the well's volume, and the well should be allowed to fill again to ensure uncontaminated groundwater is being measured. The well may be emptied using a baling device, and some examples of these are shown in Figure 8.

A petrol siphon with a one-way valve on the base is probably the easiest device to obtain. The pipe is jiggled up and down with the valve in the water, until water pumps out the top of the pipe. Continue jiggling the pipe up and down until no more water comes out or at least 1.8 litres have been removed from the standpipe.

Move on to the next piezometer, rinsing the baling device with distilled water before repeating the process. Once all the piezometers have been emptied, the first one should have recharged. This may take up to an hour. Return to the first piezometer and extract a 200–300 mL water sample from it for salinity and pH measurement.

Test your groundwater samples in accordance with the guidelines *Measuring pH* and *Measuring salinity*. Dispose of the remaining sample back down the piezometer it came from, and cap the piezometer. Record the salinity and pH measurements.

Groundwater level readings should be taken monthly for the dry periods of your year, eg September through to April, with occasional monitoring during wetter months if access is possible without causing undue damage. Optimally, samples from the piezometers would be collected for salinity and pH

measurement monthly from October through to March. An annual or biannual reading would suffice if monitoring a natural area. Additional collection of groundwater level measurements at high and low tides is informative, as long as there is no surface water on the saltmarsh near the wells.

Piezometers are easily damaged or destroyed by fire, floods or vandalism. Keep an eye on your piezometers and repair them immediately if they are damaged. Replacing the cap if it goes missing and ensuring that the piezometers are kept capped at all times when not being used is important. Rain contamination of the groundwater may create **sodic** soils around the piezometer if the cap is left off.

Interpreting tidal movement data

Both the tide and groundwater data needs to be interpreted using graphs and coloured maps showing all your results. These graphs and maps could be compared to results from reference sites if you have any available. The local harbour authority may have local tidal data, while the Mining Branch of PIRSA may be able to provide information on groundwater in your district.

When interpreting tidal movement data it is important to plot the data from each site onto a graph showing time and depth. These graphs can then be compared to each other to identify differences is shape or tidal range.

An unrestricted tidal graph will look like a 'bell curve' or 'sine wave'. It will be smooth and even. As the severity of the tidal restriction increases, so will the difference in tidal range and shape of the graph between your unrestricted and restricted sites.

The tidal range, or the difference in level between high and low tide, is one of the most important ecological aspects to monitor in a saltmarsh. It determines the areas suitable for different habitats, such as seagrass, mangrove, low marsh, high marsh and grassland.

The data also provide the observer with an idea of the tidal flushing that occurs. Areas that are regularly inundated are flushed of excess salts, whereas those that are only occasionally flooded become very saline. If the area being studied has experienced soil shrinkage due to tidal restrictions causing acid sulphate soils, and is undergoing remediation, the staff gauge data can also indicate if too much tidewater is entering the reopened estuary. Mangroves or other marine emergent vegetation will rapidly colonise areas that receive daily inundation. Areas that are only inundated a couple of times a month will be more appropriate for upland samphires, while areas that are inundated only several times a year are likely to support saltbush communities.

Putting it together

The groundwater data is used in conjunction with the staff gauge data to determine if sufficient tidal flushing is occurring. If insufficient tidal flushing is occurring in a samphire swamp, the following two scenarios could develop:

- in arid areas the groundwater will show increasing salinity and decreasing pH over a period of several months. Acid discharge could occur after rain. Salt scalds may appear on the surface, and the saltbush community will start to invade the samphire zone.
- In areas where freshwater continuously discharges into the tidally restricted area the groundwater will gradually become fresh. Areas of sodic soils may appear. Grassland plants may invade the upland marsh and reeds may invade the lower marsh.

An area with sufficient flushing should show a monthly salinity cycle during neap tides and decreased salinity immediately after a spring tide. Seasonal variations will also be experienced depending on rainfall and evaporation.

At least 12 months of data needs to be collected before seasonal trend in data can be identified. These seasonal trends will also act as a baseline, which will allow comparisons with data from other sites or over time.



Chemical assessments



Measuring dissolved oxygen

Dissolved oxygen (DO) measures the amount of oxygen dissolved in the water, and hence available to aquatic plants and animals for breathing. When dissolved oxygen levels drop, aquatic life starts to die. Some organisms need more oxygen, and so die first. Fish coming to the surface for air is one of the first signs of low DO levels.

Some animals have adaptations that allow them to deal with low dissolved oxygen. Mosquitoes have tubes they breathe through, very much like snorkels. Other organisms such as mussels and pipis may shut their shells and 'hibernate'.

A range of natural and human related factors affects the concentration of DO in water. Natural factors include temperature, time of day and light intensity. Human-related factors include pollution with chemicals that decrease the levels of oxygen, increased nutrient loads, and temperature changes that raise or lower the **DO saturation** point.

High nutrients increase the growth of algae in the water. Algae are plants, using oxygen at night via respiration and creating oxygen during the day via photosynthesis. In clean waters with low nutrients, the night to day changes in DO content are minimal. In nutrient-rich waters the amount of algae in the water increases, and the night/day DO change may become extreme.

Oxygen may be measured using either a dissolved oxygen test kit or a dissolved oxygen meter. Test kits are cheap but take considerable time. Dissolved oxygen meters provide highly accurate results and take very little time. DO meters are commonly sold as combination meters, which also measure pH, temperature and conductivity. These meters are costly and require regular calibration to maintain accuracy.

Activity: Core

Age: All

Time: 3

Why? Most aquatic organisms require at least 3 – 5 mg/L of dissolved oxygen to survive. The concentration in the water varies depending on salinity, temperature and time of day. Below 3 mg/L indicates hypoxia, and below 0.5 mg/L indicates anoxia.

Safety: Dispose of all sample and reagent mixes appropriately. The test kit uses chemicals that can be dangerous if handled incorrectly. Read the instructions provided with the chemicals and equipment. Also check first aid procedures.

What you may need:

- site record form
- safety glasses and disposable gloves
- sample bottle with screw top cap
- oxygen test kit (modified Winkler method).

To ensure good results:

Check the expiry dates of reagents prior to use.

Get two people to each analyse a separate sample, and average the results.

What to do:

Rinse bottle with sample water and submerge it in the water to about 200–mm below the surface, until filled. When full, tap the bottle sides to remove air bubbles and replace lid whilst still under water.

Immediately complete the test procedure as outlined in the instructions provided with your test kit. Be sure to follow safety instructions and wear safety equipment. Record the result on your site record form as DO mg/L.

Both the temperature and the salinity of water affect the solubility of oxygen. Seawater can only hold a little more than half the oxygen that freshwater can hold at the same temperature.

Many groups studying estuaries report the dissolved oxygen content as the percent saturation, as this takes into account the temperature and salinity effects and gives a more immediate idea of the health of your water body, in comparison to other water bodies. To calculate the percent saturation you need to know the temperature and salinity of the water.

Values above 100% saturation are usually indicative of nutrient enrichment, often in the form of sewage or fertilisers. These pollutants cause an overgrowth in planktonic algae that produce oxygen in the daytime. The downside is the amount of oxygen they use at night, when the algae may remove too much oxygen from the water, killing fish.

Values below approximately 60% are often indicative of organic pollution. Bacteria break down most organic pollutants, and these require oxygen. Therefore organic wastes are often described by their biochemical oxygen demand (BOD). This is the amount of oxygen in mg/L that a solution of the waste would demand from the environment.

Percent saturation calculation

If you would like to know the approximate percent dissolved oxygen saturation of your sample, you can use the rough conversion in Table 4. A more accurate conversion is available using a spreadsheet, which your Waterwatch coordinator will have.

To undertake this calculation you will need to test salinity, temperature and dissolved oxygen. These will need to be reported as;

- salinity as TDS (g/L)
- water temperature in °C
- the measured DO in mg/L (without temperature correction).

Use your temperature and salinity readings to establish the potential dissolved oxygen based on the tables in Tchobanoglous & Burton (1991).

First determine what concentration of oxygen is equivalent to 100% saturation in your water. In the table below locate the closest salinity reading across the top and the closest temperature reading from the left column. Scroll across the row and down the column to find the potential saturation oxygen content for your water.

Table 4—Potential saturation oxygen concentrations

	0 g/L TDS	10 g/L	20 g/L TDS	30 g/L TDS	40 g/L	45 g/L
0 °C	14.6	13.6	12.7	11.9	11.1	10.7
5 °C	12.8	11.9	11.2	10.5	9.8	9.5
10 °C	11.3	10.6	9.9	9.3	8.8	8.5
15 °C	10.1	9.5	8.9	8.4	7.9	7.7
20 °C	9.1	8.6	8.1	7.6	7.2	7.0
25 °C	8.2	7.8	7.4	7.0	6.6	6.4
30 °C	7.5	7.1	6.8	6.4	6.1	5.9
35 °C	6.9	6.6	6.2	5.9	5.6	5.5

Once you have determined the potential saturation, apply the formula below to calculate the percent saturation for your water body:

$$\text{Percent saturation} = \frac{\text{Measured DO}}{\text{Potential DO x 100}}$$

Measuring sulphide

Sulphur is an important part of estuarine ecosystems. Bacteria reduce sulphur compounds to create energy. Sulphur is an important component of the heavy metal and nutrient cycles. The oxidised form of sulphur, sulphate, is a major component salt of marine water. It is usually associated with calcium and magnesium.

Sulphide is the reduced form of sulphur. It is regularly present in low concentration under the surface of estuarine sediments, but it is rarely present in surface water. Problems occur when sulphide migrates into surface water. This chemical is highly reactive, and quickly consumes all oxygen in the water column. It may oxidise into acid, which affects the pH of the waterway.

Any sulphide present in the water column, particularly near the surface, is an indicator that your waterway has been, is or is about to become **anoxic** (no dissolved oxygen) or **hypoxic** (low in oxygen).

Activity: Extension

Age: All

Time: 3

Why? The presence of sulphide in the water column may be used as a surrogate for measuring dissolved oxygen. There should be no sulphide present in the free surface water of an estuary.

Safety: Sulphide test kits often contain concentrated acid or corrosive chemicals. Use care when handling the reagents, and read the safety instructions provided with the kit. Wear disposable gloves and eye protection.

What you may need:

- site record form
- sulphide test kit
- pH strips
- disposable gloves and safety glasses
- lidded container with kitty litter
- sample bottle or container.

To ensure good results:

Sulphide field test kits are not as precise or accurate as laboratory methods, but the kits recommended by Waterwatch SA are accurate enough for basic ecological assessment, particularly when combined with dissolved oxygen readings.

Many small test kits have a use-by date. Check your sulphide kit before going out into the field.

What to do:

Collect a sample according to the sample collection section of these guidelines. Do not unduly shake or aerate the sample prior to testing as oxygen (present in air) may oxidise the sulphide in the sample.

Test the pH of the sample, using the method outlined in the guideline *Measuring pH*. Record it on your sample sheet.

The sulphide test kit comes complete with instructions on how to use it. As kits vary between manufacturers, please read the test methods carefully and follow them as closely as you can. Record the results immediately on your field datasheet.

Dispose of liquid wastes directly into the container filled with kitty litter. Once the kitty litter is fully used, dispose of it in a sealed rubbish bag to general waste. Clean all equipment with distilled water once finished, as your next results may otherwise be affected. Allow the equipment to air dry before storing it.

If you can't understand your sulphide test kit instructions, please contact your Waterwatch coordinator. The sulphide concentration is reported as milligrams per litre of sulphide (mg/L S^{2-}). Report any positive sulphide readings at your site to your Waterwatch coordinator.

Measuring orthophosphate

The importance of nutrients in the estuarine environment is discussed in several sections of this manual. Orthophosphate is a soluble inorganic form of phosphorus, which means that it is easily available to aquatic plants and animals.

Phosphorus (in any of its accessible forms) is critical for metabolic processes, which involve the transfer of energy. Without phosphorus animals and plants would be unable to live. Phosphorus exists in the water in several other forms—mainly organic phosphates, and polyphosphates from detergents. Total phosphorus can also be measured, but it requires digestion at high temperatures.

Nutrient concentrations vary according to surrounding land use, season and geology. Nitrogen and phosphorus are two of the most important nutrients for the growth of aquatic plants. Their concentrations in the environment have increased dramatically since European settlement.

Orthophosphate in water comes from fertilisers and is the form commonly measured, as it detects poor agricultural or land management practices in the catchment. It also indicates sewage pollution further from the point of discharge than does nitrogen. Excess phosphates may also enter an estuary from soil, animal feedlot operations and lawns. Phosphates may attach to soil particles and be transported to the estuary with eroded soil. Very high phosphorus loads are often delivered by large stormwater discharges or from over irrigation.

Blue-green algae blooms are limited by the availability of phosphorus rather than nitrogen, as they can fix their own nitrogen from the air. High levels of available phosphorus in the water will enable large numbers of blue-green algae to bloom. Some of these blooms are toxic and may cause fish kills.

Activity: Core

Age: All

Time: 2

Why? Total ortho-P includes soluble ortho-P and the more easily reacted particulate P that may be loosely bound to clay particles or incorporated in algae. These forms of P are rapidly taken up by algae. The presence of high concentrations of ortho-P is frequently an indicator of fertiliser or other nutrient runoff.

Safety: The orthophosphate test kit contains concentrated chemicals, including acids and alkalis. Use care when handling them, and read the safety instructions provided with the kit. Wear disposable gloves and eye protection.

Dispose of all samples and reagents responsibly.

The key to effective nutrient monitoring is to sample as often as possible at as many sites as possible, to account for the high variability of estuarine ecosystems. Sampling during winter may be decreased, as many aquatic plants are dormant and the effects of high phosphorus levels are not so obvious. Sites may be selected to reflect their proximity to a discharge location, or because of their relatively pristine nature.

Because nutrient levels often vary with depth, especially during summer when the estuary may be stratified, Waterwatch groups may wish to collect samples at different depths. Constructing depth samplers is discussed in Appendix 6.

What you may need:

- site record form
- orthophosphate test kit
- container for sampling
- field datasheet
- distilled or de–ionised water
- lidded container filled with kitty litter
- safety equipment including glasses and disposable gloves.

To ensure good results:

Orthophosphate field test kits are not as precise or accurate as methods used by laboratories, particularly when nutrient concentrations are low. The kits rely on a colour comparison: match the colour of a prepared water sample to one on a colour card. The subjectivity of each volunteer's decision, as well as ambient light levels, may influence your results. Doing tests at a similar time of day, and averaging several people's results (duplicate analyses) will ensure more consistent results.

Orthophosphate kit reagents often have a use-by date. Check this before going out into the field.

The phosphate test kits (molybdenum blue–acsorbate method) recommended by Waterwatch for use in estuaries are compatible with water up to about twice seawater salinity. If the water you are testing is too salty, it will show up cloudy in the solution. Retesting after dilution of the sample with distilled water overcomes the problem.

Record the units measured, and the species of phosphate measured, on your results sheet.

What to do:

Collect a sample according to the instructions in the sample collection section of this manual. Test the sample as soon as possible.

The orthophosphate test kit comes with instructions. As the method varies between manufacturers, please read the test methods carefully and follow them as closely as you can. Record the results immediately on your field datasheet.

The range of orthophosphate concentrations covered by the kit is relatively small, in order to detect very small changes in the water quality. If you are testing water that is visibly polluted, dilute the sample with de-ionised or distilled water if the concentration is higher than those shown on the colour card supplied with the kit.

Dispose of liquid wastes directly into the container filled with kitty litter. Once the kitty litter is fully used, dispose of it in a sealed rubbish bag to general waste. Clean all equipment with distilled water once finished, otherwise the current results will affect your next test. Allow the equipment to air dry before storing it.

If the kit instructions are not clear, please contact your Waterwatch coordinator.

The interpretation of nutrient concentration data must be done with care. High nutrient concentrations often suggest the potential for explosive algal growth. However, low levels do not necessarily mean the estuary is receiving less nutrient input.

Phytoplankton and algae grow very quickly, so large quantities of nutrients may have entered the estuary and have already been taken up by vegetative growth. In this case, although water nutrient concentrations are low, the quantity of nutrients tied up in biomass is high. Observation of plankton blooms and water clarity readings may help determine if this is the case. Chlorophyll-a analysis or phytoplankton counts may be needed if you wish to quantify the phytoplankton biomass.

Orthophosphate can be expressed as mg/L of phosphate (PO_4) or the mass of elemental phosphorus per litre (PO_4–P). The latter method is the most common. Check your kit to see which units its results are in.

Always record the unit and species of P on your record sheet. If your test kit provides results as mg/L PO_4, and you would like to convert the result, multiply the result by 0.32 to give you the result in mg/L PO_4–P.

Measuring ammonium

Activity: Core

Age: All

Time: 2

Why? High levels of ammonium are toxic to fish. SA EPA considers <0.05 mg/L indicates good water quality for ammonium in an estuary, and that 0.5 mg/L indicates poor water quality.

Safety: The ammonium test kit contains concentrated chemicals, including acids and alkalis. Use care when handling them, and read the safety instructions provided with the kit. Wear disposable gloves and eye protection.

It is important to use a non-Nessler test, as Nessler's reagent contains mercury.

Dispose of all sample and reagent mixes appropriately.

Nutrients are essential to all ecosystems. They are the chemicals that provide building blocks for plant and animal growth. Australian estuaries naturally contain very low levels of nutrients, particularly nitrogen. These low levels limit plant and animal growth, and native flora and fauna have adapted to low nutrient levels.

Many industrial, agricultural and stormwater discharges contain large amounts of these nutrients, which unbalance our fragile estuarine ecosystems. Measuring the concentration of nutrients gives us an indication of how badly affected the estuary is.

The most commonly measured nutrients are phosphorus and nitrogen. Ammonium (NH_4^+) is a compound of nitrogen. Nitrogen comes in many different compounds, depending on what other chemicals the nitrogen atom is attached to. The most common forms of nitrogen in estuaries are ammonium, nitrate, nitrite, urea and insoluble organic nitrogen.

Plants use nitrogen in photosynthesis. Excessive nitrogen can cause huge green algal blooms and **dinoflagellate** blooms. High nitrogen levels do not usually cause blue-green algae blooms, as these cyanobacteria can fix their own nitrogen from the air or water. High nutrient concentrations in general have been linked to harmful or nuisance phytoplankton blooms such as red tides, which can produce harmful toxins, in particular *Alexandrinum minutum*, which can cause paralytic shellfish poisoning. High levels of ammonium may cause fish kills.

Measuring the concentration of total nitrogen is difficult, as it requires digestion at high temperatures and a lot of fairly expensive laboratory equipment. Many community groups and scientific surveys measure the individual forms of nitrogen instead, as some of these are simpler to measure and they may give indications of the source of any excess nitrogen.

Nutrient concentration varies according to surrounding land use, season and geology. The tidal flushing of the estuary, water temperature, biological activity and surrounding land management methods may also have an effect.

Ammonium was selected for this activity as it is easy to measure in seawater and is indicative of low oxygen levels, sewerage outfalls, animal feedlot effluents or caustic plant outfalls. These pollution sources commonly discharge into South Australian estuaries.

The key to effective nutrient monitoring is to sample as often as possible at as many sites as possible to account for the high variability of estuarine ecosystems. Sampling during winter may be decreased as many aquatic plants are dormant and the effects of high nitrogen levels are not so obvious. Sites may be selected based on their proximity to discharge locations or because of their relatively pristine nature.

Because nutrient levels often vary with depth, especially during the summer when the estuary may be stratified, Waterwatch groups may wish to collect samples at different depths. Constructing depth samplers is discussed in Appendix 6.

What you may need:

- site record form
- ammonium test kit
- container for sampling
- distilled or deionised water
- lidded container filled with kitty litter
- safety equipment including glasses and disposable gloves.

To ensure good results:

Ammonium field test kits are not as precise or as accurate as many other methods used by laboratories, particularly when nutrient levels are low. Get the best results possible by observing the following recommendations.

Ammonium kits have a use–by date. Check this before going out into the field. Fresh reagents are an essential part of accurate results.

The kits rely on a colour comparison: match the colour of a prepared water sample to a colour on a colour card. The subjectivity of each volunteer's decision, as well as the ambient light levels, will influence the results to some degree. Doing tests at a similar time of day, and getting several people to test samples (duplicate analysis) will ensure more reliable results.

Record the units measured and the species of nitrogen measured on your results sheet.

What to do:

Collect a sample according to the instructions in the sample collection section of this manual. Do not shake or aerate the sample prior to testing as ammonium rapidly off–gasses. Test the sample as soon as possible.

The ammonium test kit comes complete with instructions on how to use it. As test kit methods vary between manufacturers, please read the test methods carefully and follow them as closely as you can. Record the results immediately on your field datasheet.

The range of ammonium concentrations covered by the kit is relatively small, as very low concentrations affect the environment. If you are testing near a polluted outfall, dilute the sample with de–ionised or distilled water if the ammonium concentration is higher than that shown on the colour card supplied with the kit.

Dispose of liquid wastes directly into the container filled with kitty litter. Once the kitty litter is fully used, dispose of it in a sealed rubbish bag to general waste. Clean all equipment with distilled water once finished, otherwise the current results will affect your next test. Allow the equipment to air dry before storing it.

If the kit instructions are not clear, please contact your Waterwatch coordinator.

The interpretation of nutrient concentration data must be done with care. High nutrient concentrations often suggest the potential for explosive algal growth; low levels do not necessarily mean the estuary is receiving less nutrient input. Phytoplankton and algae grow very quickly, so large quantities of nutrients may have come into the estuary and have already been taken up by vegetative growth.

In this case, although water nutrient concentrations are low, the quantity of nutrients tied up in biomass is high. Observations of plankton blooms and water clarity readings will help determine if this is the case. Chlorophyll–a analysis or phytoplankton counts are needed if you wish to quantify the phytoplankton biomass.

Measuring chlorophyll-a

Phytoplankton are **autotrophic** single-celled micro-organisms that live in water. Phytoplankton occur naturally in all waters of the world that are regularly exposed to sunlight. The abundance of these organisms depends on the amount of light they receive and the quantity of nutrients in the water.

An increase in the concentration of nutrients (including carbon, silica, phosphate and nitrogen) in the water rapidly causes an increase in the population of phytoplankton. Therefore, their presence and biomass is an indicator of the nutrient load in the estuary. The biomass of phytoplankton can be determined by identifying them and counting them under a microscope. This takes expensive equipment and considerable experience. Chlorophyll-a is the green pigment used by plants during photosynthesis. Measuring chlorophyll-a is another way of estimating biomass, as there is a well-accepted relationship between chlorophyll–a and biomass.

Activity: Extension

Age: Adult groups

Time: 4

Why? Chlorophyll is the green pigment in plants and so is a good measure of the amount of plankton present in the water, and therefore reflects the trophic status of the estuary. This is a surrogate test for nutrients.

To measure chlorophyll-a, a sample of water is filtered, to trap all the phytoplankton on the filter pad. In the laboratory chemicals are used to destroy the cells and dissolve the chlorophyll-a. This is then put into a spectrophotometer to determine the concentration of the pigment. Most groups monitoring this parameter need to send their sample away to a specialised laboratory, as there is no way to do this in the field.

This guideline outlines the method required to collect, store and prepare a chlorophyll-a sample for laboratory analysis.

What you may need:

- site record form
- two-litre sampling bottle with lid
- 500-mL measuring container
- a vacuum pump with gauge for use in the field, or a sample location close to a laboratory with a suitable pump
- 500-mL vacuum flask to fit gauge
- 47-mm glass fibre (GF/C) filter paper
- forceps
- sealable airtight, labelled small plastic containers–each container needs to be labelled, with space to record the site location, date and time of collection and amount of water filtered
- aluminium foil to wrap small containers in
- small plastic snap lock bags for small containers
- one small esky with ice or rapid access to a freezer.

To ensure good results:

Do not exceed 400-mm mercury vacuum when pumping as chlorophyll may be forced through the filter.

Filter the sample and freeze it as soon as possible.

It is easier to centre the filter paper on the filter holder if the filter is slightly wet.

It is best to filter as much water as possible (up to two litres). However, it is also important not to clog the filter, as all water in the filtering apparatus must be filtered. The best way to make sure of this is to only put a small amount of water into the filtering reservoir at a time. If the filter starts to clog (the flow

of water through the filter slows down), cease filtering as soon as the small amount you have in the filter reservoir has filtered, and record the volume filtered on your datasheet.

If the filter becomes completely clogged before all the water in the filtering container can be filtered, the test will need to be redone.

The quantity of chlorophyll-a present may be reported by the laboratory in several forms; usually it is in µg/L (micrograms per litre), but it is wise to check carefully.

Some laboratories may prefer that the sample is given to them in an unfiltered form; if so, ask them how the sample is to be handled and how quickly the sample must reach the laboratory.

What to do:

Collect a two-litre sample from the water body 200 mm below the surface. Pour 500-mL of the sample into the measuring flask, ready for filtering.

Place the filter paper in the filter, ensuring that the wrinkled side of the paper faces upwards. Place 250-mL from the measuring flask into the top of the filter device and use the pump to create a vacuum in the flask. Keep the water level above the filter device semi-full using water from the 500-mL flask, but be careful not to block the filter.

Once the 500-mL flask has been emptied, refill to the 500-mL line and continue filtering. After all water has been filtered, or the filter has started to block up, and the filtering device is empty, leave the filter in place for a several seconds to ensure the filter paper has been sucked dry.

Record the volume of water that was filtered. Remove the filter paper from the filter screen gently using the forceps, ensuring that the upper surface of the filter paper (which contains the chlorophyll-a) remains untouched. Fold the paper (upper surface on the inside) over twice then place into a small, labelled container.

Record the site location, date, time sampled, and volume of water filtered on the label and on your datasheet.

Wrap the containers completely with aluminium foil to stop light from degrading the chlorophyll-a then place into a plastic bag in the esky or freezer. Freeze the samples immediately.

Arrange to transfer the samples from the storage area to the laboratory that will complete the analysis. Frozen samples may be kept in storage for up to a month before being transported to the laboratory for analysis, although the temperature must not exceed 0°C.

Chlorophyll-a concentrations vary depending on the time of year and weather conditions. Plankton counts (and therefore chlorophyll) tend to be higher during sunny warm months and lower during cold dark months. Recording temperature, recent weather and date of sampling is important when taking chlorophyll-a readings.

Phytoplankton do not grow so well in water with low clarity as they require sunlight. Therefore taking Secchi depth or turbidity readings at the same time as the sample is collected is advisable. Another variable that influences the quantity of phytoplankton cells in the water is the amount of flow or tidal flushing. Areas with low flow or flushing will have higher readings than other areas.

Measuring alkalinity

Total alkalinity (also known as buffer capacity) measures the capacity of water to neutralise acids. Alkaline compounds such as bicarbonates, carbonates, and hydroxides remove hydrogen ions and lower the acidity of the water (thereby increasing pH).

Alkalinity, acidity, pH and hardness are all related and are part of the carbon cycle of the estuary. Total alkalinity is measured by measuring the amount of acid (for example, sulphuric acid) needed to bring the sample to a pH of 4.2. At this pH, all the alkaline compounds in the sample are used up.

Many things, such as the surrounding soil, salts leaching into the waterway, plant growth and industrial wastewater discharges, influence the alkalinity of an estuary.

Alkalinity is important for determining the estuary's ability to neutralise acidic pollution from rainfall, acid groundwater or wastewater. The measure gives environmental managers an indication of the chemical make-up of the water contained in your estuary and any long-term trends that may be occurring.

This buffering capacity of water, or its ability to resist pH change, is critical to aquatic life. The estuary's capacity to neutralise acids will vary between the freshwater reaches of the estuary and the portions with higher salinity.

Activity: Core

Age: All

Time: 2

Why? Alkalinity measures the water's ability to neutralise acidity. Fresh water varies from 30 to 90 mg/L $CaCO_3$, while seawater has around 116 mg/L.

Safety: The alkalinity test kit contains concentrated acid. Use care when handling the reagents, and read the safety instructions provided with the kit.

Wear disposable gloves and eye protection.

Dispose of all reagent/sample mixes appropriately.

What you may need:

- site record form
- alkalinity test kit
- disposable gloves and safety glasses
- lidded container with kitty litter
- sample bottle or container.

To ensure good results:

Alkalinity test kits are not as precise or accurate as methods used in laboratories, particularly as the drops need to be counted manually, therefore duplicate analyses are recommended.

Alkalinity kits have a use–by date. Check this before going out into the field.

What to do:

Collect a sample according to the instructions provided in the sample collection section of this manual. Do not unduly shake or aerate the sample prior to testing as carbon dioxide (present in air) has an effect on alkalinity.

The alkalinity test kit comes complete with instructions on how to use it. As the method may vary between manufacturers, please read the test methods carefully and follow them as closely as you can. Record the results immediately on your field datasheet.

Dispose of liquid wastes directly into the container filled with kitty litter. Once the kitty litter is fully used, dispose of it in a sealed rubbish bag to general waste. Clean all equipment with distilled water once finished; otherwise the current results will affect your next test. Allow the equipment to air dry before storing it.

If the kit instructions are not clear, please contact your Waterwatch coordinator.

The results are reported as milligrams per litre of calcium carbonate (mg/L $CaCO_3$).

A high alkalinity reading does not mean that the waterway is alkaline or has a high pH. Some water can test as acid, or have a low pH, yet still have a high alkalinity. This means that while the water might be acidic, it still has a capacity to buffer or neutralise, acids.

A low buffering ability means that the pH of the water will fluctuate considerably, and only plants or animals that can tolerate large pH ranges will survive.

Total alkalinity in seawater averages 116 mg/L. This is greater than that of freshwater, which ranges from 30 to 90 mg/L depending on the watershed. Estuarine water should have a total alkalinity between these values.



Measuring total suspended solids

Suspended solids in water are the solids that, once picked up by the water, do not settle out. They are very fine particles of organic matter, pollutants and soil that are held suspended in the water column. These particles interfere with water clarity, causing turbidity and blocking the passage of light to the animals and plants in the benthic zone.

High loadings of suspended solids can cause starvation in filter feeders such as mussels and sea anemones, as well as blocking the gills of fish.

Suspended solids are measured by filtering a sample through a fine glass fibre filter (GD 120), which captures all solids over 2.7 µm (2.7 micron) and allows finer particulates and clean water through.

Activity: Extension

Age: High school

Time: 4

Why? Suspended solids is related to turbidity and indicates how many solid particles are in the water. These fine particles can clog fish gills and foul benthic filter feeders.

Safety: Heat risks apply as TSS is dried in an oven.

What you may need:

- site record form
- one-litre sampling bottle with lid
- 500-mL measuring container
- a vacuum pump for use in the field, or access to a laboratory with a suitable pump
- 500-mL vacuum flask to fit pump
- 47-mm glass fibre (GD-120) filter paper
- bottle of distilled or demineralised water
- forceps
- small square trays made of aluminium foil, marked with sample numbers (one per sample)
- drying oven
- heatproof or heat resistant gloves
- laboratory scales accurate to 0.0002 g
- a desiccator or a flat, lidded container containing silica drying crystals.

To ensure good results:

Do not exceed 400–mm mercury vacuum when pumping, or the filter paper may break down or sediment may be forced through the filter.

It is easier to centre the filter paper on the filter holder if the filter is slightly wet.

Continuous stirring or shaking of the sample not yet in the filtering apparatus is recommended.

It is best to filter as much water as possible (up to one litre). It is also important not to clog the filter, as all water in the filtering apparatus must be filtered. The best way to make sure of this is to only put small amounts of water in the filtering container at a time.

If the filter starts to become clogged, or the flow of water through the filter slows down, cease filtering as soon as possible and record the volume filtered on your datasheet. If the filter becomes completely clogged before all the water in the filtering container can be filtered then the test will need to be redone.

Before drying and weighing, the filter paper needs to be thoroughly rinsed with distilled water to remove any dissolved salts that may be caught in the fibres. You are only measuring solids, not soluble salts.

What to do:

Collect a one-litre sample of the water body, from 200-mm below the surface.

Using forceps place a filter paper onto an aluminium tray and weigh them. Record the weight to the last decimal place on your datasheet.

Pour 200–mL of the first sample into the measuring flask. Place the filter paper in the filter, ensuring that the wrinkled side of the paper faces upwards. Pour 100-mL from the measuring flask into the top of the filter device and use the pump to create a vacuum in the flask. Keep the filter paper wet or immersed using water from the flask, but be careful not to block the filter.

Once the flask has been emptied refill to 200-mL line and continue filtering.

After all water has been filtered or the filter has started to block up and the filtering device is empty, pour 100–200 mL of distilled water into the filter device to rinse any salt out of the filter. Once the rinse water has been filtered, pour or spray distilled water onto the walls of the filtering device to ensure that all sediment has been washed onto the filter.

After the filter paper has been sucked dry, record the volume of sample that was filtered. The colour of the sediment on the filter may also be recorded.

Using the forceps, gently remove the filter paper from the filter screen, ensuring that the upper surface of the filter paper remains untouched. Place the filter on its labelled aluminium tray.

Place the filter and its tray into the drying oven at 100°C for one hour.

Wearing heatproof gloves, remove the tray and filter from the oven. Allow them to cool in the desiccator until they are at room temperature then weigh them carefully.

Record the weight on the data sheet.

Calculate the concentration of suspended solids per litre using the formula below:

$$SS = B\text{-}A \times (1000/C) \times 1000$$

where:

SS = Suspended solids in mg/L

A = Unused (starting) filter paper and tray (g)

B = Used filter (ending) paper and tray (g)

C = Volume of sample filtered (mL)

The data is presented as mg/L suspended solids. If multiple sites are visited, a map of the suspended solids concentrations in the estuary may be made using a topographic map and some coloured pencils.

If you regularly test for suspended solids over a period of time at one location, you may be able to correlate them with rain or other events that may raise the suspended solid concentration in your estuary or at your site.

If water clarity or turbidity are measured at the same site and time as the suspended solids, a relationship between these measurements could be determined for your site(s).

Mass balances to estimate pollutants

The **National Pollutant Inventory (NPI)** is Australia's national database of pollutant emissions. In 2006, the online database held emission data for more than 3700 facilities, in 29 catchments around Australia. Large industries provide information to the government on their emissions to air, land and water using a technique referred to as **mass balance**. Local and state governments provide additional data to the NPI that includes the more diffuse pollution sources, such as stormwater runoff.

Individuals may access the NPI database online to examine areas of interest to them. By calling up a map of your estuary you can see those facilities large enough to be required to report to the NPI, and obtain statistics on the emission loads they discharge to land, air or water.

In this way you may estimate the total loads of pollutants that are discharged into the waterway. The first activity in this section shows you how to access the NPI database.

The mass balance technique is a simple method that can be applied to all types of developments, not just large industries. The method may be applied to your home, school or local small businesses. Read the section below that describes how to perform a mass balance. One of the benefits of a mass balance is that the method highlights areas where waste is being produced.

Activity: Extension

Age: High School

Time: 4

Why? Many contaminants that end up in estuaries are toxic to marine life. These activities describe how to calculate the overall load of contaminants entering into an estuary, and how to determine what contaminants may be coming from a single facility.

Safety: This is a desk-based activity.

Think about waste for a moment. Isn't a waste something you have paid money for originally, but are now throwing away? If you reduce waste, you reduce your up-front costs, saving yourself money as well as reducing impacts on the environment. Maybe the mass balance you undertake will show you a way that your group could reduce waste, save money and help the environment.

What you may need:

The NPI website at <www.npi.gov.au>, and visit the 'Make a map' link.

What to do:

Look at the overall pollutant loads going into your estuary. Go to the NPI website at <www.npi.gov.au> and click on the button that will open the 'Make a Map' window. A map of Australia with many blue squares marking industries that are reporting to the NPI will be displayed. At the top of the map is a row of 'tools'. The first tool is a '+' symbol. Click on this symbol, then use your mouse to draw a 'box' around the area that interests you. The map will redraw, and you will be closer to outlining the area of your estuary. Continue enlarging the map until just your estuary is contained in the map page.

On the toolbar you will see a selection of green circles with dotted outlines in them. These are selection tools. They enable you to select facilities to examine. Choose the shape (circle, rectangle or irregular polygon) that will allow you to capture all the facilities that may contribute to the estuary pollution loads, and draw your selection onto the map.

This time the program will open a window that tells you how many facilities are in the area you selected. If you click your mouse on the word '*Facilities*' you will be provided with a list of facilities and a link to each of their pollutant load reports. The tables show whether a pollutant is released to land, air or water. The facilities do not report anything that they send to sewer or landfill, as these pollutants will be recorded as **transfers** by those facilities. Hence any pollutant recorded as discharging to water, may be discharging into the estuary.

Total up all the facilities' discharges to water. This is the minimum total load of pollutants that your estuary receives in any given year. So, is this load a big load, or a little load? That is a difficult question. The NPI ranks the loads, so a facility with a load rank of 100 is the largest producer of that waste in the country, while a ranking of 1 shows that the facility is in the 1% of smallest producers of that waste. The ranking is relative, not based on fixed quantities.

Additionally, a large estuary, with large tides and a positive river flow may be able to accept much larger loads than a small, microtidal estuary with little freshwater input, before environmental impacts become obvious.

Conducting a simple mass balance:

Choose a small facility to develop a mass balance for. It may be your home, school or a small local business. If the latter, remember that any information a local business shares with you is confidential. Local businesses are often interested in improving their environmental performance, and a lack of discretion on the group's part may be counterproductive.

A mass balance assumes that everything that enters the front gate of a facility (raw materials, energy, fuel) goes somewhere. The materials either become part of the product, are converted to something else (heat, smoke, steam) or are expelled from the site by some other means (down sewers and drains, or in the garbage can).

In a huge factory, tracking all the things that enter the site may be extremely complex. However, businesses have one advantage—their accounts reveal what they bought in, and the fees pertaining to at least some of their disposal costs, along with the quantities of product sold. Typically auditors doing a mass balance will ask questions such as 'Why do 100 tonnes of woodchip only produce 80 tonnes of fibreboard?' to find out where waste is formed.

In a small operation, it is easier to see what happens to materials, but household mass balances are complicated by the fact that few households keep accounts, so you need to take estimates for things like how much food, detergent or petrol is purchased each year.

The diagram (Figure 9) shows a material flow in a fish and chip operation. By putting figures on the **inputs** and **outputs**, you would be able to determine the amount of each waste and its destination.

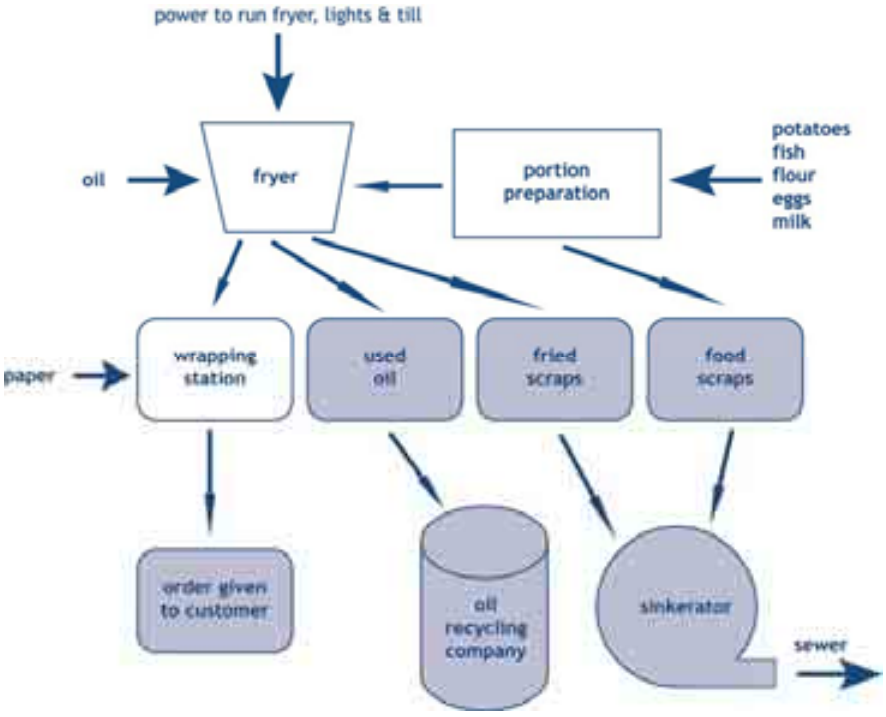


Figure 9—Material flow in a fish and chip shop

Measuring soil salinity and soil pH

Soil salinity and pH are two important indicators of saltmarsh ecological health, particularly in areas that have potential acid sulphate soils or salinity problems. Salinity readings are also useful for students doing hydrological studies on saltmarshes and supratidal or intertidal estuarine ecosystems. Changes to the hydrological regime may greatly influence both soil salinity and pH.

Soil salinity is strongly influenced by tidal flushing, evaporation and rainfall. The supratidal areas are the most saline due to infrequent tidal flushing combined with evaporation. Areas that receive greater tidal flushing are less saline.

Soil salinity and soil pH are measured using similar methods, and both may be done together in one sample or individually. These factors are not often measured in isolation, but as part of an overall collection of information when doing vegetation assessments or hydrological studies.

The method given below uses a 1:5 soil–water solution with field equipment. More accurate results can be obtained using laboratory equipment, although the equipment specified will give a reasonable result. The 1:5 solution method was selected for its widespread use and ease of measurement.

Activity: Extension

Age: High school

Time: 2 or 3

Why? The salinity and pH of saltmarsh soils determines the types of vegetation that will develop. These parameters may change rapidly after tidal gates or impoundments are placed in intertidal areas, resulting in large changes to the vegetation. In some cases there may be releases of acid from the oxidized soil into the main estuary.

Safety: Glass equipment needs to be handled gently. Use a sharps container for broken glass. Dispose of all reagent/sample mixes appropriately. Saltmarshes may contain rough terrain and ill-defined waterways.

What you may need:

- saltmarsh record form
- topographic map (or GPS)
- small hand trowel
- small flat trays or boxes for drying soil
- glass screw–topped container marked at 300 mL
- distilled water
- hydrometer(s), thermometer and pH strips
- pocket scales accurate to 0.2 g with a maximum mass of 100 g
- battery operated timer
- mechanical stirring device (optional)
- tube for hydrometer readings.

To ensure good results:

Check your equipment before going out into the field. Back at base, check your reagents and equipment before testing the soil samples. See *Measuring pH* and *Measuring salinity* for more details.

Clean your sampling equipment (trowel) between samples to prevent contamination of the next sample.

What to do:

Decide where you will test the soil—you may obtain more useful information if you make a traverse away from the waterway towards high land, sampling at intervals. Record your sampling locations on a topographic map or by using a GPS.

At each sampling location, use the hand trowel to collect a small soil sample from about 100 mm below the surface. Around a handful will do. Place it in a labelled plastic bag. Repeat this for as many samples as you are testing. Once all samples are collected, return to your base and place each sample in a

separate drying tray in a warm spot (but <40°C) until all the samples are dry and crumbly. This usually takes at least 24 hours. If the soil is dry to touch prior to air-drying, testing can commence immediately, in the field, but this is unusual in saltmarsh areas.

Fill the lidded glass container to the 300-mL mark with distilled water. Weigh 60g of soil and place in the distilled water and screw the lid on well.

Either shake vigorously for two minutes every 15 minutes for two hours (a total of 16 minutes of shaking) or place on the mechanical stirrer for one hour.

Leave sample to settle for 20 minutes and take a pH reading according the *Measuring pH* guideline. Record the pH value on your record sheet.

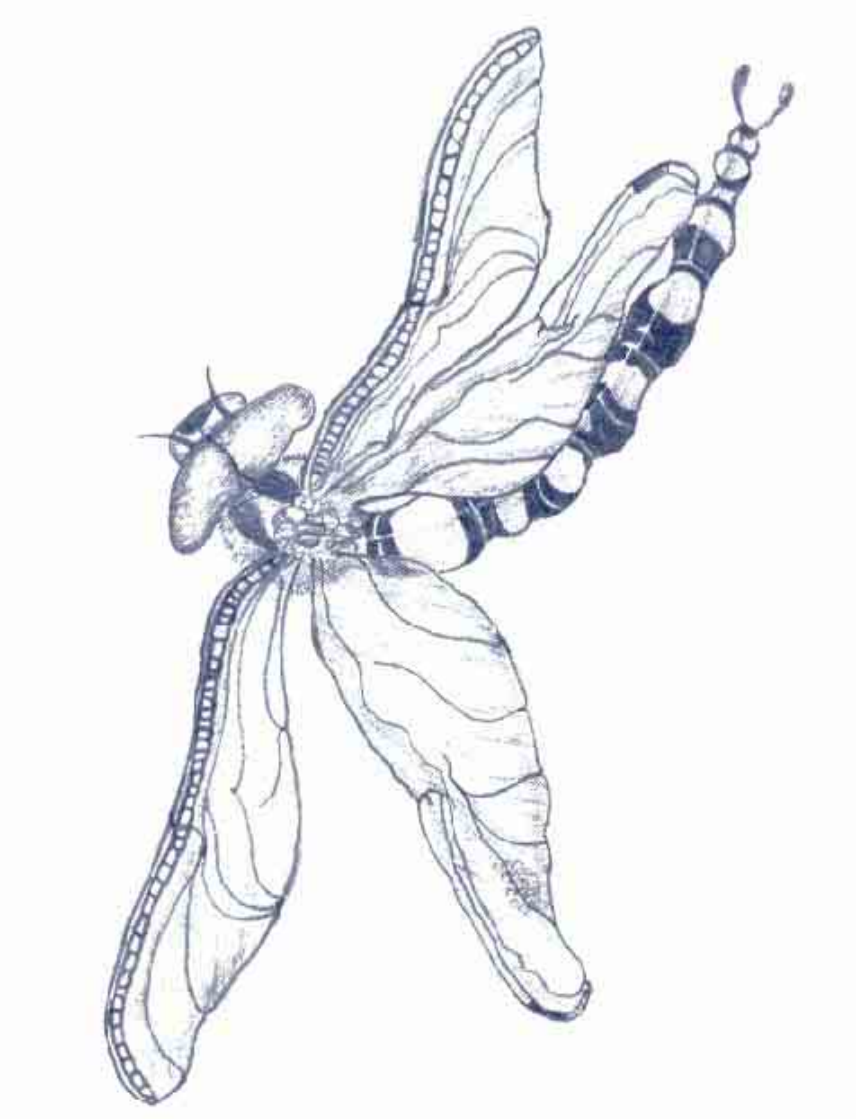
Decant the clear (or semi-clear) liquid into the tube used for hydrometer readings. At least 200 mL is needed. Use the hydrometer(s) to take a specific gravity reading according the *Measuring salinity* guideline. Record the temperature of the liquid to enable you to make a temperature correction later.

The 1:5 soil–water method of analysis does not provide the true soil salinity or pH reading that a plant would encounter in the actual environment. However, the method does provide a well recognised indication of soil conditions. There are several soil salinity and pH measurement methods. Each method has its merits and is used for different reasons. The 1:5 soil–water solution method is the most commonly used in Australia, and there is a large database of plant salinity tolerances for this method.

Ensure that any data you record or use about soil salinity or pH states the method used. The standard protocol is to report the method as a subscript. Soil pH may be reported as: $pH_{(1:5)} = 6.9$, for example.

Potential, and actual, acid sulphate soils are found in many coastal depositional environments such as areas of mangrove and saltmarsh. Managing these areas so as not to increase the chance of oxidising the soils and causing acid generation is important. In 2003 the South Australian Coast Protection Board produced an issue of their newsletter *Coastline* that discusses coastal acid sulphate soils. *Coastline 33* may be obtained from the Coast and Marine Branch of the Department for Environment and Heritage, or downloaded from their website <www.environment.sa.gov.au/coasts/pub.html>.





Keeping a visual record of plankton blooms

Activity: Core

Age: All

Time: 1

Why? Plankton blooms are often the result of high nutrient concentrations.

Safety: Algal blooms may be toxic. Do not get into water that has a dense bloom and use gloves while collecting samples.

In the estuarine environment, just as in our own bodies, there is such a thing as too much of a good thing. Even though nutrients are essential for growth and survival, too much of them will result in blooms of planktonic algae.

These blooms may affect the estuary in several ways. Water clouded by plankton does not allow sunlight to penetrate to the benthic zone. Seagrasses and other submerged plants that require light may die if the water is permanently turbid.

While in the daylight, plankton produce oxygen by photosynthesis, in the dark they use it to respire. When there is a large bloom there is a huge swing each day/night cycle in the amount of dissolved oxygen (DO) in the water. If the DO falls far enough, the water becomes **hypoxic** (low in oxygen), putting massive stress on all life in the water. Once the water of an estuary has less than 4 mg/L DO, fish may start to die.

Plankton blooms are often made up of certain groups of planktonic algae that belong to the **dinoflagellate** group. This is because the waste streams that provide so much nitrogen and phosphorus are often short of other elements such as silica, which is required by many valuable plankton such as diatoms. This leads to a situation where only certain types of phytoplankton such as the dinoflagellates can grow. These blooms are often called red tides and brown tides and some of these algae produce toxins that may kill fish or accumulate in shellfish, poisoning people.

In South Australia, the Port River supports regular blooms of the toxic dinoflagellate *Alexandrium minutum*.

What you may need:

- site record form
- Mitrovic, S (1995), *What Scum is That?*, Water Quality Services Unit, Department of Land & Water Conservation, Sydney.

What to do:

On arrival at your site, look for any red, brown or yellow colour in the water, or any scum floating on the surface. If there is a slight colouration only, record the colour on your site record form.

If there is an obvious bloom or scum, attempt to describe it or photograph it. Using a reference such as *What Scum is That?* try to determine what type of event may be occurring. Collect as much detail as you can from the site—what kind of area can you see affected, is the bloom deep in the water column or is it floating on the surface?

You may wish to collect a sample to provide to your Waterwatch coordinator, who may be able to identify the algae responsible. If you do attempt to collect a sample, remember that algal blooms may be toxic—wear disposable gloves while collecting your sample, rinse off the outside of the sample bottle with clean water and ensure you wash your hands thoroughly after the activity.

Getting to know phytoplankton with a net tow

Phytoplankton are single-celled plants that occur in most natural water bodies. They float freely as individuals, colonies or in rope-like strands. They do not attach themselves to surfaces. A microscope is needed to see them, as they are often only a few 10s of microns (thousandths of millimetre) long.

A single drop of estuarine water may have hundreds of these microscopic plants in it. These plants are the foundation stone for ecological health. Phytoplankton directly and indirectly support much of our marine life, including large animals like whales and sharks. Unfortunately some species produce toxins that may kill humans or any other animal that consumes enough of them. Red tides are caused by a selection of **dinoflagellate** species, some of which produce toxins and some that are harmless.

Overabundance of phytoplankton may cause big swings in dissolved oxygen concentrations in the water, leading to a condition called hypoxia, where the low oxygen concentrations may cause fish kills.

This activity introduces the use of a very fine plankton tow-net and some basic identification methods to help you collect and become familiar with some of the phytoplankton found in your estuary.

If you would like to complete a more detailed assessment of your estuarine phytoplankton, feel free to complete the activities given in the guideline *Counting plankton in a water sample.*

Activity: Extension

Age: High school

Time: 3

Why? Different types of plankton are always present in the water. The dominant types vary depending on the conditions. For example, diatoms require a source of silica (usually present in riverine water entering the estuary) as well as nutrients, while dinoflagellates only require nutrients. Plankton 'blooms' are often the result of high nutrient concentrations in shallow estuarine waters.

Safety: Net tows may be conducted in deep or fast-flowing waters.

What you may need:

- 50–100 micron phytoplankton tow net
- plastic collection bottle with lid
- 100–200× microscope (preferably with phase contrast)
- microscope slides and cover slips
- dropper or pipette
- alcohol, methylated sprits or glycerine (optional)
- drawing book for recording your phytoplankton, or digital camera.

What to do:

Obtaining a phytoplankton sample from your estuary is relatively easy. All it requires is for you to attach your collection bottle (without its lid) to the base of the plankton net, using a screw mount or a worm-drive hose clamp to ensure the bottle stays in place.

The net is then lowered off the end of a jetty or over the side of a bridge directly into the main flow of the estuary. This is best done just after high tide when the outgoing flow is relatively strong. Tie the net rope onto the structure and leave it there for approximately 15 minutes. Alternatively, you may tow the net behind a seaworthy boat at a slow speed.

Pull the net vertically out of the water so that any phytoplankton on the sides of the net wash down into the bottle. Once the net is onshore, wash anything left on the sides of the net into the collection bottle using seawater. Carefully remove the collection bottle without spilling it, remove any large visible objects and screw the lid on. This bottle will need taking back to the laboratory immediately to examine under the microscope.

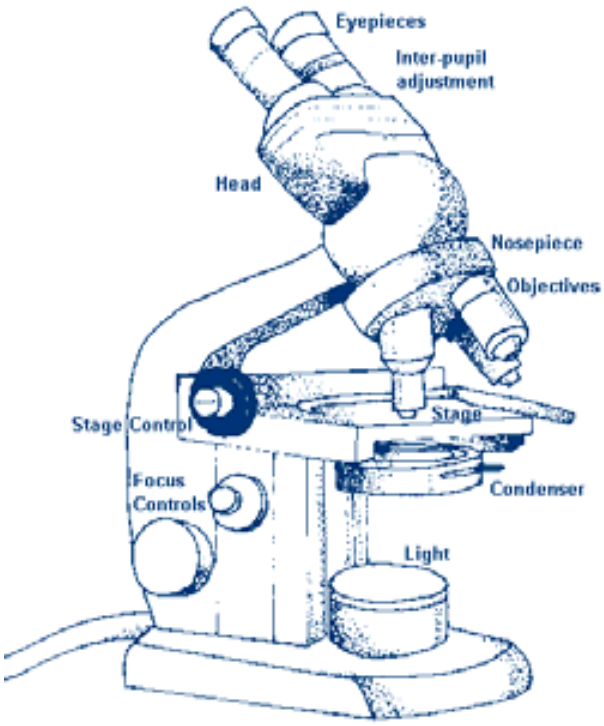


Figure 10—A typical microscope

Back in the laboratory, take a small sample of the phytoplankton and place a few drops onto a microscope slide using a pipette or dropper. Place the cover slip on top of the water.

If you have never used a microscope have a look at a typical one (Figure 10). Once you have familiarised yourself with your microscope, place your slide and cover slip on the stage.

Rotate nosepiece so that the 10× objective is in use, this gives you 100× magnification. Start with the objective down near the slide and coarsely focus upwards by turning the focus control towards the operator. Be careful if trying to focus downwards as the objective could smash into the slide.

Use the fine focus control to gain the clearest image. Adjust the eyepieces to suit your eyes. The eyepieces adjust both for distance between pupils and individual focus.

It is often easier to look through a binocular microscope if you don't actually touch the eyepieces with your face, but view down the eyepieces from a slight distance.

Close the condenser iris just enough to give the specimen some contrast. It should be about one third closed. Too much closure results in a decreased depth of field.

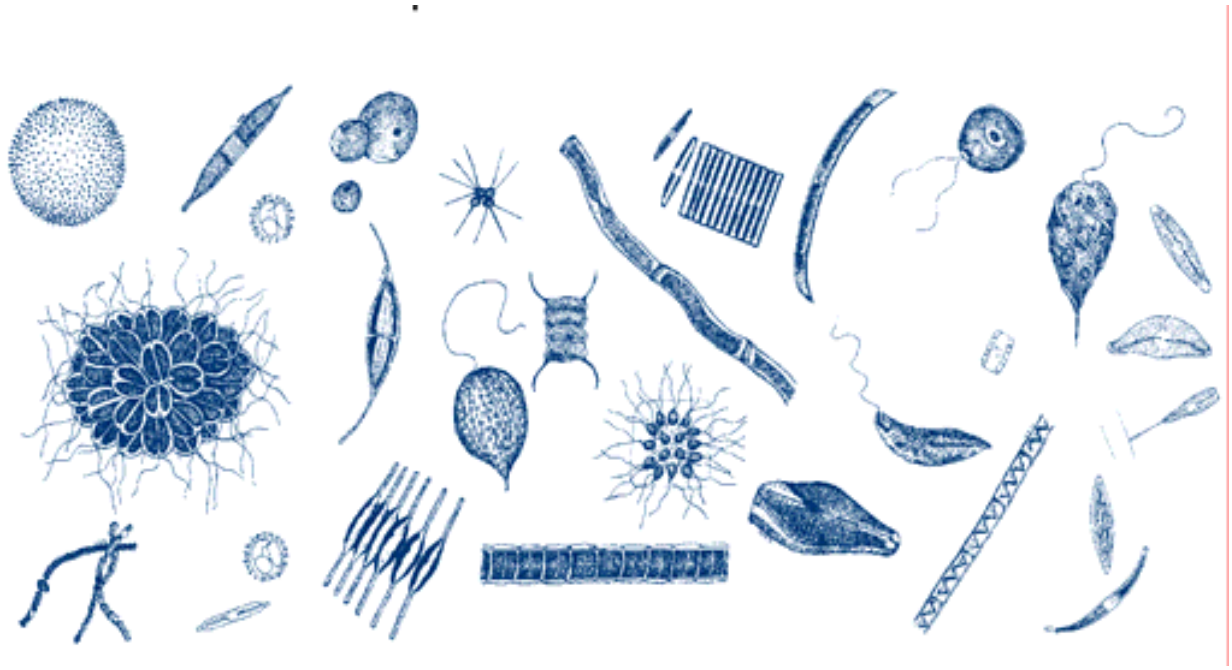
What do you now see down your microscope? Did you notice that some plants swim? If the plankton are moving too fast for you to focus on them, take the slide out and place a drop of glycerine onto the slide. This will make the water thicker and harder for the phytoplankton to swim through.

Alcohol or methylated spirits may be added to the whole sample if you find it easier to look at dead specimens, although you lose the different movement methods, which may help you identify some species or groups of plankton.

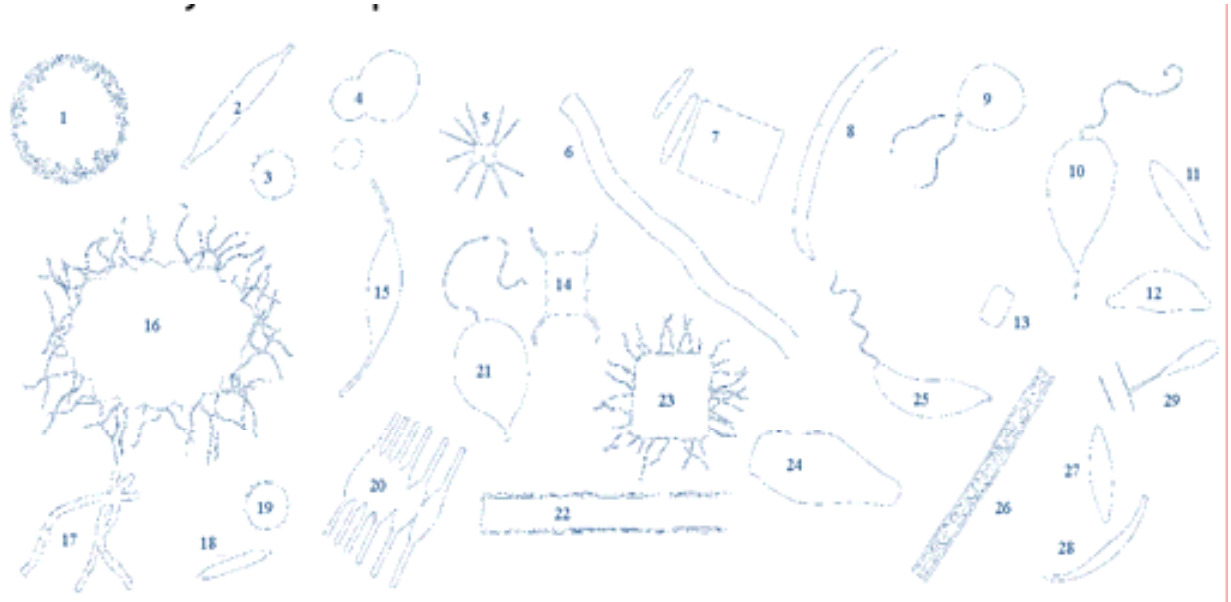
You could now try and draw the plankton you see under the scope, or try and match them up to the pictures shown in Figure 11 of some phytoplankton found in estuarine wetlands near Adelaide.

A digital camera placed on the eyepiece may be able to take photographs of the field of view, and these photographs may be downloaded onto your computer. These could be identified by a specialist or by using specialist identification materials.

You may wish to prepare a list of the types of phytoplankton present in your sample, along with any of the photographs you took or the drawings that you did. Displaying this is a public place helps raise public awareness of the range of organisms that live in your estuarine waterways.



Key to some plankton of South Australian estuaries



1	Volvox	9	Chlamydomonas	17	Anabaena	25	Euglena
2	Nitzschia	10	Phacus	18	Fragilaria	26	Spirogyra
3	Cyclotella	11	Navicula	19	Cyclotella	27	Closterium
4	Chlorella	12	Cymbella	20	Fragilaria	28	Closterium
5	Micractinium	13	Coscinodiscus	21	Phacus	29	Gomphonema
6	Mougeotia	14	Scenedesmus	22	Zygnema		
7	Fragilaria	15	Nitzschia	23	Gonium		
8	Closterium	16	Synura	24	Gomphonema		

Figure 11—Examples of phytoplankton

Counting plankton in a water sample

Activity: Extension

Age: Adult groups

Time: 4

Why? The number of plankton cells present in a water sample, as well as their type, provides information on the health of the estuary.

Safety: Sample/reagent mixes should be disposed of appropriately.

Phytoplankton are single-celled plants that occur in most natural water bodies. They float freely as individuals, colonies or in rope-like strands. They do not attach themselves to surfaces. A microscope is needed to see them, as they are often only a few tens of microns (thousandths of millimetre) long.

A single drop of estuarine water may have hundreds of these microscopic plants in it. These plants are the foundation stone for ecological health. Phytoplankton directly and indirectly support much of our marine life, including large animals like whales and sharks. Unfortunately some species produce toxins that may kill humans or any other animal that consumes enough of them. Red tides are caused by a selection of **dinoflagellate** species, some of which produce toxins and some that are harmless.

This activity uses a condensed water sample and a basic **flowchart** to help you identify and count the common phytoplankton phyla. These are very coarse classifications, but the proportions of one phylum to another may provide an insight into the water quality of the estuary, and the risk of toxic dinoflagellate or blue-green blooms.

If you would like to complete a more detailed assessment of your estuarine phytoplankton, feel free to look at some of the other identification aids referenced in this guideline, or try to obtain other information from your local university library.

What you may need:

- 200–500 mL collection bottle with lid
- 100–200× microscope (preferably with phase contrast)
- 250-mL measuring cylinder
- haemocytometer and cover slips
- dropper or pipette
- 0.5 mL of Lugol's media per sample
- a fine piece of clear flexible plastic piping to use as a siphon
- lidded bucket containing kitty litter
- a plankton count datasheet.

To ensure good results:

Identifying phytoplankton can be difficult, in fact distinguishing phytoplankton (microscopic floating plants) from zooplankton (microscopic swimming animals) may be very difficult, as there are many single-celled clear animals that feed on phytoplankton, and their food items are visible through their cell walls.

Without a great deal of experience you can't be entirely sure of what you are looking at all the time. Even identification guides are not foolproof, as only a small portion of plankton have been described in the scientific literature. Expect to make a few mistakes, and ask someone else their opinion if you are not sure.

A taxonomic surety system is commonly used when trying to identify how confident you are of your data. These systems generally involve placing a number between 1 and 3 after your identification. Number 1 means that you, and maybe a couple of other people, are very happy with your identification. Number 2 means that you are reasonably sure, but have not had someone else's opinion, or they are not entirely sure. Number 3 means that you are not sure at all, but this was the closest identification you could come up with.

Be entirely honest when giving these ratings. If the data is used for management of your estuary, it is better that the decision-maker knows how confident you are of your data. Taking a photograph of any that you give a rating 3 to would mean that these identifications could be checked further at a later date.

An alternative is to simply call all plankton you are unsure about 'unidentified plankton', which will allow you to still count the number present.

What to do:

Obtaining a quantitative phytoplankton sample is usually done at the same time as collection of water samples for other measurements. A 200–500–mL sample bottle is filled with water, obtained from 200 mm below the water surface. This is best done at the end of a jetty or other structure.

This sample is returned to the laboratory as soon as possible, where 200 mL is poured into a 250-mL measuring cylinder. Approximately 0.5 mL of Lugol's media is added and the sample is well shaken or stirred. This is then left to settle overnight.

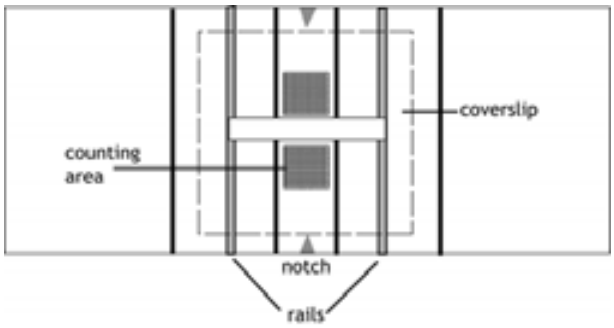


Figure 12—Haemocytometer, general arrangement

The top 180 mL is then decanted off carefully, using a gravity siphon, so that the bottom 20 mL is left undisturbed. This is then shaken up and a drop of the liquid is placed on each half of a haemocytometer slide and a cover slip is placed over the slide.

The haemocytometer is a glass slide normally used to count blood cells. It can be used to count algal cells in the same manner, as discussed in this guideline. The general structure of a haemocytometer is provided in Figure 12.

Place the haemocytometer under the microscope and use the fine focus control to gain the clearest image. Details on how to do this are given in the guideline *Getting to know phytoplankton with a net tow* (page 75).

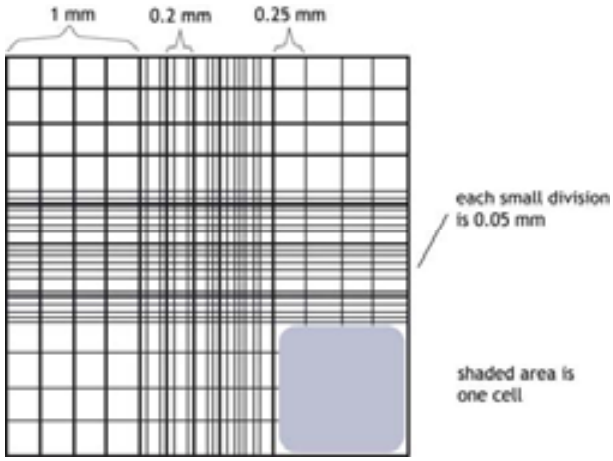


Figure 13—Counting area of a haemocytometer

The haemocytometer has two main counting areas (Figure 12). A more detailed diagram of a single counting area is shown arrangement in Figure 13. Each counting area is divided into nine equal portions of one millimetre by one millimetre. These portions are referred to as cells. There are 18 cells.

The algae present in the counting areas are identified to phylum level with the aid of the chart provided in Figure 14 (a larger version is provided in Appendix 4), the pictures provided in the *Getting to know phytoplankton with a net tow* guideline and any other literature or photographs that you have access to.

The chart identifies marine or estuarine phytoplankton to phyla. This is a very coarse level of identification, but there are many very different phytoplankton species, and identifying them past phylum level requires access to specialised literature. Using the flow chart is very easy. Starting at the top, you look at the statements on each of the paths. Which one does the organism you are looking at match best? Move along that branch and repeat the process until a name is given. Compare your object

to the pictures in the chart. Do they look anything like your specimen? If you cannot make up your mind record the organism as 'unidentified plankton' on your datasheet.

If there are too many algae present to count in all 18 cells, count a smaller number of counting cells. In cases where there is a very high density of algae, only one counting area (comprising nine cells), or in extreme cases only one cell, needs to be counted.

The number and type of algal cells in each haemocytometer cell is recorded on your datasheet. The number of counting cells you counted is written in the neighbouring column. When all the samples have been counted, the remaining sample brines should be disposed of by pouring them into the bucket containing kitty litter. Once the absorbent material can contain no more liquid, it should be bagged and placed in the waste bin for disposal to landfill.

Data interpretation

The data from this type of activity is often presented as the number of plankton present in one mL of water, or the number of plankton from each phylum present in one mL of sample. To calculate the number of phytoplankton per mL or the number of each type per mL you need to apply the formula below:

$$\text{plankton count} = \frac{\text{no of plankton} \times 10^3}{\text{no of cells (squares) counted}}$$

Plankton data is usually presented in list or graph form, with the classification listed down one side and the counts on the other side. Comparisons between the number of plankton in each phylum present provides an informative picture of the water quality in your estuary.

The total number of phytoplankton and the ratios between the phyla are the most useful figures. A high total count indicates a high biomass, therefore a high oxygen demand and large amounts of nutrients in the water. Large numbers of blue-green algae suggest that there are high concentrations of phosphate in the water. Large numbers of diatoms suggest that the water is rich in silica and nutrients.

Play around with the data and combine it with data from other sites or tests. It is fascinating to see what trends or correlations may be found this way.

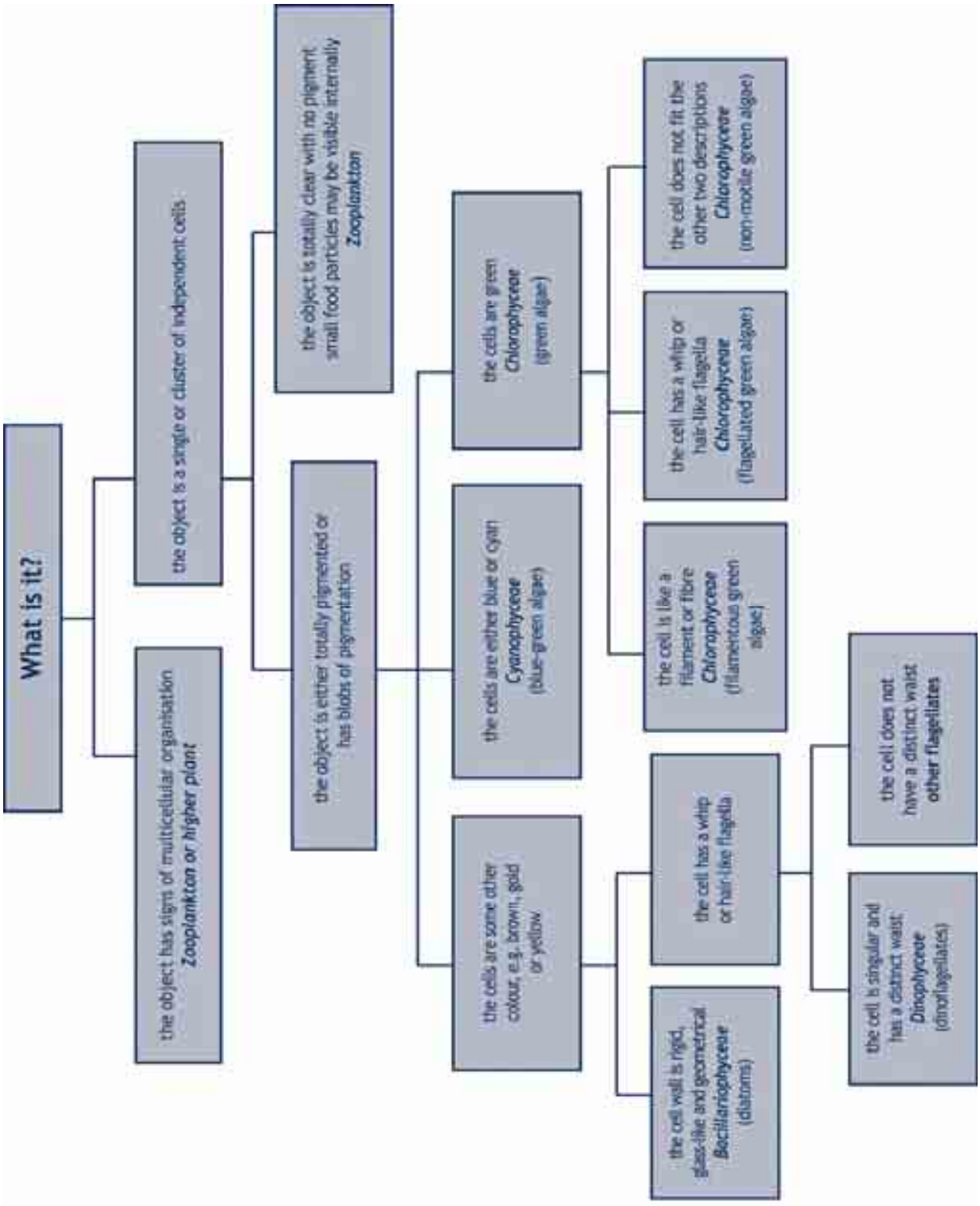


Figure 14—Plankton identification flow chart

Monitoring a seaweed bed

Seaweeds are **macroalgae**, meaning that they form large plants visible to the naked eye. They can be red, green or brown. They have no roots, but often have holdfasts, a cup-shaped appendage that fastens onto solid surfaces, including rocks or jetty pylons.

Seaweed and seaweed distribution are good indicators of water quality in an estuary. As seaweeds are algae, they can grow and die off very quickly. The common indicators of estuarine health—nutrients, pH, turbidity, dissolved oxygen and salinity—all have huge and rapidly identifiable impacts on seaweed communities. Temperature also has an effect on these plants.

In common with most biological indicators, the degree of identification required for this activity depends on what you want to use the data for. The effects of long-term turbidity or nutrients may often be seen by simply identifying the seaweeds to their colour, then estimating the approximate amounts of each colour at your site.

Activity: Extension

Age: High school

Time: 3

Why? The more complex types of brown seaweed (macroalgae) may respond to disturbance by disappearing from seaweed beds.

Safety: Conducted over deep water (jetty, bridge, boat or wharf)

More detailed identifications may give you more detailed information. Catastrophic events such as an **anoxic** event can kill entire algal communities. The structure of each plant may provide you with an indication of how long the community has been growing, and therefore how long it has been since one of these events. Flat sheet-like algae such as *Ulva* start to grow on a site almost immediately the event is over. Complex algae, such as *Codium* species or the complex browns like kelp, need a considerable time after the event before they colonise the site.

This activity leaves the choice of identification resolution to the group. The guideline discusses creating a herbarium or collection of pressings before commencing monitoring, as this allows you to identify how time consuming (or not) detailed identifications may be at your location. This part of the activity may need a permit from the NPWS or PIRSA—check before starting the project.

Once pressed and dried, the specimens could be taken into the State Herbarium (at the Adelaide Botanic Gardens) or to a seaweed expert in your area for detailed identification. This would allow you to simply match the plants you see in the field with those on your named pressings, which would make regular detailed identification much quicker than otherwise.

Several types of equipment for monitoring seaweed beds are suggested—select the most suitable for your group and monitoring location.

What you may need:

For preparing the herbarium

- bathers and mask or a pole with a hook and net at one end
- bucket with waterproof lid
- permit(s) from the appropriate authorities
- sink with plug and freshwater
- A3 sheets of paper, one or two per sample
- several wads of newspaper
- waxed paper
- wooden board a little larger than an A3 sheet
- A3 plastic sleeves
- A3 arch-lever folder.

For doing the monitoring

- GPS and detailed topographic map
- underwater camera, normal camera with polarising lens, or camera in a glass aquarium
- 500-mm quadrat (optional)
- measuring tape
- site herbarium (optional)
- clear transparency film
- transparency film marked with a grid
- permanent markers in a few colours.

What to do:

Site selection

Sites are selected on the basis that the seaweed beds should be obvious from the surface, easily accessible and free from any dangerous currents or deep water. The seaweed bed may be present on a jetty pylon, on a rocky outcrop or any other hard stable surface.

Site selection is best done on a fine day. Visit each jetty and pylon within your estuary or your section of the estuary. Is there anywhere that meets the criteria above? If there are sites, take GPS locations and select your favourite site. Mark the site clearly on your topographic map of the area. If there are no sites meeting the above criteria, then perhaps a different activity may be more appropriate.

Preparing a herbarium

Preparing a herbarium is an important step in the process of getting to know your seaweeds and an essential part of seaweed monitoring.

Select a fine, warm, still day to collect the herbarium samples. The collection may be done in one of two ways. Samples could be cut free of their substrate and caught in a small net using a pole with a hook and net attached, or they may be collected by hand when swimming or snorkelling.

Collecting by hand gives you better samples, but the hook and net method is safer if members of your team don't know how to swim, the water quality is inappropriate for swimming, or in areas that are deep or may experience strong currents.

Once in the field, collect at least one sample of each seaweed you see. Try not to take the samples directly from the site you intend to monitor. You may need more than one sample to comply with your permit conditions. Place these samples into a bucket containing a little seawater and keep them cool.

Once all the specimens have been collected, place the lid on the bucket and take them back to where you plan to press them, generally your home, meeting hall or school.

Back at base, rinse each of the samples off, removing all sand, salt or animals from the fronds and follow the procedure below:

- plug the sink and place a sheet of A3 paper in it
- add cool water until it is about 20 mm deep
- place the first sample in the water and arrange it so that it looks nice and relatively natural on the page
- ensure that holdfasts, the shape of the fronds and any other possible identifying characteristics are visible
- carefully lift a corner or the page and partially unplug the sink, so that the water slowly drains out
- ensure that the seaweed is still arranged how you put it then carefully lift the paper, with the algae on it, out of the sink and onto a few sheets of newspaper

- if the paper rips, redo the activity
- allow this sample to dry in the shade while the rest of the samples are prepared
- place a sheet of waxed paper on top of each sample and place new newspaper above and below them
- stack the samples and place a wooden board and some phone books on top
- change the newspaper whenever it gets wet-probably be every few hours initially then every couple of days
- once all the samples are dry, dust any sand off
- check that the seaweeds are all stuck to their pages, they have not discoloured the paper and are relatively flat
- if the paper is discoloured, carefully lift off or cut out the sample and stick it onto a new sheet of paper
- if the samples are a little loose, stick them back onto their paper with acid-free glue
- once you have finished, place each sheet into a plastic sleeve and put them into a large folder. This will be used regularly during the rest of this activity, so ensure the folder is rigid.

Identifying each of the seaweeds in the folder is an important part of this activity, although identification to species is not required. Asking a specialist or using identification aids to help you identify the specimens to genus level would be more than sufficient. Alternatively, contact Reef Watch or look at their website at <www.reefwatch.asn.au>

Monitoring method

Monitoring your seaweed bed is relatively simple once your herbarium has been prepared and identified to a level you are comfortable with.

Select an area between 0.5–1.0 m wide and the same dimensions lengthwise. Record the location of this using a GPS and mark it on your topographic map. Write a description of the site on the bottom of the map. Place the quadrat or some other device of known length close to the area you plan to photograph and take a picture at low tide from a distance, so that landmarks (eg big boulders or jetty pylons) are visible around the seaweed bed. This photograph is to help you find the location next time you come back.

Hammering in a wooden stake or spray-painting some locating marks may also be possible, depending on your location. Be careful not to damage the area to be monitored or create visual pollution.

Once you have located the area, place the quadrat or something of known length (a scaling object) immediately next to it. Take a picture of the monitoring area and the scaling object, ensuring that the monitoring area and the object take up the entire viewing area of the camera.

The picture can be taken in one of three ways:

1. A disposable waterproof camera may be used with its lens resting on the water surface or submerged below it.
2. A standard camera fitted with a polarising lens is used. Standing on a jetty directly above the site, carefully adjust the polarising lens so that you can see the monitoring area clearly.
3. A standard camera may be placed in a glass aquarium, which is held partially in the water. The picture is taken through the glass bottom. Be careful not to wet your camera if you use this method.

The last two options will probably require a zoom lens of some variety, depending on the size of your monitoring area and the geography of your sample location.

The main aim of this exercise is to get a clear photograph of exactly the same area on a regular basis. With this aim in mind, select the photographic method most appropriate for your group and your site.

Interpreting your results

Once the photographs have been processed, they can be analysed using the methods outlined in the guideline *Using aerial photographs to map habitat change*. The photographs taken are basically homemade aerial photographs and they will yield a similar range of data.

Classification of the seaweeds may be as simple as the percentage of green, red or brown algae, or you may attempt to identify the algae in the photographs to genus, using your identified herbarium specimens or other reference materials.

The most stable areas tend to be dominated by complex brown algae such as *Sargassum* and *Ecklonia.* Intermittently disturbed areas may have *Codium* (a complex green algae), while the filamentous and sheet-type green algae such as *Enteromorpha* and *Ulva* are rapid colonisers after a disturbance or indicate high nutrient concentrations. Right after a major disturbance a few very tiny, fine brown furry algae such as *Giffordia* may be seen.

Once you have finished doing any analysis you wish to do on the photographs, send a list of the herbarium identifications, a copy of the photographs and the results of any analysis to your Waterwatch coordinator and to any agencies that issued permits for the activity. These items of data may be compared with those collected by other groups in other locations, or at other times.

This activity should be undertaken regularly. It depends on the resources of your group and the aims of the program, but annually is probably sufficient. Ensuring that the monitoring is done in the same season each year will reduce the effect of seasonal variation on your data, as the opportunistic green algae in particular, have wide seasonal variations in abundance.

Useful references

Christianson, IG, Clayton, MN & Allender, BM (1981) *Seaweeds of Australia*, Reed Books, Sydney.



Monitoring an intertidal SAM bed

Intertidal submerged aquatic **macrophytes** (SAMs) are vascular plants, with modified flowers, seeds, roots, stems and leaves. Estuarine SAMs include seagrasses, widgeon grasses and watermats. They are aquatic versions of our terrestrial flowering plants.

Measuring the percent cover of SAM quantifies the amount of macrophytes in an area, and allows changes in macrophyte cover to be detected over time. The measure gives an indication of the status and stage of development of a macrophyte meadow.

A macrophyte meadow with a high percentage of cover that displays little variation over time or space indicates a stable community that is well developed. If changes in cover are identified, or an increased amount of coating algae or encrusting animals are detected on the leaves of the plants, the SAM bed may be subject to natural or human induced stress.

This activity uses 500-mm quadrats placed at regular intervals along three transects within an intertidal macrophyte community. A rapid assessment of macrophyte cover is made. The dominant species are also identified.

Depending on the location you wish to study, a permit from the Native Vegetation Council, Transport SA or PIRSA may be required to complete this activity, particularly if you are planning to leave permanent markers for the transects.

Activity: Extension

Age: High school

Time: 3

Why? SAM (submerged aquatic macrophytes) beds are an essential habitat in estuaries, and are fish nursery areas. Most SAM beds require high light levels to survive, and appropriate inundation, temperature and salinity regimes.

Safety: Do not use steel star droppers. They corrode and may also be a health and safety problem to people and boats.

Use suncream for this activity, particularly on the back of the neck. Ensure that hats and suitable shoes are worn by all participants.

Only undertake this activity at low tide.

What you may need:

- two brightly painted garden stakes
- rubber mallet
- quadrat labels
- camera with polarising filter
- 50-m measuring tape(s), preferably made of fibreglass
- compass
- GPS
- 500 mm × 500 mm quadrat (may be subdivided into 100-mm squares with string)
- aerial photograph, topographic or othophotographic map
- identification sheets showing local SAM species (these are available for some areas from Reef Watch or the Coast and Marine Conservation Branch of the Department for Conservation and Heritage).

To ensure good results:

Seagrass meadows experience seasonal and climatic trends in their percentage cover. At least three years of data (preferably more) are required to track unusual changes.

What to do:

Select a 50m × 50 m site using an aerial photograph, orthophotographic map or by walking across the site. The site needs to be relatively homogenous with no obvious sandbanks or changes. Ensure that it appears to be representative of the SAM community at that location and is not difficult to revisit.

Once a site is selected record its position using a GPS and by taking compass bearings from prominent land features. Record these measurements and plot the location on the aerial photograph or topographic map. This will assist with finding the site when revisiting.

Three transects are required. Each transect should run perpendicular to the sea and be 50-m long. All quadrats should be placed on the right-hand side of the transects, so only walk on the left hand side. Mark the middle transect by driving a garden stake into the ground at either end, leaving approximately 100 mm sticking out. Take a GPS reading at each peg and attach a site marker tag to each marker.

The other two transects should run parallel to, but 25-m to the left and right of, the middle transect. These should be unmarked, and will need measuring each visit, or GPS locations recorded to locate their start and finish points.

Always start monitoring an hour or so before low tide. At the beginning of the first quadrat, place a 500 mm × 500 mm quadrat to the right hand side of the transect. Place a quadrat label next to the quadrat and photograph the quadrat so that minimal glare interferes with the photograph (turn the polarising filter until you get no reflections from the water).

You may estimate the percentage cover of macrophytes in the field or at your desk once the photos have been developed. This may be easier if you subdivide your quadrat. Once you have obtained an estimate of macrophyte cover, record your result onto the data sheet.

Once the photograph has been taken, identify and record the species of macrophyte present in the quadrat. If there is more than one species present, an estimate of how much of the total cover each species contributes will be required. If you are unable to identify the macrophyte species, take a specimen (if you have the appropriate permit) or take a photograph of it.

Repeat the above procedure at the beginning, middle and end of all three transects. This activity should be repeated annually at the same time of year, to minimise the impact of seasonal variations.

Data from this activity may be presented as average percentage cover for the site, or dominant species for each site. Presenting the data as a graph or series of graphs is a good method for assessing trends over time at the site or between sites. SAM beds experience seasonal and climatic trends in their percentage cover. At least three years of data (preferably more) are required to track unusual changes.



Monitoring submerged SAM beds

In sheltered estuaries that support SAM (submerged aquatic macrophyte) beds, a stable population of these plants is the hallmark of a healthy estuary.

SAM beds contribute to the estuary in several ways. They provide food for several types of waterfowl and a nursery for juvenile fish. In death, the plants provide huge quantities of decomposed matter as leaves die, and some aquatic invertebrates use this detritus as their main food source. During the warmer growing season, SAMs supply oxygen to the water. The SAM beds lock up nutrients during the summer, and as they die off in autumn they slowly release these back into colder water that will not support large plankton blooms.

SAM beds require high light levels to survive, and appropriate inundation, temperature and salinity regimes.

In South Australia the Coast and Marine Branch of the Department for Environment and Heritage has developed maps of submerged SAM beds, derived from analysing aerial surveys. These are available for many parts of the state, from the South Australian node of the Coastal Atlas, accessed through the internet on <www.atlas.sa.gov.au>.

Activity: Extension

Age: Adult groups

Time: 4

Why? SAM (submerged aquatic macrophytes) beds are an essential habitat in estuaries, and are fish nursery areas. Most SAM beds require high light levels to survive, and appropriate inundation, temperature and salinity regimes.

Safety: This is a deep water activity.

It is not always easy to separate some types of seaweed (algae) from SAMs, and aerial surveys may miss small beds. To improve the accuracy of these maps, **groundtruthing** is used, where the sites identified from the aerial photographs are visited, and sampled, to confirm that they are indeed SAM beds. Groundtruthing submerged SAM beds in your estuary provides users of your data with information on the accuracy of the larger scale aerial mapping, as well as providing information on the location of smaller beds.

If you wish to sample SAM beds, you may need a permit to collect native vegetation from the Native Vegetation Council. These permits are issued by the NPWS.

What you may need:

- seaworthy boat with adequate safety and running equipment
- GPS
- map showing locations of SAM beds in your estuary
- a long-handled rake
- identification sheets showing local SAM species (these are available for some areas, from Reef Watch or the Coast and Marine Branch)
- plastic zip bags for specimens, with a marker pen to label them
- polarised sunglasses, swimming goggles or a clear-bottomed container for viewing the SAM beds
- groundtruthing datasheet.

To ensure good results:

Go out on the calmest day you can, at a reasonably low tide. This will allow you to see into the water more clearly.

Undertake this activity at a similar time of year (preferably summer) to minimise the impact of seasonal variation if you visit the sites repeatedly to monitor their health. Some species of SAMs die back in winter.

What to do:

Before going out in the boat, mark the locations you wish to visit on your map, and write their map coordinates next to them. Record the proposed locations on your datasheet as well.

Proceed to the first location on your sheet. On approaching a SAM bed, SLOW DOWN. Ensure you will not damage the bed with your propeller itself or from the perturbation it may cause. Are you at the location you were heading towards, or have you found a small bed that is not marked on your map?

Float over the SAM bed in your boat. You will get a clearer view by using polarised sunglasses, or by putting on your swimming mask and submerging your head (be careful not to fall in the water), or by looking through a clear-bottomed container (old aquarium or similar).

Record your location, and the size and shape of the SAM bed. Slowly circumnavigate the bed and taking readings from the GPS to determine the shape.

Can you identify the type of SAM? If you are unsure of the species, use your rake to GENTLY fish up a small specimen, bag it, label it, and return it to shore for identification. If you can see what species it is, just record the species on the datasheet.

How healthy does the SAM appear? If you have visited this bed before, is it any different? Note the location of any erosion scarps or blowouts using the GPS. Record whether there is much **epiphytic growth** (visible as a soft brownish fuzz) on the blades of the SAM.

Proceed to the next bed and repeat the process.

On your return to base, identify all samples, or contact your Waterwatch coordinator to help you find someone who can identify them for you. On your SAM bed map or a topographic map, try to draw in any new bed locations, or any other changes as accurately as you can.

If you notice a regular reduction in the size of SAM beds, or increasing numbers of blowouts and propeller scars over several years, talk to your Waterwatch coordinator, who can put you in contact with the appropriate people.



How continuous is the fringing vegetation?

Activity: Extension

Age: High school

Time: 2

Why? Width and continuity of riparian vegetation is related to water quality, particularly water clarity. Other important indicators examined in this activity are weediness and erosion.

Safety: Winter months are normally the best time of the year to conduct assessments as the climate is milder and the risks of encountering snakes is lower.

Always ensure that boots, long pants and a hat are worn by all participants. Water bottles or regular refreshment stops are also recommended.

Riparian vegetation is important in estuarine situations. Riparian vegetation grows alongside tidal watercourses above the high-tide mark, where only king tides, floodwaters or runoff regularly inundate it. In the upper tidal freshwater reaches this vegetation is often distinctly different from the surrounding vegetation, often including emergent **macrophytes** due to the better availability of freshwater. However, further down the estuary the vegetation becomes less distinct from the **supratidal** vegetation, with the vegetation bands often comprising various types of samphire.

Riparian vegetation aids in preventing erosion, provides habitat for small birds or other animals, and cleans stormwater runoff before it reaches the estuarine system.

Much of Australia's riparian vegetation is degraded. Previous clearing for urban, industrial and agricultural development has reduced the quality of riparian vegetation while weed and feral animal invasions have taken over the areas still left in their natural state.

Considerable community and government effort has been spent trying to restore these estuarine riparian zones over the past 10 to 20 years. Some Adelaide councils have built large areas of artificial wetlands to help recreate a small portion of this habitat, and these are used to treat stormwater before it enters the Barker Inlet and the Port River estuary.

This activity aims to provide a rapid assessment of riparian vegetation along a 100-m stretch of estuarine creek and give an overview of the condition of remaining riparian vegetation within the tidal area. The activity uses aerial photos to select homogenous stretches of riparian vegetation to help reduce the amount of fieldwork. Representative sites on the ground are assessed. Five key indicators of riparian vegetation disturbance are examined to provide an index score of riparian health.

What you may need:

- current aerial photos of area to be examined in an appropriate scale
- topographic map of the area in a similar scale to the photographs
- 50-m tape measure
- one-metre measuring stick or similar object
- camera
- riparian vegetation datasheet.

What to do:

This activity can be performed on just your regular sample site, a number of sites, a single tidal creek or on the entire estuary. The activity described here details how you would assess the riparian vegetation of the entire length of a tidal creek. However, it is simple to cut it down to a 100-m site by performing the fieldwork section on your regular water sampling locations, or to gradually assess different sites until you have covered your entire estuary.

Homogenous stream units are sections of stream that have consistent characteristics along their length. This method assumes that there is little variation in the structure of the riparian vegetation within each

unit. This means that an assessment of the entire riparian zone may be made by visiting one site within each unit.

The number of homogenous stream units for each stream will vary considerably, depending on the nature of the stream and its vegetation. Using aerial photos and topographic map, divide your estuary banks into homogenous units using the following method:

1 Divide the estuary at each bend and at any tributary junctions

2 Divide these sections further where the width of the riparian zone changes or discontinues

3 If land uses change, divide the current sections further so different land uses are in different units

4 Ensure that each of the divisions is marked onto the topographic map or a transparency sheet taped onto it.

Each stream unit needs to be greater than 300 m long. Select a representative 100-m length of each stream unit that is accessible to your group.

The remaining part of this activity comprises the fieldwork that is conducted on each 100-m stretch. Each stretch needs to be visited, and the following parameters assessed. Always obtain permission from landholders if travelling on private property is required.

Mark out a 100-m stretch of riparian vegetation from a point that is easy to relocate on future visits. Measure the width of the riparian vegetation on the bank by running a tape measure from the high-water mark to the outer, or landward, edge of the riparian vegetation. Record this on your datasheet. If mangroves are present, measure the width of the mangrove community separately and record on the data sheet.

Look at the extent of the remaining riparian vegetation and estimate the percent remaining by walking along the landward edge of the vegetation and looking towards the estuary. If a bank has a well-vegetated riparian zone that is continuous and consistent, it has excellent continuity. Are there any gaps in the vegetation, or is it one long belt? Record the number and width of breaks in the riparian vegetation and use this information to calculate percentage cover. Note grazing or ploughing of the riparian vegetation. Describe the existing vegetation and identify it, if you can.

Look around for weed species. Are the plants mainly weeds or are they natives? What noxious weed species are present? Note your observations on your datasheet.

Assess the severity of erosion on the bank. Circle the category on the datasheet that best describes the extent of the erosion at this site.

Take a photo of the riparian vegetation by standing at one end of your transect on the landward side, looking along your transect. Ensure a measuring stick is placed in an easily repeatable location (next to a distinct tree, for example). Repeated photos from this point may be scaled against the measuring stick and any changes will be easy to observe.

Record any other visible signs of degradation including litter or dumping. Describe the presence and extent of revegetation efforts or other environmental works and the presence and location of drainage outlets or other man made structures.

The datasheet provides a method of scoring each site. This is an index score for the health of the vegetation, based on the amount of human disturbance. These scores may be compared with scores from other sites to help determine where the most or least degraded sites are.

If your group assesses an entire tidal creek, a map could be developed showing the locations of higher and lower scored areas. Such a map would provide local Landcare groups or the local council with assistance in identifying and prioritising any environmental improvement programs they may be planning. The photopoint photographs taken over several years are also useful in tracking the progress of revegetation efforts.

Monitoring mangrove leaf/twig litter production

In South Australia, only one species of mangrove occurs. This is *Avicennia marina* (its name refers to its sea-going habit). It is commonly called the White (or Grey) Mangrove, due to the colour of the underside of its leaves. It is the most cold tolerant of all mangroves, and is also one of the fastest colonising species.

Tropical areas, such as the Northern Territory, may have up to 36 species of mangrove in large **mangals** or mangrove forests.

Mangrove litter production refers to the shedding of leaves, twigs, flowers, seeds or other vegetative matter by a mangrove tree. This may be caused by age, stress or mechanical factors (eg wind, tides or floods).

Measuring the litter production of individual trees may monitor the health of a mangrove forest. A healthy system should have a high and/or stable monthly litter production, although this may have large seasonal variations (May, 1999). Declining leaf litter production over a period of years, or sudden copious litter production may indicate that the community is under stress.

The amount of reproductive material may also be used as a measure of health, as reproduction effort changes if plants are stressed. **Propagules** from the White Mangrove take up to two years to form, then fall from the parent plant, depending on climate, so a downward trend in the numbers of propagules may take many years to detect.

Litter fall from mangrove trees represents a significant part of the net primary productivity of a mangrove forest, although a considerable amount of extra detritus is brought in with each tide.

Activity: Extension

Age: High school

Time: 3

Why? Leaf and flower production is an indicator of mangrove health. The litter from mangroves is an important part of the detrital cycle and a reduction may affect fauna.

Safety: Snakes may pose danger during the summer months, especially the drier approaches to the mangroves. Always wear suitable clothing (strong shoes and long trousers) and work in pairs to minimise the risk.

Keep a careful eye on the litter when drying it in the oven, to ensure it does not catch alight.

Heat risks apply.

Litter fall is measured by installing leaf litter traps along a transect in a mangrove community. Trapped litter is collected and sorted into different categories, oven dried and then weighed. The dry weight of each category provides a measure of the overall litter productivity of the mangal.

A permit from PIRSA will be required for this activity. If any aquaculture or mining leases are held over the land you are working on, you will also need permission from the leaseholder. It is better to access mangroves through a boardwalk, where these exist, to minimise your impact on the forest.

What you may need:

- GPS and topographic map or map of the boardwalk you are accessing
- 50-m measuring tape
- a metal tape
- leaf traps (500 mm × 500 mm) tagged with unique numbers
- heavy-duty nylon cord, preferably in a bright colour
- a large plastic bag for each trap
- six smaller plastic bags for each trap
- lab scales (accurate to 0.01 g)
- access to drying ovens
- litter record form.

To ensure good results:

Leaf litter varies considerably between trees, depending mainly on the size of the trees and their location in relation to the tide. Many transects would be required to allow a comparison of sites, but fewer locations are required to monitor one site over time. Ensure you select a range of similar sized trees through the width of the forest, and mark those trees so that you may use them again in subsequent years.

What to do:

Select a survey area within the tallest part of the forest. The stunted landward edges of the forest will not provide representative samples. Determine the approximate canopy height using a metal tape and record this on your litter record form.

If you are using a boardwalk to access the mangrove forest, traps may be installed at regular intervals along the boardwalk, through the central portion of the forest. Alternatively, set your traps so that each trap is a similar distance from the low or high tide lines. The number of traps used is entirely up to the resources of the group, although more than one is required to account for variability between plants. Eight or more provide a reasonable number if the group has sufficient resources.

To install a trap, attach a nylon cord to each corner of the trap and tie it onto the mangrove branches so that the trap hangs fairly level. Make sure that the bottom of the trap is above the high tide mark, which is often visible in a mangrove forest as a line of debris caught in the branches.

Mangrove litter traps need to be emptied fortnightly, as *Avicennia marina* leaves have salt in them, and this attracts moisture, causing them to decompose quickly. Empty the trap by removing any large sticks and placing them in plastic bag marked with the trap number. Next you place the bag under the trap chute, untie the chute and empty the trap contents. Retie the chute securely then move on to the next trap.

Should a large storm or king tide disrupt your monitoring by stripping large amounts of leaves or filling the trap with debris, empty the trap onto the forest floor and examine it for damage. Record that the data was lost for this trap during this period. Reset the trap and continue monitoring.

Back at your base, sort leaf litter contents from each trap into the following groups: leaves, flowers, bark (include wood), propagules and 'other' (often dried seagrass or algae that may have blown into the trap from nearby branches). Do not mix the contents of one trap with material from other traps. For each trap, count the number of parts in each category (if possible) and record these numbers on the datasheet.

Place the sorted contents into labelled smaller bags and place these bags together into the original labelled plastic bag for storage until drying. If there is too much litter to dry at once, or the ovens are not immediately available, litter may be refrigerated for up to a week before being dried.

The litter should be dried in its separate categories and trap numbers at 70°C for three full days. The litter is dry when it is brittle and the leaves are easily crumbled between your fingers. If the weather is hot and dry it may be possible to dry, or partially dry, the litter in a sheltered place in the sun, under glass or behind a window. Keep a careful eye on the litter to ensure it does not burn. The propagules many not dry completely, so counts are important to supplement the weights.

Once the litter is dry, use lab scales to separately weigh the contents from each category and each trap. Record each of the weights (in grams to two decimal places) on the datasheet. Dispose of litter back to where it was collected or into municipal waste.

The data from this activity is expressed as g/m^2/fortnight, for each event. If you wish to look at production annually, express the data as a range of values per month, eg x–y g/m^2/month, or present the data as a graph showing each sampling event.

Significant declines or sudden increases in leaf litter fall or reproductive effort may indicate that the community is under stress. Seek advice if such trends occur.

Monitoring mangrove expansion

Wet coastal ecosystems containing habitats such as mangroves and saltmarshes are **seral** communities (Chapman, 1960). The distribution of the different habitats is governed by sediment supply, tidal regime, wind-wave climate and the relative movement of local sea level (Packham and Willis, 1997).

For the development of **mangals** and saltmarshes, sand or mud flats must accumulate until their level is high enough to allow colonisation by plants. This can only occur where there is sufficient sediment supply (either from land or offshore) and where the water flows are of low energy. Construction of embankments, death of offshore benthic flora such as seagrass beds and channelling of stormwater flows may influence bank formation by changing the tidal regime, water flow rates or wave action.

Changes in these communities occur reasonably quickly, and simple photographic monitoring may detect the changes within a few years. One particularly useful way of assessing this change is to establish a photopoint at a boat ramp that traverses the width of a mangrove forest.

Activity:  Extension

Age: High school

Time: 2

Why? Regular examination of the seaward and landward edges of a mangrove forest can determine whether the forest is expanding or retreating landward. This may indicate local sea-level change, or sediment availability.

What you may need:

- camera
- fixed locations for taking photographs (may be paint marks on a boat ramp, above which you stand your camera tripod, a marked jetty rail or something similar)
- a metre rule or other measuring stick with the date marked on a sheet attached to it.

To ensure good results:

Choose a ramp, wharf or other location where you can see along both the seaward and landward edges of a mangrove forest. Ensure that you can access both areas to place your metre rule against a tree.

What to do:

This activity is best conducted annually, to record the expansion or retreat of the edges of the mangrove forest.

Establish a location that is easy to mark and close to the seaward edge of the mangroves from which to take your photographs. Place your metre rule against a mangrove tree that will be in the foreground of the photograph. Take a shot that looks along the seaward edge and that includes your metre rule as a scale and date.

Move inland until you reach a point where you can see along the landward edge of the forest. Repeat the activity outlined above.

Once you have collected several years of photographs you may wish to scan the prints, and enlarge or reduce them so that the metre rule is the same size in all of them. Most image editing software will allow you do this, and to overlay the photographs so that you can see the difference. Alternatively, you could scale the prints using a photocopier, then place a grid over the scaled photographs to estimate the change, as described in the guideline *Using aerial photographs to map habitat change*.

Is your mangrove forest expanding, retreating or moving inland?

Studying saltmarsh plants

Saltmarshes in South Australia have changed extensively since European settlement. Drains and dykes have been used to convert marsh areas into agricultural lands, and embankments have changed the hydrology significantly.

There is evidence to suggest that, in the Port Adelaide area, saltmarsh communities are declining due to a landward expansion of mangrove communities. This is due to a combination of soil subsidence (a result of embankment works in the 1890s) and sea level rise.

Healthy saltmarsh communities show a zonation from the lower marsh to the upper marsh. In South Australia, saltmarshes are samphire-dominated. Species in the lower marsh may include *Sarcocornia*, then there are bands of *Sclerostegia*, *Halosarcia*, *Maireana* and *Atriplex*, and then at the highest zone a band of grasses may be found.

This activity looks at the percent cover and species dominance of saltmarsh species along a line intersect transect. The transect can run either perpendicular to (from land to the mangrove fringe), or parallel to, the tidal gradient. Samphires may be very dense and grow over highly uneven terrain, and so it is preferable to work from a boardwalk. If you have access to a boardwalk, you may consider it to be the transect line and assess the plants to one side of the walk.

The presence and distribution of species over time is a simple but useful indicator of ecosystem function over time, with their loss or decline indicating potential environmental stress (Zedler, 2001). Vegetation patterns may change in response to, and may indicate, changing soil salinities or pH, tidal flushing regimes or climatic patterns. Therefore this activity is a useful one for assessing the progress of saltmarsh rehabilitation projects that involve changed tidal regimes (ie after floodgates have been removed or modified).

Activity: Extension

Age: High school

Time: 3

Why? Saltmarsh areas are valuable wader habitat and fish nurseries. Saltmarshes are very vulnerable to hydrological change, which may be revealed by a change in the vegetation.

Safety: Saltmarshes are home to snakes and other small creatures. They also have large numbers of hidden creeks or overhangs which are easy to fall down. Look where you are walking and ensure that all members of the group are wearing long pants and covered shoes.

Saltmarsh environments have no shade and can become extremely hot. Wear a hat, take a bottle of water and try to work in the cooler parts of the day.

What you may need:

- 50–100 m tape measure
- saltmarsh identification guides
- compass and GPS
- topographic or site map
- plastic or painted wooden stakes
- mallet or hammer
- saltmarsh vegetation record form.

To ensure good results:

Do not monitor immediately after a very high storm tide. The saltmarshes are likely to be flattened, which will bias results.

What to do:

Site selection

Closely examine aerial photographs of the marsh you wish to monitor. If there is a boardwalk or walking path through the marsh, take a walk along it. Observe the species composition, cover and canopy height of the saltmarsh and the extent of each of the habitats.

It is important to select a monitoring site that is easy to access. Walking across saltmarshes damages them, and they may take a long time to recover. The harder the site is to access, the more damage accessing it will do. Using the edge of a boardwalk or walking path as the transect line is probably best for minimising damage and making this activity easier on participants.

The next most important point is to ensure that the site appears to be representative of the state of saltmarshes in the area.

Establishing a transect or line of intercept

The direction and length of the line intersect transect depends on the objectives of the monitoring program, site characteristics and access.

Intersect lines that run from the mangrove edge to the highest point in the marsh will generally capture the fullest range of habitat gradients. However, lines running parallel to the tide will give you the largest sample of one habitat type.

Each transect should be 50 to 100 m long. If you are running the transect line across the marsh, measure this out and lay the measuring tape along the ground. At the start point of the line, hammer a small stake in (with the permission of the landholder). Record the location using a GPS or your site map. Hammer another stake in at the other end and record its location. Attach the measuring tape to each stake so that it is relatively straight and level.

If you are using a boardwalk as a transect, simply mark the start and end points with a dab of paint on the boards, and record their locations using your GPS or map.

It is recommended that 100–300 m of transect is established in each area of saltmarsh that you wish to monitor, although this will depend on your resources and time availability.

Monitoring the marsh

Starting at the beginning of your transect and look at the plants that intersect it. What is growing directly below the measuring tape, or right next to the boardwalk? Use your guides to identify it to either genus or species level. If you can't identify it, take a picture or describe it. A few good identification books are listed at the end of this guideline. How much of the first metre of transect line does each species cover?

Record the distance along your transect this species covers. For example, you may have a two metre-wide swathe of *Sarcocornia quinqueflora*. It is not necessary to record bare mud if the patches are less than 200 mm across. Bare areas larger than this need to be recorded.

Look at each metre along the transect line and make a similar assessment. If you get long lengths of the same thing, just record this as one entry and draw brackets enclosing the area it covers.

When you get to the end of the first transect work out the total amount of each species in linear metres or percentage. Record the unit that you use. Repeat this procedure for each of your transects.

The information you obtain will tell you about species dominance, the percentage cover of saltmarsh species and the percentage cover of weed species. A copy of your field sheet and calculations for the figures mentioned above should be sent to your Waterwatch coordinator.

This activity detects changes that occur over a long period and that may not be noticeable to the eye. An annual measurement at the same season may be required for three years or more, before you can detect slow degradation. Two measurements a year apart may pick up any rapid improvement that occurs on remediated sites. A once-only measurement will tell you quite a lot about the type of saltmarsh you are

monitoring, but will not tell you much about any environmental impacts that may be occurring, apart from the presence and quantity of weeds.

Some areas, such as the high marsh areas near Port Pirie that abut natural **sabkhas** (giant mud or salt flats), will naturally have a low percentage cover, and will be dominated by a very few species. Other areas, particularly low marshes, will have a high percentage cover and will also have high number of species. Neither of these are more, or less, healthy than the other.

A useful purpose of saltmarsh monitoring is to perform a 'before and after' assessment for regeneration projects or hydrological changes on the site. If the monitoring is being used for this purpose, control sites should be established to determine if the detected changes are site specific or are the result of more widespread variations such as the weather.

Data on soil salinity, pH, soil elevation and tidal flushing regimes would also be useful when interpreting the saltmarsh species data. Guidelines on measuring these parameters are available in earlier sections of this manual.

Useful references

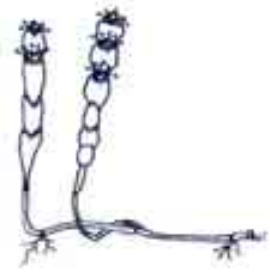
Dashorst, G & Jessop, J (1998*), Plants of the Adelaide Plains & Hill*s, 2nd edition, South Australian State Herbarium, Finsbury Press.

Datson, B (2002), *Samphires in Western Australia: A Field Guide to Chenopodiaceae Tribe Salicorniae*, Department of Conservation and Land Management, Perth.

George, A (ed)(1984), *Flora of Australia: Volume 4—Phytolaccaceae to Chenpodiaceae*, Commonwealth of Australia, Griffin Press, South Australia.

Jessop, J & Toelken, H (1986), *Flora of South Australia. Parts I—IV*, 4th edition, South Australian State Herbarium, South Australian Government Press, Adelaide.

Zedler, JB (2001), *Handbook for restoring tidal wetlands*, CRC Press, Boca Raton, Florida.



Monitoring *Melaleuca* leaf/twig litter production

In wetter areas of South Australia, *Melaleuca* or Tea-Tree swamps often replace mangroves at the fresher end of estuaries.

'Litter production' means the shedding of leaves, twigs, flowers, seeds or other vegetative matter by a plant. This may be caused by age, stress or mechanical factors such as wind or floods.

The health of a *Melaleuca* swamp may be assessed by measuring the litter production of its major plant species. A healthy system will have a high and/or stable monthly leaf litter as the older leaves are shed when the plant produces newer ones, although there may be large seasonal variations. Declining leaf litter production over several years may indicate that the community is under stress. The quantity of reproductive material may also be used as a measure of health as reproduction effort changes if plants are stressed.

Litter fall from *Melaleuca* species represents a significant part of the net primary productivity of a **supratidal** *Melaleuca* swamp. Examples of these types of swamps can be found in estuaries throughout the southeast of South Australia.

Litter fall is measured by installing leaf litter traps along a transect in a *Melaleuca* community. Trapped litter is collected and sorted into different categories, oven dried and then weighed. The dry weight of each category provides a measure of the litter productivity of the *Melaleuca* community. This method should only be attempted if groups can obtain access to drying ovens.

A permit may be required for this activity. Attempt to find out who owns the land you plan to collect litter from. If privately owned, get written permission from the owner. If the land is owned by the Crown, a permit to take native vegetation (available from the NPWS) may be required.

Activity: Extension

Age: High school

Time: 3

Why? In SA, *Melaleuca halmaturorum* fringing wetlands are often present in the estuarine parts of swampy watercourses. These freshwater-intertidal wetlands are an important filter system for floodwaters, and also attenuate the progression of floods into the more marine parts of the estuary.

Safety: Snakes may pose danger during the summer months, especially in long grass. Always wear suitable clothing (strong shoes and long trousers) and work in pairs to minimise the risk.

Keep a careful eye on the litter when drying it to ensure it does not catch alight, and ensure no other flammables are near the litter.

Heat risks apply when working with ovens.

What you may need:

- GPS and topographic map
- 50-m measuring tape
- steel measuring tape
- leaf traps (500 × 500 mm) tagged unique numbers
- four wooden garden stakes for each trap
- heavy-duty nylon cord, preferably in a bright colour
- a large plastic bag for each trap
- six smaller plastic bags for each trap
- lab scales (accurate to 0.01 g)
- access to drying ovens
- litter record form.

To ensure good results:

Select your survey site so that it is completely contained in habitat that appears homogenous. If the habitat changes, then litter collection will also vary.

What to do:

Record the dominant species present, and use the steel tape to approximate the canopy height of your site. Record this on your litter record form.

Traps may either be installed at regular intervals along a transect or located randomly in a 20 m × 20 m grid. The number of traps used is entirely up to the resources of the group. However, more than one is required to account for variability between plants. Eight or more is a good number if the group has sufficient resources.

To install each trap, hammer four stakes into the ground until about one metre high. Place them in a square pattern just over 500-mm apart. Attach the trap to the stakes with heavy-duty cord, ensuring that the chute is off the ground. The trap is not generally secured to the tree, as *Melaleuca* branches snap easily. Ensure that the chutes are securely tied.

If your area of *Melaleuca* swamp is regularly inundated, locate the traps in the higher areas of the wetland, discontinue monitoring during flood periods or place the traps high enough above the ground to prevent inundation.

If traps become flooded during wet periods discontinue leaf collecting from this trap until the flood has dispersed. When the water is gone, return to trap and empty it onto the ground. This litter will have rotted or have been contaminated with sediment, so is not useful. Record that the data was lost for this period. Reset the trap to continue monitoring.

Traps need to be emptied every month. This is to prevent leaf decay and to help determine monthly or seasonal trends. Empty the trap by removing any large sticks and then place them in a plastic bag marked with the trap number. Next you place the bag under the chute, untie the chute and empty the trap contents. Retie the chute securely then move on to the next trap.

Once back at your base, sort leaf litter contents from each trap into the following groups: leaves, flowers, bark (include wood), seeds, other species (non *Melaleuca*) and weeds. Do not mix contents of one trap with material from other traps. Count the number of parts in each category (if possible) and record these numbers on the datasheet.

Place the sorted contents into smaller bags and the smaller bags back into the original labelled plastic bag for storage until drying can be attempted. If there is too much litter to dry at once, or the ovens are not immediately available, litter contents may be refrigerated for up to a week.

The litter should be dried in their separate categories and trap numbers at 70°C for three full days. The litter is dry when it is brittle and the leaves are easily crumbled between your fingers. If the weather is hot and dry it may be possible to dry, or partially dry, the litter in a sheltered place in the sun, under glass or behind a window. Keep a careful eye on the litter to ensure it does not burn.

Once the litter is dry, use lab scales to separately weigh the contents from each category and each trap. Record each of the weights (in grams to two decimal places) onto the datasheet. Dispose of leaf litter back to where it was collected or into municipal waste.

The data for each sampling event is expressed as g/m^2/month. Should you wish to look at an annual figure, express the data as ranges of values per month, eg x–y g/m^2/month, or graph the year's events.

Significant declines in leaf litter fall or reproductive effort may indicate that the community is under stress. Seek advice if such trends occur.

Using aerial photographs to map habitat change

Activity: Extension

Age: High school

Time: 3

Why? This activity measures the changes in coastal habitats that occur over a long period of time.

Safety: This is a desk-based activity.

The first time aeroplanes were used to photograph a large section of South Australia was in 1949. This area included Adelaide and its surrounding plains. The photos were in black and white, but the quality was exceptional for the time.

In the last 54 years these aerial photographs are taken on a regular basis. The Adelaide metropolitan area is photographed at least every year. Other lowly populated areas are photographed less frequently.

These photographs were initially taken for planning reasons, as they are used to create up-to-date orthophoto maps in the 1:20,000, 1:10,000, 1:5000 and 1:2500 scales. Environmental scientists, managers and geologists quickly found uses for aerial photographs, as they are plentiful sources of data. Aerial photography is now commonly available in black and white, colour, false colour and digital formats.

For this activity current or historic orthophoto maps or aerial photographs may be used. Where available, these are the two cheapest sources of spatial data on your estuary. Obtained in an appropriate scale, usually between 1:10,000 and 1:2500, these maps and photographs can be used to identify land management changes, new areas of development, changes in vegetation or pollution discharge areas.

Current aerial photos, satellite imagery, topographic maps and orthophoto maps are produced by and can be purchased from the State Government, through Mapland SA at (08) 8463 3999 or <www.mapland.sa.gov.au>. This group also produces CD ROMs of aerial photographs for different parts of the state, and these are a very economical way to purchase large areas of coverage.

This activity is simplest to complete if all the data sources are obtained in similar scales, as it makes comparison easier; scaling can be done later if required. The personnel at Mapland or any other retail outlet should be able to assist you in selecting the right scale for this activity. If in doubt, ask to look at an example of your area in each of the different scales and pick the one you feel best fits your requirements.

What you may need:

- aerial photos of your estuary area, both historic and recent
- latitude and longitude, Australian Map Grid or Universal Map Grid coordinates for a range of landmarks surrounding or in your estuary (these may be obtained from a good quality topographic map)
- clear transparency film
- black-lined graph paper, photocopied onto transparency film
- fine-tipped permanent markers
- topographic map with a similar scale to the photograph
- ruler
- paper clips, pins or blue tack
- calculator
- good light.

To ensure good results:

Use at least three, and preferably four, reference points to check the scale of your aerial photograph and remember to **groundtruth**—check your interpretation by visiting the sites.

What to do:

Interpreting maps and aerials: orientation

Lay your photographs and maps out in front of you. Locate landmarks that you have visited on the ground. Can you find any? Do they look different from how you thought they would look?

Lay a transparent sheet over the photographs and mark the landmarks with a permanent marker. Write the coordinates next to the landmarks on the acetate sheet, then lay it over a map of the same scale. If you do not have a map of the same scale, you may reduce or increase the size of your transparency on a photocopier.

Do the landmarks on the transparency line up with those marked on the map? How far out are they? Aerial photos are distorted due to the curve of the earth and the angle the plane was at when the photo was taken. How distorted are your photos?

Interpreting maps and aerials: tracing objects of interest

Place a transparent sheet onto your aerial photo. Select the objects that you wish to map. Examples could be vegetation types, housing and industrial areas, area of the estuary or the location of the shoreline. Use your fine tipped permanent markers to trace around each of the objects of interest, using a different colour if you want to show several things on the same sheet. For instance, mangroves could be outlined in one colour and samphires in another.

Be careful, when tracing, to be as accurate as possible, otherwise your data will not be of very good quality. It is generally recommended that the outside of your marker line matches the outside of the object or area you are mapping, and that the line is as fine as possible.

If mapping the changes that occur over time in habitats, trace each of the different dated aerial photographs onto different transparent sheets.

Interpreting maps and aerials: working out area

Once you have finished tracing all the objects, reduce or enlarge them on your photocopier until they are all to the same scale. Once you are happy with them, photocopy them onto film that has graph paper markings on it, or overlay two bits of film and stick them together.

Determine the area of each of the squares on the film. Count the number of squares that fall completely within each of the traced objects and estimate the number of partial squares. Calculate the total area (on the film) of each of the traced objects. Multiply this by the appropriate scale to get the area of each of the objects on the land.

Interpreting maps and aerials: comparing change

Change can be measured in a number of ways. It may be measured as changes in area, or it may be measured as changes in location. Compare your tracings and your area calculations. Has any object or land cover type changed significantly in its total area? Are the individual areas of vegetation smaller or larger?

Lay the tracings on top of each other. Has any object or land cover type changed significantly in location? If so has it moved inland or seaward? and by how much?

These figures provide very useful information for environmental managers. For example, in the Adelaide area, much of the coastal area around Port Adelaide and Gillman has potential acid sulphate soils. In the 1890s seawalls were put in, to keep the tide out of large areas south of St Kilda, so the land could be used for grazing. This plan was not very successful, and by the late 1930s the seawalls were breached to allow the sea back in. However, the sea did not just come back in to where it had originally: in the time it had been kept dry, the soil had oxidised, generating acid. This had dissolved much of the

carbonate (shelly) deposits in the soil, and the land had shrunk. It was now much lower than it had been when the seawalls were first installed. As a result the mangrove zone has moved inland by several hundred metres in some areas. Acid sulphate soils are not restricted to the Adelaide area, they occur in depositional coastal environments around the state. Activities such as *Measuring soil salinity and soil pH* will help you determine if your estuary has areas of acid sulphate soils.

Interpreting maps and aerials: facing the ground truth

After completing your analysis it is recommended that your data be groundtruthed. This simply means going into the field with a GPS and checking that what you thought you saw on the photos or maps is actually there.

Mark any areas that are different from your original assessment and redo any calculations based on this new data.

Further information on mapping mangroves and saltmarsh can be found in Wilton & Saintilan (2000).

More detailed analysis

If your group becomes very interested in analysing aerial photography, you may be prepared to spend the time to learn the use of a computerised geographic information system (GIS). These packages simplify the **georectification** and scaling of your photographs, and may provide very sophisticated analyses. Free public domain GIS packages are available for those interested in exploring this technology. More information (and the software) can be found at the following web addresses:

- <www.microimages.com> is the site for free TNTlite software (size limited version of TNTmips)
- <grass.baylor.edu>is the site for free, open source GRASS software developed by the US military
- <www.esri.com/software/arcexplorer>is a very basic free GIS from the makers of ArcInfo
- <www.tiem.utk.edu/~sada> is the free Spatial Analysis and Decision Assistance software page
- <www.mapmaker.com> is the site to download Mapmaker Gratis.

Presenting your data

Data from this activity is presented as a loss or gain in habitat area or development changes over a period. When discussing this data it is important to mention the years being compared and the scale of the original photographs or maps.

Aerial photograph interpretation is somewhat subjective, which is why groundtruthing is very important.

The significance of changes must be assessed when interpreting data from this activity. Changes in land cover of less than 10% over 10 or 20 years may not be significant. The error in the processes used may account for a considerable amount of the error. If there was a consistent 10% change in land cover every year, for a period of 3–4 years, this may be significant.

Availability of photographs, or poor quality historical photos, may be a difficulty for some groups or areas. The Coast and Marine Branch has placed a considerable quantity of coastal habitat mapping (including some historical data for parts of the SA coast) online in the South Australian node of the Coastal Atlas. The Atlas may be accessed by visiting the website at <www.atlas.sa.gov.au/coastal/>.

Measuring beach litter

Litter on our beaches and floating in Australian marine and estuarine waters is a big problem, particularly non-biodegradable litter. It harms our marine life, divers and beach-users. Soft drink rings may trap seabirds, plastic bags may be eaten by sea mammals or entangle fish, sharp needles and bits of glass give nasty cuts or diseases to beach-users, and bits of net entrap anything from humans to marine mammals or fish. Cans full of propellant and heavy oil cause mini oil-spills that may kill significant colonies of barnacles or other marine life. Australian beaches are some of the best in the world, and litter makes them to look unsightly.

This activity encourages volunteers to collect all the litter they find along a belt of beach, rock embankment or mudflat. The collected litter is then sorted into different categories and weighed.

The information gained from this activity provides your Waterwatch coordinator and KESAB (Keep South Australia Beautiful) with useful data on the amount of litter building up and also gives you a good opportunity to clean up your shoreline. This activity could be undertaken as part of Clean-up Australia Day activities each year. If you wish to register for Clean-up Australia Day, contact KESAB via their website at <www.kesab.asn.au>.

Another useful source of information is the brochure *Keeping Tabs on Marine Debris*. The brochure and record forms are on the internet at <www.environment.sa.gov.au/coasts/pdfs/marine_debris_info.pdf>.

To obtain the most valuable data, your stretch of beach should be cleaned every three to six months, although once a year will suffice. Data from this activity can help determine if education programs or legislation to reduce littering are working, identifies the major sources of litter and helps raise public awareness of the problem of litter in aquatic environments.

Activity: Core

Age: All

Time: 2 or 3

Why? Many non-biodegradable articles cause harm to marine life (entanglements and ingestion), people (diver entanglements, cuts to beach-users) and to marine vessels (propeller snags, etc). The estuarine benthic habitat may also become smothered with non-biodegradable wastes.

Safety: Ensure everyone is wearing gloves and protective shoes.

As with all field work, ensure that a first aid kit is available. A yellow sharps container should be on hand to place all broken glass and needles into.

If an object is large or heavy, ask for someone else to help you pick it up.

Dead aquatic plants, animals and birds often wash up on the shore. Leave them there—they are part of the estuarine ecosystem and are usually meant to be there. Note large numbers of dead flora or fauna if the quantity seems unnatural.

What you may need:

- beach litter record form
- heavy-duty plastic, hessian or Clean-up Australia Day bags
- bathroom scales accurate to 0.2 kg
- 50-m measuring tape
- clipboard and datasheet
- topographic map or GPS
- special container for sharps
- gloves and protective shoes for everyone.

To ensure good results:

Beach litter collection is fairly subjective. It depends on what the volunteers consider to be litter, how thorough the search is and the time of year that the survey is done. Another limitation is that only visible litter can be collected. Some litter may be buried by sand.

What to do:

Select a suitable beach, muddy shore or rocky embankment in your estuary. It should be easily accessible, be known to have a build-up of litter and have no other routine cleaning. Estuarine sites should be free of mangroves or other structures, and be clear of directly dumped rubbish. Do not monitor beach dunes for rubbish, as they are fragile and monitoring may sometimes be more harmful than the rubbish.

Select a starting point and lay out a 500-m transect (or as close as you can get) using a measuring tape. A 50-m tape may be used, by getting several people to measure out 10 lengths of the tape. Record the width, starting point, length and direction of the transect on a map or using a GPS.

Start walking along the beach at the beginning of the transect and walk in a close zigzag pattern, covering the entire area of the transect. Collect all rubbish and place into a suitable strength rubbish bag. Once finished take all bags from the beach to a sorting area.

At the sorting area empty all bags and sort the litter into the rubbish types listed on the datasheet. Count the number of litter items in each category and record them.

Brush sand or mud from each item of litter using a brush (or hose off) and place into plastic bags labelled with the type of rubbish the bag contains. Weigh all the bags for each category using your scales. Record the weights for each category on your sheet.

Foam or other light items can be put into bags of a known size rather than cleaning and weighing them. Record the number and size of these bags on your datasheet. Fishing line can be recorded in its approximate length rather than being weighed.

Dispose of the debris items into a rubbish skip or at a rubbish tip. Where possible, recycle rubbish.

You may also record the presence of washed up marine organic matter (eg seagrasses or algae) on your record sheet.

Separating litter into categories makes analysing the data easier. It ensures that the source and transportation methods of each of the rubbish categories can be assessed. Have a try at guessing the sources of your rubbish. Where do you think it came from? What clues are given about how it got to your transect area? Do you think that there was an acceptable amount of litter on the beach?

Data is better interpreted as weight of litter per length of beach (rather than weight per unit area) due to the tendency for much beach litter to be clumped along a narrow band at the high tide mark. It is better to use weight as an indicator than total number of items, as many items tend to break up into smaller fragments.

Beach litter monitoring is best conducted every one to three months. Please note that increased quantities of litter are likely to be found after strong winds, currents or storms. Always collect litter at low tide when the beach area is exposed.

