MANGROVE AND SALTMARSH STUDIES FOR SECONDARY STUDENTS

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The excursion to the mangrove swamp has long been a part of the educational experience of secondary school students of biology on the east coast of Australia. It is felt that the time has come to update this traditional experience in the light of an increased awareness of the importance of our coastal wetlands and estuarine areas, and an increased understanding of the complex and fascinating physiology of mangroves as a whole.

The experiments and observations described in this paper have been developed from a series of activities presented during the Youth Programme of the XIII International Botanical Congress held in Sydney during August 1981. They include both laboratory and field experiments and observations which would be suitable for students of varying ages. By selecting activities suitable to the particular age group, it should be possible for teachers to develop an understanding of the saltmarsh-mangrove community in pupils from the upper primary levels through to the Higher School Certificate level.

The general theme of the activities might best be summed up as "Mangrove and the problems they face". The aim of the exercise is to present a picture of the mangrove as a whole. In presenting the exercises, it is particularly important to avoid the 'test-tube' approach where problems are presented as isolated phenomena rather than as parts of an integrated whole.

MANGROVE DISTRIBUTION

Mangroves are widely distributed round the coast of Australia, some 29 species having been recorded. The major concentration both by total numbers and by variety occurs along the northern coastline of the continent. In the Sydney region and along most of the New South Wales coast only two species occur, *Avicennia marina* (Forsk.) Vierh., and *Aegiceras corniculatum* (L) Blanco. *Aegiceras* does not occur south of Merimbula. *Avicennia* extends southward into Victoria and is also found in Gulf St. Vincent and Spencer Gulf in South Australia.

Avicennia is a shrub or medium sized tree with a well-defined trunk and numerous vertical pneumatophores. The leaves are opposite, ovate with an acute apex, glossy green above and with a greyish mat of fine hairs below. On the New South Wales coast it is the more abundant species. *Aegiceras* is a shrub, often with several small trunks and with no pneumatophores. The bark is blackish, often with prominent lenticels at the trunk base. Leaves are alternate, ovate obtuse glossy-green above and paler but hairless below. This plant may occur as an understory in *Avicennia* stands.

The suggested experiments and activities are presented under subject headings. Teachers should select activities from under the various headings and modify them as necessary in the light of their students' capabilities and the time and equipment available to them.

ECOLOGICAL ACTIVITIES

Ecological transect through Saltmarsh and Mangroves

The techniques of the ecological transect will be familiar to most biology teachers. The activity aims to investigate, in an organised way, the changes in the distribution and abundance of plant species which occur across a typical section of the saltmarsh-mangrove area. These changes can be related to changes in the physical environment. Ideally, the line of the transect should be surveyed using a dumpy level or some other suitable surveying instrument to measure in fine detail the changes in elevation of the soil surface. In the absence of these measurements, it is sufficient to note visible variations in slope and elevation of the soil surface together with the approximate high and low tide levels.

Select a suitable transect line and mark it out with pegs or markers at 30 metre intervals. Using a 25cm x 25cm quadrat (or larger), sample the vegetation at intervals along the transect line. The interval between quadrats will depend on the rate at which the vegetation changes and may vary along the length of the transect.

At each sampling point record the distance of the quadrat from the beginning of the transect, the species which are present within the quadrat, and the approximate proportion of ground cover provided by each species. Express your estimate of ground cover on a scale from 1 to 5.

Scale number	Ground cover
1	less than 20% cover
2	20% to 40% cover
3	40% to 60% cover
4	60% to 80% cover
5	80% to 100% cover

Also record the area of bare ground, the presence of surface water, the number of pneumatophores and whether the quadrat is under the mangrove canopy.

The key to the species of coastal saltmarshes in New South Wales published in the first issue of this journal will assist in the identification of the plants found (Adam 1981).

On your return to the laboratory, results should be plotted in the form of histograms on a scale diagram of the transect showing changes in elevation in a vertically exaggerated form.

FIELD INVESTIGATION OF MANGROVE PHYSIOLOGY

Mangrove Root Systems

Mangroves have developed a variety of structures which appear to facilitate the supply of oxygen to the root system. In *Avicennia* specialised roots called pneumatophores are developed. The surface of the pneumatophore is covered by a corky layer penetrated by large numbers of lenticels. These permit the passage of air into extensive areas of aerenchyma within the cortex of the pneumatophore. This aerenchyma, which appears as a white spongy layer when the pneumatophore is cut or broken, is continuous with other regions of aerenchyma in the horizontal part of the root system, thus providing a pathway for the transport of air throughout the whole root system. The aerenchyma tissue in the roots of both *Avicennia* and *Aegiceras* can contain up to 50% free air space.

Select a suitable location between one and two metres on the landward side of the stand of mangroves in an area where a large number of pneumatophores appear. Lay a large sheet of plastic on the ground close to the area selected and using a spade, dig a hole 60cm long, 30cm wide and 30cm deep. Place the soil removed from the hole on the plastic sheet.

Working on the vertical side of the hole, carefully remove the soil from a portion of the root system. Use a small trowel, dissecting needles and a spatula together with a water spray from a washbottle or, preferably, a garden sprayer to expose the roots. Show the relationship between the pneumatophores and the horizontal roots, the presence of feeding roots arising from pneumatophores (Fig. 1) and the presence of aerenchyma just below the surface of any woody roots found.

It should be possible to demonstrate the continuity of air spaces within the root system by carefully removing a section of horizontal root with a pneumatophore attached and blowing through the cut end of the pneumatophore.

When you have finished the experiment, carefully replace the soil in the hole and restore the soil surface to its original appearance. The small amount of damage done to the root system by this experiment will not affect the health of the trees as they have efficient mechanisms to repair damage done by such natural factors as attacks on the root system by crabs.

Root Ventilation

The soils in which mangroves grow are almost invariably low in oxygen. Measurements of oxygen in soil water taken from the landward side of the mangrove area give oxygen levels between 20% of the air saturation value at the start of the pneumatophore region and about 5% of air saturation under the outer limit of the mangrove canopy.

In the area under the mangrove canopy the presence of hydrogen sulphide in the soil indicates that the soil is in a highly reducing state. Significant amounts of oxygen would have to be added before any free oxygen could be detected in the soil.

Mangrove roots permeate the whole of the area under the canopy and these roots require oxygen for respiration and growth. In *Avicennia* oxygen and carbon dioxide exchange is thought to occur through the pneumatophores whereas in *Aegiceras*, this exchange may occur through lenticels at the base of the trunk. Lenticels can also be formed on roots which emerge above ground level.

Activity. Demonstrate the movement of air into a pneumatophore

It is possible to demonstrate the ease with which air moves into the root system of *Avicennia* by use of a simple manometer system as shown in Fig. 2.

A young undamaged pneumatophore, free from algal growth and barnacles and with a dry surface, is selected. A strip of thin rubber cut from a rubber glove is wrapped tightly round the pneumatophore at ground level. The rubber is then liberally coated with petroleum jelly and the barrel of a 10ml plastic syringe is forced down over the pneumatophore and rubber strip to form an airtight seal at the bottom. The nozzle of the syringe is then connected to the manometer by means of a piece of thin flexible tubing and water is poured into the open end of the manometer to produce an increased

Figure 1. Pot-grown *Avicennia marina* plant showing pneumatophores, horizontal roots and feeding roots.

Figure 2. Apparatus to demonstrate air movement into a pneumatophore.

pressure in the air around the pneumatophore. If the closed arm of the manometer has been made from a graduated burette tubing, it is possible to measure the volume of air entering the pneumatophore in a selected time interval. After pouring the water into the open arm of the manometer, note the level of the water in the closed arm and the difference in water levels between the closed and open arms. As air moves into the pneumatophore, the water level in the closed arm will rise. The pressure differential can be maintained either by adding water to the open arm or by moving the open arm up and down.

Record the rate at which air enters the pneumatophore at various pressure differentials and plot your results on a graph.

By lowering the open arm, it is also possible to cause air to move out of the root system when the air pressure around the pneumatophore is less than the ambient pressure.

Investigate the effect that wetting the surface of the pneumatophore has on the rate at which air moves into and out of the root system.

This experiment does not imply that air movement into and out of the mangrove root system is caused by absolute pressure differentials, but rather demonstrates the presence of pathways along which air movement can occur with ease. The actual mechanisms by which oxygen and carbon dioxide move within the mangrove root system are imperfectly understood.

SALT BALANCE AND SALT EXCRETION BY MANGROVE LEAVES

Mangroves as terrestrial plants transpiring water from their leaves require a constant supply of water. As the water available in the soil almost always has a high salt content, the plant must adopt a strategy which enables it to prevent the build-up of salt within its tissues.

Several mechanisms are possible and mangroves as a group of plants have adopted two such mechanisms. The first is to exclude salt at the root level, in which case the xylem sap contains salt levels similar to those found in most land plants. The second mechanism is to exclude most of the salt at the root level and actively excrete excess salt from their leaves. In this case xylem sap contains salt levels higher than those found in other plants. The first group are known as salt excluders and have xylem sap salt concentrations between 2 $mol.m^{-3}$ (mM) and 7 $mol.m^{-3}$ (mM) and the second group are known as salt excreters and have xylem sap salt concentrations between 20 $mol.m^{-3}$ (mM) and 100 $mol.m^{-3}$ (mM).

Both *Aegiceras* and *Avicennia* are salt excreters and excrete salt from specialised salt glands on their leaves.

<u>Activities</u>. <u>Salt Excretion</u>

The simplest experimental observation of salt excretion in both mangrove species is by visual inspection of the leaves and by testing the surface of the leaves of both species. On dry days, salt crystals can be seen on the upper surface of the leaves of *Aegiceras*. The salt present on the leaves of *Avicennia* is not usually visible as it is hidden by the dense mat of hairs which covers the lower surface of the leaves. If the surfaces of the leaves of both species are licked, the presence of salt is immediately obvious and, with care, it is possible to determine on which surface excretion is most extensive.

At a slightly more advanced level it is possible to wash both leaf surfaces with distillled water using a wash bottle. Collect washings in a plastic sample tube. The washings may be tested for the presence of chloride with 1% silver nitrate solution and for sodium by introducing a small portion of the washings in a bunsen flame using a platinum wire. Published data suggests that a leaf of *Avicennia* can excrete about 5mg of salt a day and *Aegiceras* about 1.2mg of salt a day.

MORPHOLOGY, PHYSIOLOGICAL ANATOMY AND BEHAVIOUR

The most outstanding feature of the mangrove environment is its highly saline nature, and the response of the mangrove to this environment has been extensively investigated in recent years. In the field mangroves are found growing in situations which range in salinity from occasionally hyper-saline to brackish and in the laboratory both *Avicennia* and *Aegiceras* can be maintained successfully by watering with tap water.

The dispersal of seeds and establishment of seedlings presents a special problem to the mangrove because of the tidal nature of the environment. Seeds which are initially buoyant must be able to anchor themselves in unstable mud or sand within the tidal range to have a chance of survival. In *Avicennia* , fruits remain on the plant until the embryo ruptures the testa and fills the pericarp which enlarges in proportion to the growth of the embryo. This precocious development of the embryo is called vivipary and is a common phenomenon in mangroves. When the fruit falls it absorbs water and then splits allowing the seedling to break out of the pericarp.

<u>Activities</u>. <u>Distribution of seedlings</u>

Observe the distribution of seeds and seedlings in an area of mangroves. In the Sydney district most *Avicennia* seed fall occurs between October and December. At this time it is possible to observe the distribution of the current year's crop of seeds, together with the seedlings of the previous year and also young plants which are several years old.

<u>Germination</u>

Collect seeds of *Avicennia* from the mud surface and set up a germination trial. The seeds can be placed in a

Figure 3. *Avicennia marina* seedling grown on water culture. This plant is about 4 months old.

container of sand and vermiculite, pushing the seed slightly under the surface of the sand and watering regularly with tap water and occasionally with salt water. The pots containing the seeds should be placed in a warm position out of direct sunlight. The growth of the seedlings can be monitored over several months, summer holidays permitting.

When the seedlings have grown to the two-leaf stage they can be transferred either to 15cm pots containing a mixture of sand and soil or used to set up the water culture experiment described below. If the plants have been potted they can be transferred to a shaded location outside and watered with tap water and occasionally with sea water. The plants will grow more readily if each pot is placed in a 2-litre icecream container which is kept full of water.

If a number of 10-15mm holes are bored round the base of the pot, the horizontal roots formed by the plant will grow out through these holes and these roots form pneumatophores. It is also possible to transplant small plants from the field and maintain them in a similar fashion.

Water culture

It is quite easy to grow the seedlings in water culture. Germinated seeds at the two-leaf stage can be supported in a hole bored in a piece of plastic or waxed hardboard so that the roots project into a suitable nutrient culture medium. A piece of foam plastic will help to support the plant in the hole (Fig. 3). A 2-litre icecream container makes a suitable solution vessel.

The nutrient medium does not need aeration and should be topped up regularly with fresh water, to replace water lost by evaporation and transpiration. The nutrient medium should be changed every two weeks.

A simple and effective nutrient medium consists of 20% seawater (1 part fresh seawater to 4 parts tap water) to which is added a soluble complete plant nutrient such as 'Aquasol' at the rate of about 1 gram per litre.

Salt tolerance

Since mangroves seem to be able to tolerate variations in salinity, it is interesting to examine the response of seedlings to increasing concentrations of sodium chloride in culture solutions. The previous experiment can be adapted to determine the optimum seawater concentration for seedling growth.

Eight containers are set up containing various seawater concentrations as follows:

% seawater	% Tap water	Soluble nutrient (1 gl^{-1})
100	0	0
100	0	✓
80	20	✓
60	40	✓
40	60	✓
20	80	✓
0	100	✓
0	100	0

In planning your experiment, consider what would be a suitable number of replicates.

Connor (1969), describing a similar experiment, suggested that, rather than introducing seedlings immediately to high salt concentrations, the amount of salt in the nutrient solutions should be gradually increased over a period of several weeks.

During the growth period records should be kept of height, leaf number, and mineral deficiency or toxicity symptoms. After about 3 months, the plants can be harvested, separated into tops and roots, oven dried and weighed. The results can then be graphed to present the data in a variety of ways.

Pneumatophore development

As mentioned previously, small plants transplanted from the mangrove swamp can be made to grow and form pneumatophores if the pot containing the plant is placed in an outer container which is kept full of water. Observe the way in which the pneumatophores develop from the horizontal roots. This is a long term project which may take 12 months to complete.

Handcut microscope sections of the pneumatophore and the horizontal root can be prepared to show the structure of the aerenchyma. Note particularly the stellate thickening of some of the cells in the aerenchyma and the presence of large air spaces.

Salt glands

Salt glands occur on both surfaces of the leaves of *Avicennia* and *Aegiceras*. Salt excretion occurs mainly on the lower leaf surface in *Avicennia* and on the upper leaf surface in *Aegiceras*. Handcut microscope sections of the leaves

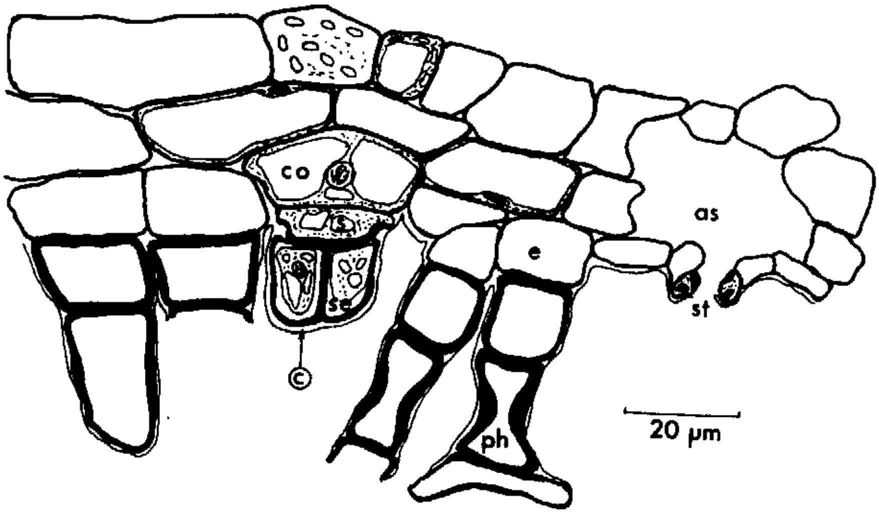

Figure 4. Transverse section of portion of a leaf of *Avicennia marina* showing salt gland, drawn from fixed stained section. Airspace (as); cuticle (c); collecting cell (co); epidermis (e); peltate hair (ph); stalk cell (s); secretory cell (sc); stoma (s).

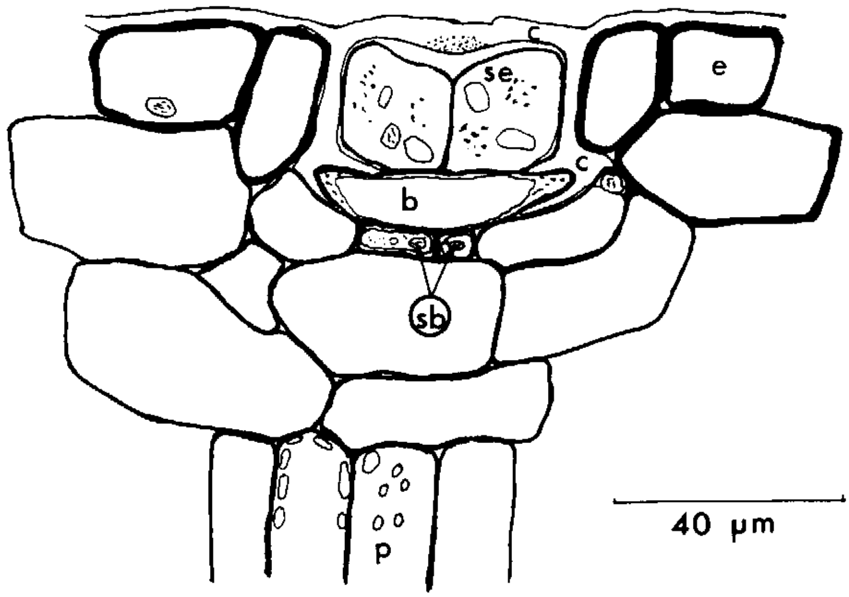

Figure 5. Transverse section of portion of a leaf of *Aegiceras corniculatum* showing salt gland, drawn from fresh, hand-cut section. Basal cell (b); cuticle (c); epidermis (e); palisade cell (p); secretory cell (sc); sub-basal cell (sb).

of both plants can be prepared to show the salt glands and other structures within the leaf (Fig. 4 and Fig. 5).

ORGANISATION OF A MANGROVE EXCURSION

The success of an excursion to the mangrove swamp will depend to a large extent on careful planning and organisation. It is important to ensure that the site selected for the excursion is suitable, that access is possible for the number of students involved and that the state of the tide is suitable. A map showing the location of some suitable sites in the Sydney area together with comments on them is included in this paper.

It is possible to organise successful excursions at almost any time during the year but if it is planned to collect seeds of *Avicennia*, October and November are the most suitable months. A day should be selected on which the tidal range is greater than one metre and the excursion should aim to arrive on the site about two hours before low tide.

Suitable clothing and foot-wear are essential. It is inevitable that students will get dirty and muddy so old clothing is indicated. Overalls or jeans and long-sleeved shirts are probably most suitable and in summer a hat is essential. The most suitable footwear are old sandshoes or gumboots. Rubber thongs or other forms of open footwear are completely unsuitable for use in the swamp, however an extra pair of rubber thongs to change into after the excursion will prevent excessive soiling of homeward transport. A spray jacket or plastic raincoat is useful in case of inclement weather.

In some areas, insect repellent will make for a much more pleasant day and a supply of water for washing hands and equipment is useful. It is a prudent precaution to carry a simple first-aid kit for the treatment of bites and scratches. As most mangrove areas are remote from shops, students should carry a cut lunch and something to drink.

The scientific equipment carried will depend on the activities to be carried out and the preparation of this equipment requires careful forward planning. The preparation for the excursion is an essential part of the scientific activities and, if possible, should be carried out by the students themselves.

Items which are often forgotten are tape measures, razor blades, masking tape, plastic bags, sample bottles, writing and labelling materials, string, pieces of wire and some simple tools. Also allow for breakages and for the contamination of clean glassware to be used for sampling. Carry a bag to take away your garbage.

A NOTE OF CAUTION

The mangrove and salt marsh communities are fragile and are easily damaged by human intervention. Care must be taken to avoid excessive trampling especially in *Sarcocornia* areas. Holes made to examine root systems must be filled in and all litter removed from the sites. Try and leave the site cleaner than it was when you arrived. Respect the regulations concerning reserves and National Parks. Restrict your collections to the minimum necessary and do not denude sites of seeds or seedlings.

SUGGESTED STUDY SITES

1. Pittwater - Careel Bay. Gregory's Map 84, Ref G12. Off Hitchcock Park, Barrenjoey Road. Excellent site for all types of work.
2. Hunters Hill - Boronia Park. Gregory's Map 57, Ref G16. Tipperary Falls Picnic Area off Princess Street. A good site with a limited saltmarsh zonation; some pollution.
3. Concord - Brays Bay. Gregory's Map 40, Ref A7. Enter Park at end of Killoola Street, Concord (Rotary Club Picnic Area). A good site with saltmarsh zonation to right of walkway. *Aegiceras* rare or absent, some pollution. Toilet facilities in Park.
4. Rhodes - Homebush Bay - Powells Creek Reserve. Gregory's Map 39, Ref J12. Good *Avicennia*. *Aegiceras* appears absent. Some saltmarsh succession. Polluted. A fair site.
5. Padstow, Riverwood. Salt Pan Creek, Gregory's Map 37, Ref B2., D8. Site 1. Stuart Street Reserve at end of Stuart St. Very good *Avicennia*. Some *Aegiceras* along creek in S.E. corner of reserve. Saltmarsh species present along creek not good for zonation. Polluted. Site 2. Salt Pan Creek Bridge, Henry Lawson Drive. Good *Avicennia* and saltmarsh species under bridge. *Aegiceras* just north of bridge. A fair site. Polluted.
6. Grays Point - Point Danger. Gregory's Map 92, Ref D12, B11. Site 1. Point Danger at end of Grays Point Road. Excellent mangrove site. Saltmarsh species present but zonation poor. A very pleasant site. Site 2. Reserve at end of Shallow Rock Road (boat ramp). Excellent for mangroves. Saltmarsh zonation fair. Toilet facilities nearby.

Many other suitable sites can undoubtedly be found in the Lane Cove River, Middle Harbour and Port Hacking areas. The sites on Towra Point and at Kurnell have been deliberately omitted.

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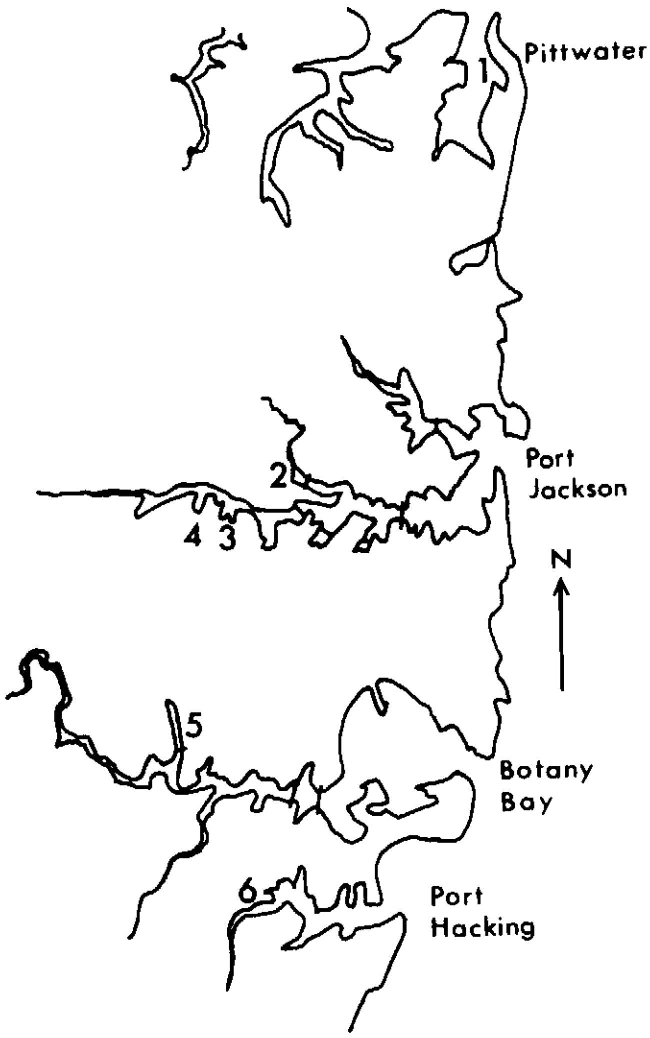

Figure 6. Outline map of Sydney district showing Mangrove Study Sites.

1. Pittwater – Careel Bay
2. Hunters Hill – Boronia Park
3. Concord – Brays Bay
4. Rhodes – Homebush Bay
5. Padstow – Salt Pan Creek
6. Grays Point, Point Danger.

MARINE AND ESTUARINE RESERVES IN AUSTRALIA WITH PARTICULAR REFERENCE TO NEW SOUTH WALES

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CONCEPTS OF MARINE PARKS AND RESERVES

A gradual realization throughout the world that the resources of the oceans and estuaries are becoming more affected by the impacts of man, has highlighted an urgent need for the reservation of representative areas of marine and estuarine ecosystems.

This idea of marine parks and reserves as a logical extension of the terrestrial park concept into the underwater realm, seems, like that of terrestrial national parks, to have flowered originally in the U.S.A. The concept was given impetus by the first World Conference on National Parks held in Seattle in 1962 which "recognized that the oceans and their life are subject to the same dangers of human interference and destruction as the land, and encouraged that the governments of all countries with marine frontiers examine, as a matter of urgency, the possibility of creating marine parks and reserves". (Randall 1971). Further impetus was given to the concept by a special symposium on marine parks held at the Eleventh Pacific Science Congress in Tokyo in 1966 and the International Conference on Marine Parks and Reserves, also held in Tokyo, in 1975.

Two broad options for the effective protection of the marine and estuarine environment were outlined by Talbot and Rooney (1978/1979); these are:

(i) To prevent adverse impacts on selected areas by declaring them to be reserves and by the creation of buffer zones of protection around them. Distance and proper management then become the principal factors in their preservation.

(ii) To establish a co-ordinated system of management and protection, thus enabling areas of impact to be contained while protecting the overall system.

Although some attempt has been made in New South Wales towards the latter goal by the establishment of a Coastal Council, the former is probably a more realistic approach to the problem in the immediate future.

The main objectives in the establishment of marine reserves have been discussed in a number of places (McMichael 1972; Collett and Pollard 1975; I.U.C.N. 1976; Pollard 1977; Rooney *et al.*, 1978; Ottaway *et al.*, 1980), and can be summarised thus:

(i) Preservation of self perpetuating populations of particular species of organisms and their habitats.

(ii) Preservation of samples of natural ecosystems, both common and rare.

(iii) Preservation of areas of particular scientific and aesthetic interest.

(iv) Preservation of areas of the natural environment for the purposes of education and recreation.

MANAGEMENT

Before marine or estuarine reserves can be established, certain conflicts which are characteristic of them need to be