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# The Fauna of Australian Mangroves

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Mangrove forests are among the world's most productive ecosystems. In Australia, mangroves have an extensive distribution and are probably important for the maintenance of estuarine fisheries. Despite these values, there has been relatively little research on the ecology of Australian mangrove communities. Botanical studies have been most extensive, work on mangrove fauna has been largely restricted to a few commercially-important or pest species. Many of the data available are non-quantitative, anecdotal or unpublished. This lack of data on mangrove fauna prevents the development of detailed plans of management and therefore poses long-term conservation problems. In order to identify areas where research on Australian mangrove fauna is needed and, it is hoped, to stimulate such work we summarize information on the Australian mangrove ecosystem and discuss the structure and evolution of these communities.

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## INTRODUCTION

Mangroves are among the most productive of the world's forests (Westlake, 1963; Lugo and Snedaker, 1974) and contribute importantly to the productivity of tropical and sub-tropical estuaries. Working in southern Florida, Odum and Heald (1975) demonstrated that the organic matter produced by mangroves formed the base of a detritus food chain that culminated in the rich fisheries of Florida Bay. Mangroves occur around the coast of Australia (Lear and Turner, 1977) (Fig. 1). In the estuaries of northern New South Wales, Queensland, the Northern Territory and parts of Western Australia, mangroves form extensive forests which, with seagrasses and salt marshes produce the organic matter that is the base of the fisheries of northern Australia. Many of Australia's commercial fish species feed on mangrove fauna or use the mangroves as a nursery (Newell and Barber, 1975; Pollard, 1976, 1981). Crab, prawn and oyster are other fisheries intimately associated with mangroves (Ruello, 1973; Staples, 1980 a,b).

Despite their ecological and economic importance, research on Australian mangroves has been largely botanical, describing vegetation (MacNae, 1966, 1967; Chapman, 1975; Saenger *et al.*, 1977; Bunt and Williams, 1980, 1981; Williams and Bunt, 1980), floral biology (Clarke and Hannon, 1970, 1971; Duke and Bunt, 1979; Tomlinson *et al.*, 1978, 1979), geomorphology in relation to distribution of mangroves (Thom *et al.*, 1975) and mangrove physiology (Clough and Andrews, 1982). Faunal studies have mostly been restricted to surveys of species present in mangroves (e.g. Hutchings and Recher, 1974; Saenger *et al.*, 1977). Studies on ecosystem dynamics have been initiated (Bunt *et al.*, 1979; Clough and Attiwill, 1982, a, b; Goulter and Allaway, 1979), but there is little information on mangrove productivity or the pathways by which energy flows from mangroves through Australian estuaries. The information that is available tends to support the findings of Odum and Heald (1975).

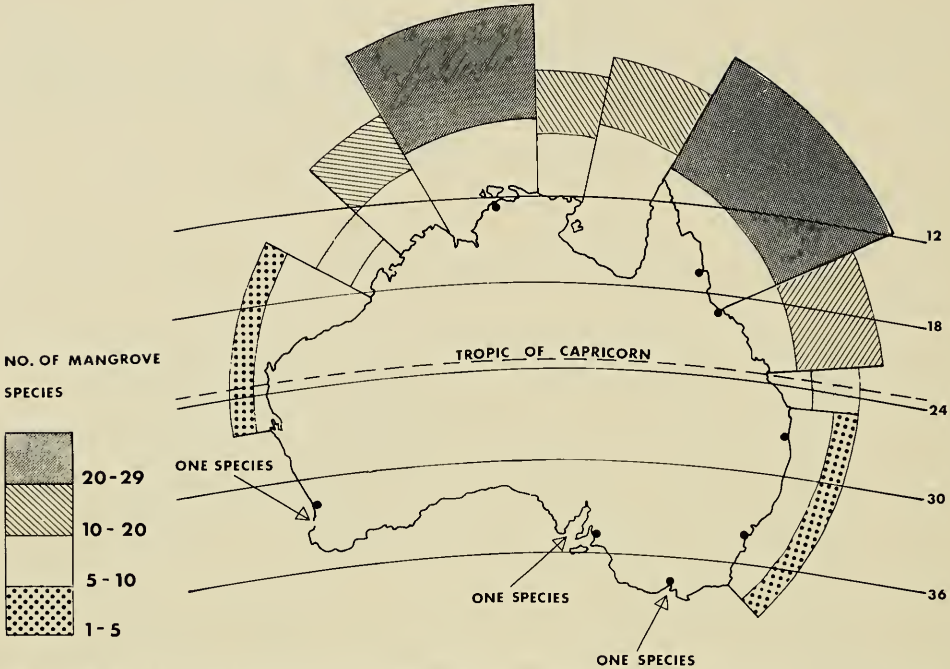



*Fig. 1.* The number of mangrove species increases from temperate areas to the tropics. Only one species, *Avicennia marina,* occurs around the coast from South Australia to Cape York. With increasing species number, there is a concomitant increase in community complexity.

Odum and Heald (1975) examined the food webs in a simple estuarine mangrove community, *Rhizophora mangle,* in southern Florida. The community was characterized by a large vascular plant production with little input from plankton or algae. Most of the leaves and stems produced by the mangroves (Duke *et al.,* 1982; Williams *et al.,* 1982) were not eaten by herbivores, but became part of the decaying matter ('litter') on the forest floor. Mangrove detritus formed the basic component in the diet of primary marine consumers ('detritivores'). Among the primary consumers studied by Odum and Heald, detritus of vascular plant origin formed 20 per cent of the diet. The authors concluded that mangrove leaf detritus was the most important element in the food web. However, Redfield (1982) has presented a modified version of their model with increased emphasis on the consumption of mangrove leaves by insects (see Onuf *et al.,* 1977) and mud dwelling herbivores (see Malley, 1978) and decreased emphasis on the importance of bacteria and fungi in the breakdown of mangrove detritus.

As in all communities, animals are an integral part of the mangrove ecosystem. Herbivores and detritivores living in the mangrove forest have been shown to be important in the transfer of energy from the mangroves to the estuary (Goulter and Allaway, 1979; Odum and Heald, 1972; Malley,1978). In the absence of detailed information about the fauna of Australian mangroves, models of local mangrove ecosystems must be considered incomplete. In turn, the lack of data on the mangrove ecosystem, its fauna and the relation of these to the estuary seriously hampers the conservation of mangrove forests and the management of estuarine fisheries. As we have previously pointed out (Hutchings and Recher, 1977; Recher and Hutchings, 1980), mangroves are a threatened habitat throughout eastern and southern Australia. The development of a national conservation strategy for mangroves and their management is of critical importance for the sustained production of estuarine and near-shore fisheries (Hutchings and Recher, 1977).

In this paper we review what is known of the mangrove fauna in Australia. Data are often sketchy or anecdotal and much of the information presented here is as yet unpublished. We do not apologize for these deficiencies; our intention is to focus future research work on areas of greatest need.

## Mangrove Fauna

The mangrove fauna is composed of animals from terrestrial, marine and freshwater environments. It is a diverse fauna with an abundance of vertebrate and invertebrate forms. Some are restricted to mangroves; others occur more widely. For many species the full range of habitats used is unknown and species currently classed as mangrove endemics may occur elsewhere. Some animals are only temporary residents. Birds may use mangroves for roosting, fish move into and out of the mangroves with the tides, others come in seasonally like flying foxes (*Pteropus* spp.) to feed on nectar. In this review we have ignored records of animals which do not occur regularly in mangroves.

### VERTEBRATES

Few vertebrates are restricted to mangroves. The majority are casual visitors or accidental occurrences. Saenger *et al.* (1977), for example, record over 200 species of birds from Australian mangrove habitats, but fewer than half occur regularly (Schodde *et al.*, 1982).

#### *Mammals*

No mammal is endemic to mangroves in Australia, nor is there any species for which mangroves are the principal habitat. The rat, *Xeromys myoides,* has been recorded living among mangroves on the Tomkinson River, Arnhem Land, and on Andranang Creek, Melville Island in the Northern Territory (Magnusson *et al.*, 1976). It has also been recorded as frequenting mangroves near Mackay in central Queensland and on North Stradbroke Island in southern Queensland (Van Dyck *et al.*, 1979). In these situations it builds nests of leaves and mud among the mangrove roots of *Bruguiera;* the nests are flooded on the highest tides (Magnusson *et al.*, 1976). *Xeromys* feeds on crabs and is at least partially arboreal, but also occurs in a wide range of habitats other than mangroves (R. Strahan, pers. comm.).

Many other terrestrial animals enter mangroves and may obtain part of their food there. Frith (1973) records a number of rodents (*Rattus colletti, Mus musculus, Melomys* spp., *Mesembriomys* spp. and *Conilurus* spp.), bandicoots (*Perameles, Isoodon*) and the northern brush-tailed possum *Trichosurus arnhemensis* as occurring in mangroves. The water rat *Hydomys chrysogaster* forages regularly in mangroves (Frith, 1973; Recher, pers. obs.). Two species of flying foxes, *Pteropus poliocephalus* and *P. alecto* commonly come into the mangroves to feed on nectar or to camp. *P. poliocephalus* occurs along the entire east Australian coast whereas *P. alecto* is restricted to tropical mangroves. Another species, *P. conspicillatus,* sometimes camps in mangroves. Some species of tree-roosting bats such as *Tadarida planiceps,* the flat-headed mastiff-bat and *T. loriae,* the little northern mastiff-bat, are occasionally found in mangroves. The northern blossom bat, *Macroglossus lagochilus* occurs in stands of *Sonneratia alba* in Western Australia.

Mangroves do not appear to be used by marine mammals. Heinsohn and Wake (1976) stress the importance of sheltered waters for dugong *Dugong dugon* and the association of dugong with seagrass beds but make no mention of dugong using mangroves. Recently dugongs and dolphins have been seen in the mangrove channels on Hinchinbrook Island (Bunt, pers. comm.).

*Birds*

Birds are a conspicuous component of all mangrove forests, although they are not abundant. Schodde *et al.* (1982) suggest that the comparative uniformity of structure within the canopy of mangrove forests, which provides little variety of foraging surfaces, accounts for the small number of individuals. In many regions, mangroves have a fragmented distribution which Schodde *et al.* suggest may also be important in limiting numbers. Feeding time for ground foragers is restricted by tidal flooding. Nest sites may be limited. These reasons may also explain why many birds occurring in mangroves, also occur in other habitats. Data are not available on whether these species occupy similar niches in all habitats or if they broaden their niche in the mangrove forest.

Over 200 bird species have been recorded from Australian mangroves (Saenger *et al.*, 1977). Of these, 14 species are virtually restricted to mangroves; 12 species use mangroves as a primary habitat in part of their range, and 60 species use mangroves regularly throughout the year or in particular seasons (Schodde *et al.*, 1982). This is a rich mangrove bird fauna compared with other parts of the world (MacNae, 1968).

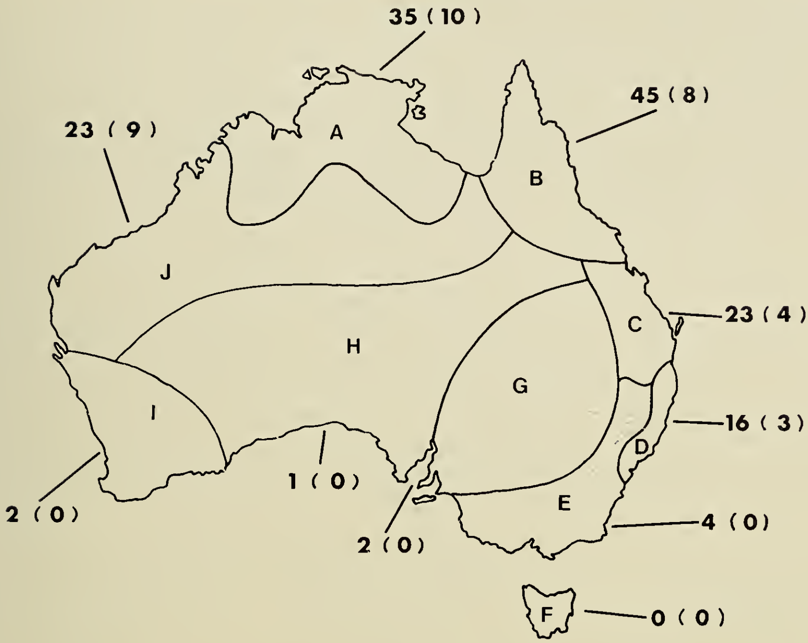
The number of species of birds using mangroves and the number of mangrove specialists increases from south to north with increasing floristic richness (Fig. 2). Thus near Sydney (34°S) only one species, the mangrove heron *Butorides striatus,* is restricted to mangroves. The other birds in temperate mangroves are widely distributed in a variety of aquatic or forest habitats (e.g. rufous whistler *Pachycephala rufiventris* and white-face heron *Ardea novaehollandiae*). In contrast, on the Cape York Peninsula (19°S) nineteen species of birds are considered mangrove specialists and seven of these are endemic to mangrove habitats (Schodde *et al.,* 1982). Birds which are wholly or partially dependent on mangroves include two herons, a kite, a rail, a pigeon, a cuckoo, three kingfishers, five pachycephaline flycatchers, four myiagrine flycatchers, three acanthizine warblers, three honeyeaters, a silvereye and a butcher-bird. None shows major morphological adaptations to the mangrove environment. However there is a tendency for bills to be longer than in non-mangrove congeners (Schodde *et al.,* 1982). The white-breasted whistler *Pachycephala lanioides* has a comparatively heavy and hooked bill for handling marine invertebrates.

Birds which regularly use mangroves, but which cannot be considered mangrove specialists, include aquatic species and a wide range of passerines. Aquatic and wading birds (e.g. herons, ibis, sandpipers) forage among mangroves and many use mangroves as high tide roosts. Some species (e.g. pied cormorant *Phalacrocorax varius,* straw-necked ibis *Threskiornis aethiopicus*) nest in mangroves (White, 1917; Seton, 1971; Schodde *et al.,* 1982). Among the passerines, honeyeaters commonly visit mangroves for nectar when blossom is abundant. The sulphur crested cockatoo *Cacatua galerita* has been seen feeding on the fruits of *Lumnitzera littorea* in north Queensland by Bunt and his co-workers (pers. comm.). Other birds (e.g. rufous fantail *Rhipidura rufifrons* and grey fantail *R. fuliginosa*) frequent mangroves during migration.

*Reptiles*

Although they may be important feeding grounds, for the majority of terrestrial reptiles using mangroves, mangroves are peripheral habitats. In some areas, mangroves are the only habitable forest and may, therefore, be important corridors for the movement of individuals.

Reptiles are common in tropical mangroves, but are rarely seen in temperate




Faunal areas based on terrestrial birds ( after Kikkawa & Pearse, 1969 )

No. of bird species ( no. of species confined to or most abundant in mangroves )

Total for Australia is ≈ 58 ( 14 ) species of terrestrial birds

*Fig. 2.* Kikkawa and Pearse (1969) divided Australia into regions based on the similarity of the bird fauna. These regions are convenient to illustrate the number of species of birds which occur regularly in mangroves. The number of bird species endemic to mangroves in each region are shown in parentheses. Species number and the number of endemics increase from south to north. This latitudinal gradient in bird species diversity is correlated with an increasing area of mangroves and the richer floristic and structural complexity of tropical mangrove forests.

ones. The salt water crocodile *Crocodylus porosus* is probably the best known mangrove resident; a notoriety derived from its occasional consumption of humans. Salt water crocodiles occur in river systems from Broome in Western Australia, around the Northern Territory and south to Maryborough in Queensland (Cogger, 1979). The animal is most abundant in the tropics and comes into mangroves to feed. Juvenile crocodiles take crabs (especially sesarmids), prawns, mud skippers, and small fish. Larger animals take mud crabs *Scylla,* birds, and mammals including *Xeromys* and flying foxes (Taylor, 1979). Crocodiles do not nest in mangroves (Webb *et al.,* 1977).

The fresh water crocodile *C. johnstoni* occurs rarely in mangroves and is probably accidental at the landward margins of the mangroves and in less saline areas. Cogger (1979) has recorded the pitted-shelled turtle *Carettochelys insculpta* in the Daly, Victoria and Alligator River systems in the Northern Territory where it may enter mangrove areas.

A small number of snakes and lizards occur regularly in mangroves. Mangroves are the primary habitat for the mangrove monitor *Varanus indicus* which occurs in the Northern Territory, Torres Strait and Cape York (Cogger, 1979). It feeds on crabs and mud skippers. Four other goannas, *V. semiremex, V. prasinus, V. timorensis* and *V. tristis* are common in tropical mangroves, but range widely in other habitats (Cogger, 1979). The littoral skink *Emoia atrocostata* is common in mangrove areas of the Torres Strait and northern Cape York Peninsula (Cogger, 1979). The Northern Water Dragon (*Lophognathus temporalis*) feeds on insects in the mangroves of northwest Australia and the Northern Territory (Swanson, 1976).

Several species of pythons (*Liasis fuscus, L. olivaceus*) occasionally use mangroves and are attracted by large camps of flying foxes on which they feed. The carpet snake (*Morelia spilotes*) and *Liasis amethystinus* and two common colubrid snakes, the green tree snake *Dendrelaphis punctulatus* and brown tree snake *Boiga irregularis* also occur in mangrove habitats. The file snake *Acrochordus granulatus* is virtually restricted to mangroves in northeastern and northern Australia. It lives on the mud flats in front of the mangroves where it feeds on crabs and fish (Cogger, 1979). Mangroves are also an important habitat for the bockadam *Cerberus rhynchops,* the white-bellied mangrove snake *Fordonia leucobalia,* and the mangrove snake *Myron richardsoni* which occur in northern Australia (Cogger, 1979.). Some sea snakes are estuarine and occur commonly in mangroves (Cogger, 1979.). *Ephalophis mertoni, E. greyi* and *Hydrelaps darwiniensis* are found in mangroves in the Northern Territory and *Hydrophis elegans* and *Aipysurus eydouxii* are found in central Queensland.

*Amphibians*

Two frogs have been reported from mangrove habitats in the Northern Territory. The northern dwarf tree frog *Litoria bicolor* has been recorded on the Wildman River, in an area greatly affected by freshwater, and the marbled frog *Lymnodynastes convexiusculus* occurs in the *Ceriops tagal* zone of the South Alligator River (Hegerl *et al.,* 1979).

*Fishes*

Fishes are a conspicuous component of the mangrove ecosystem with large numbers invading the mangrove forest at high tide and retreating to deeper waters as the tide falls. Either as juveniles or adults, virtually all the common fishes of the estuaries can be found in mangroves (Ellway and Hegerl, 1972; Shine *et al.,* 1973; Saenger *et al.,* 1977; Beumer, 1978; Blaber, 1980). Few species are restricted to mangroves.

The major group of fishes adapted to living in mangroves belong to the gobiid sub-family Oxcidercinae. This includes mud skippers which are represented in Australia by five species in two genera, *Periophthalmus* and *Periophthalmodon.* Mud skippers are common throughout the tropics but are absent from temperate mangroves. They occur only as far south as Hervey Bay in Queensland (25°S). Other representatives of this family are the genera *Boleophthalmus* and *Scartelaos* which burrow in the mud and occur in the Northern Territory and Queensland.

Other gobies are common in mangroves, but are also found elsewhere in the estuary. Included are the genera *Mugilogobius, Taenioides* and *Arenigobius* which occur throughout Australia. The oyster blenny *Omobranchus* occurs in frontal mangroves where residual water is trapped. All these fish can stand some exposure to air. Most live in burrows where some water is present even during low tide.

A diverse fish fauna occurs in creeks or lagoons in the mangroves where permanent water occurs. These will be estuarine species, characteristic of the geographical region (Saenger *et al.,* 1977; Ellway and Hegerl, 1972 and Shine *et al.,* 1973). Among the more common estuarine species which frequent mangroves are toados *Torquiger hamiltoni*, mullet *Myxus elongatus*, and fortesques *Centropogon australis*.

Blaber (1980) has designated feeding categories of the fish of Trinity Inlet, Cairns. Beumer (1978) has studied the feeding ecology of black bream (*Acanthopagrus berda*), bony bream (*Anodontostoma chacunda*), hair fin goby (*Ctenogobius criniger*) and milk-spotted toad fish (*Chelonodon patoca*) in a mangrove creek in the Townsville region.

## Invertebrates

There are two components to the invertebrate fauna of mangrove communities, spiders and insects associated with the forest canopy and aquatic animals inhabiting the intertidal. This fauna is richer than the vertebrate community. Our approach in reviewing the information available on mangrove invertebrates has been to use a classification based on taxonomic and ecological attributes. We first consider insects and spiders, but then review the aquatic fauna according to where they occur in the mangroves.

### *Insects*

Although neither the insects nor spiders of mangroves have been extensively studied in Australia there is a great variety of species. These show a variable degree of dependence on mangroves. Whether the diversity in mangroves is similar to that in other forest habitats at the same latitude or whether mangrove forests have an array of mangrove specialists is unknown. C. Smithers (pers. comm.) suggests that each species of mangrove probably will have an associated unique suite of insect species.

In general, insects in mangroves appear to have the same range of adaptations that they show in other forest environments. For many species, mangroves are an important habitat and insects may be favoured by the often large, almost monospecific stands of trees within the forest.

A comprehensive list of insects from a temperate mangrove system is provided in the Australian Littoral Society Report of Towra Point, Botany Bay (1977). The only detailed study of the insect and spider communities of mangroves has been carried out by Simberloff and Wilson (1970) and Wilson and Simberloff (1969a, b) in the Florida Keys and more recently in north Queensland*. Simberloff and Wilson fumigated small mangrove islands and observed the recolonization of the islands with time.

Most work in Australia on mangrove insects has been on species of potential commercial importance (termites) or which may be involved in the transmission of disease (mosquitoes, biting midges).

Termites are an important component of tropical mangroves. Three species of Kalotermitidae occur in the Darwin region: *Neotermes insularis, Cryptotermes secundus* and *C. domesticus*. *C. domesticus* is widely distributed in South-East Asia and the Western Pacific and occurs in both natural and man-made habitats. Whether the mangrove populations in Australia are indigenous, or were introduced is not known. *Cryptotermes secundus* has also been recorded from *Rhizophora* at Kalumburu in Western Australia, and from *Avicennia* at Groote Eylandt. At Cooloola in southern Queensland *Cryptotermes primus* occurs in species of *Avicennia* and

*The extensive insect collections made by Simberloff on Hinchinbrook Island have been deposited with Dr R. Taylor, C.S.I.R.O.

*Rhizophora*. At Weipa, mangroves support large colonies of *Incisitermes barretti*. Another species, *Nasutitermes graveolus*, is common on the landward fringe. This termite builds arboreal nests externally on the trunk or branches. Some species may range below high tide level. *Mastotermes darwiniensis* has been recorded in this situation on *Ceriops* in the Darwin region, but this is unusual (Miller and Watson, pers. comm.). The location of this termite at high tide is unknown. It may nest in the forest canopy. The same species has been recorded from Corio Bay, Queensland, at the southern limit of distribution of *Mastotermes* on the Queensland coast (Ellway, 1974).

The grasshopper *Valanga irregularis* has been seen feeding in the mangrove canopy at Corio Bay (Ellway, 1974). The pygmy grasshopper *Coptotettix mastricatus* has been recorded on the mud of mangroves. In the New World mangroves, many species of crickets and a number of tettigoniids occur (Rentz, pers. comm.).

The beetle fauna of mangroves is diverse and largely undescribed. It probably includes species which feed on dead wood as larvae, others whose larvae feed on mangrove seed pods, while the adults feed on foliage. Some weevils have been recorded from mangrove seed capsules (Zimmerman, pers. comm.). MacNae (1968) records coccids covering the leaves and young twigs of Rhizophoracea (species not given) in north Queensland.

Diptera occur in mangroves as both free living and parasitic forms and are a diverse component of the mangrove fauna. Fourteen species were collected by Hutchings and Recher (1974) at Careel Bay, near Sydney. Some Diptera, such as *Melanagromyza avicenniae* which is restricted to mangroves, appear to feed on new shoots. Diptera are also associated with rotting wood. The adults and larvae of *Copidita nigronotata* are secondary timber borers. Other dipterans specialize on the fruits and propagules of mangroves (see Hutchings and Recher, 1974, and Spencer, 1977).

According to Common and Waterhouse (1972) several species of butterflies are commonly associated with mangroves. All belong to the Lycaenidae (blue butterflies). *Hypochrysops epicurus* which occurs from Port Macquarie to Brisbane, appears to be restricted to stands of *Avicennia marina*. *Hypochrysops apelles* and *H. narcissus* are characteristic elements of the mangrove fauna, although their larvae also feed on non-mangrove species. *Hypochrysops apelles* which occurs along the east Australian coast from north of Yeppoon, feeds on *Rhizophora stylosa, Bruguiera gymnorhiza, Ceriops tagal* and *Avicennia marina*. *Ogyris amaryllis hewitsoni* which occurs from Maryborough to Cairns, is common around mangroves, as its larvae feed on the mistletoe *Amyema mackayense* which grows on mangroves.

A less common butterfly *Nacaduba kurava* occurs from the Richmond River (New South Wales) to Cape York. It feeds on *Aegiceras corniculatum* but also uses other plants. The larvae and pupae of *Acrodipsas illidgei* have been found in the nests of the ant *Crematogaster laeviceps* near Brisbane. The ant nests in hollow branches of mangroves. Three to four larvae or pupae of *Acrodipsas* were present in each colony; it seems likely that the larvae of *A. illedgei* feed on the immature stages of the ant (Common, pers. comm.). Similarly, *Hypochrysops appollo* is associated with ants in mangroves, as it breeds in ant house plants (Saenger *et al.*, 1977).

The larvae of the tortricid moth *Procalyptis parooptera* feed on the leaves of *Ceriops tagal* at Yeppoon, firmly joining adjacent leaves with silk to form a shelter in which the larvae live. Pupation occurs in this shelter. This empty shelter is then used by the larvae of the butterfly *Hypochrysops apollo* as a daytime retreat where it is attended by ants and from which they emerge at night to feed on the surrounding foliage (Common and Waterhouse, 1972). The moth *Macrocyttara expressa*

(Cossidae) is restricted to mangroves. The larvae of this species tunnel gregariously in the trunks of *Excoecaria agallocha*. The larvae of *Cenoloba obliteralis* (Oxychirotidae) develop in the cotyledons of fallen seeds of *Avicennia marina* (Common, 1970).

All the Lepidoptera mentioned occur in eastern Australia but other species closely associated with mangroves probably occur in other regions. Two unidentified species have been recorded from South Australian mangroves (Butler *et al.*, 1977).

The ant fauna of Australian mangroves has not been studied in detail but many species occur. No species has been found which is totally restricted to mangroves. For ants, colonization of mangroves means coping with the tidal cycle. Thus most mangrove ants are arboreal and several species nest in hollow twigs. Dead mangroves provide shelter for three species of ants (not identified) in Corio Bay, Queensland (Ellway, 1974). Some species nest in the canopy while other ants nest on the ground where they are inundated by the tide (Taylor, pers. comm.). Overseas, the ant fauna in the Florida Keys has been well studied by Wilson (1964).

MacNae (1968) records the weaver ant *Oecophylla smaragdina* in *Bruguiera, Ceriops* and *Sonneratia* forests in north Queensland. This species has a similar life history to species of *Oecophylla* occurring in coconut palm forests in Zanzibar which have been described by Vanderplank (1960). MacNae also suggests that species of ants which occur below high tide level may be able to trap air in their burrows with plugs of mud. Whether ants living in inland areas where freshwater flooding regularly occurs, adopt a similar strategy is unknown. If they do not, then the ants found in mangrove muds have developed a unique adaptation enabling them to invade the intertidal environment. An unidentified species occurs at low tide in the Hinchinbrook region (Hutchings, pers. obs.) and presumably adopts this strategy. Another unidentified species at Hinchinbrook has been seen living in tunnels made by *Teredo* in the prop roots of *Rhizophora*.

Two species of ant house plants *Myrmecodia antoinii* and *Hydnophytum formicarum*, occur in northeastern Queensland. Their tuberous stems are hollow and often used by ants of several species. The ant *Pheidole myrmecodiae* is restricted to this habitat, where it obtains protection from desiccation and predation. The advantages to the plants are less clear, but the ants may protect them from herbivores.

In contrast to other groups of insects, there is considerable information about the mosquito (Lee *et al.*, 1980; Griffiths, in ms.) and biting midge fauna of mangroves. Mosquitoes are typically found in the ephemeral pools at the back of the mangroves, rather than within the mangroves where there is regular tidal exchange. In disturbed mangroves, stagnant pools may be created as a result of dredge and fill operations. These pools are ideal mosquito habitat. The three most common mosquito species occurring in Australian mangroves are *Aedes vigilax, A. alternans* and *Culex sitiens*. The distribution of *A. vigilax* is largely coastal, with a special relationship to the low-lying land of mangroves and mangrove zones (Sinclair, 1976). It also occurs inland.

Typically, *A. vigilax* breeds in temporary waters and is intermittent in occurrence. The water must be stagnant and exposed to the sun. Sunlight is necessary for the growth of the algal plankton on which the larvae feed. Reproduction occurs largely during the summer wet season. *Aedes* can complete larval development within 10 days. Low temperatures inhibit breeding and greatly prolong the duration of the larval stages (Iyengar, 1965; Griffiths, in ms. and pers. comm.).

*Aedes alternans* occurs in all mainland States, and is particularly associated with estuarine areas. It also occurs inland. *A. alternans* breeds in temporary stagnant pools, both fresh and brackish, exposed to the sun. The eggs are laid singly (probably on mud at the edge of drying pools) and can withstand drying. The eggs hatch when the depression fills with water (Marks, 1967, 1971). The eggs take seven days to hatch under favourable conditions but below 21°C hatching is delayed. In coastal situations the larvae of *A. alternans* are often found with those of *A. vigilax*. The larvae of *A. alternans* are predacious from the second instar onwards on other mosquito larvae. The adults are strong fliers, and are known to migrate with *A. vigilax*, but only in the summer (Hamlyn-Harris, 1933).

*Culex sitiens* occurs from New South Wales northwards, and westwards to Western Australia. In the Northern Territory, Hill (1917) found *C. sitiens* abundant near the coast and inland as far as 55 km south of Darwin, breeding in pools, hollow stumps, tins, crab holes, mangrove swamps, weedy lagoons, inland waterholes and shallow wet-season accumulations of water on grassland. Marks (1953) also found it in a variety of habitats, in sunlit, muddy, brackish pools and in deep shade in mangrove swamps, both amongst roots and in more open water, and in footprints on mud flats.

Three species of *Anopheles* also occur in mangroves. *Anopheles amictus hilli* breeds most abundantly in brackish water, and occurs in north Australia from Western Australia to the Queensland/New South Wales border. *A. annulipes* occasionally breeds in brackish water and occurs throughout Australia. *A. farauti* is found in the north of Australia from Western Australia to the east coast of Queensland. It sometimes breeds in brackish water. Perry (1946) reports it breeding in extensive brackish water pools in the Solomon Islands. These were high in organic debris and subject to tidal fluctuations. Similar habitats in Australian mangroves are likely to be suitable.

Biting midges belong to the family Ceratopogonidae and are erroneously called sandflies. More than twenty species are associated with mangroves; many are still undescribed. For most, knowledge is restricted to the adult form. This information is largely based on emergence trapping which may or may not indicate larval habitat.

A considerable amount of work has been carried out on the biology of coastal biting midges, with a view to developing control techniques. Debenham (1979, and pers. comm.) has reviewed the biology of coastal species of biting midges. Of the twenty-odd species, seven are common in mangroves. *Culicoides henryi* occurs in coastal southern Queensland, coastal and subcoastal New South Wales; it appears to prefer muddy sand as a larval habitat, possibly with tree cover. The pupae float on the water surface with their long axes parallel to the surface, and are unable to submerge. The major source of blood is unknown, but people are attacked. Reye (1972a) ranks it as the seventh most important pest midge of coastal Queensland, while noting that it reaches pest proportions only in restricted localities. *C. histrio* occurs in Australia from coastal northeastern Australia south to the Sydney region. Immature stages have been collected from a *Juncus* pool at Careel Bay (New South Wales). At Townsville, *C. historio* occurs on mangrove flats well inside the mouth of the Ross River. Populations are maximal during the summer and negligible in winter (Kay and Fanning, 1974). It has been only recorded feeding on birds. *C. magnesianus* occurs on the coast and offshore islands of the Northern Territory and Queensland. It has been collected biting humans (Lee and Reye, 1955), but it is probably an avian feeder. Activity is nocturnal; peak activity in the Townsville area occurs between 2100 and 0300 hr (Lee and Reye, 1961). *C. marmoratus* occurs in Australia from north Queensland to southern New South Wales. Larvae occur in low-lying estuarine zones, often in association with *Salicornia, Sporobolus virginicus* or *Sueda maritima*. The eggs cannot withstand desiccation and breeding occurs after spring tides which flood the salt marsh. This species is known to occur outside its breeding area. It has been reported to bite humans and can be a pest in coastal regions. Lee *et al.* (1963) suggest it is an opportunistic feeder, with wallabies its primary native host. Biting activity is primarily crepuscular. *C. molestus* occurs throughout coastal eastern Australia. Reye (1972a) has characterized the larval habitat as clean sand in the open or among trees disturbed by slight to moderate wave or current action. A wide range of salinities is tolerated. The larvae occur with the top 7.5 cm of sand, and there is evidence that the pupae will drift in on a rising tide, be stranded and emerge there. This species has invaded the sandy banks of canal (housing) estates in southern Queensland (Reye, 1971). *C. molestus* has been recorded attacking people, but except in canal estates, it is not considered a problem (Kettle *et al.*, 1975). *C. subimmaculatus* occurs throughout coastal eastern Australia. Immature stages are found on sandy estuarine foreshores, and in the *Salicornia* zone. They have also been found in the vicinity of crab holes (often associated with *Avicennia*), and Reye (1969a,b) suggests that the presence of soldier crabs *Mictyris platycheles* is essential for the breeding of this species. Kettle (1977) has recorded the larvae feeding on polychaete worms and desmids. Mass emergences appear to be correlated with neap tides. The adults are opportunistic feeders. Activity is largely crepuscular but can be diurnal if humidity is high and there is little wind.

The last common species is *C. ornatus* which occurs in the Torres Strait islands and coastal northern Australia. It does not occur south of Tin Can Bay in Queensland but this species has been often confused taxonomically giving it an erroneous distribution. The larval habitat is the mean neap tide zone of estuarine areas, mud substrate, completely sheltered from wave action, and with a dense tree cover, often *Rhizophora stylosa*. Reye (1972a) has suggested that there is an obligatory association with *Aegiceras corniculatum*. Adults are abundant in mangrove swamps, and Reye (1972a) regards this species as the most important Queensland pest species. It also feeds on flying foxes and birds.

*Spiders*

The spider fauna of Australian mangroves is undescribed but from casual observations appears to be rich in species and individuals. Hutchings and Recher (1974) recorded 18 species in temperate mangroves at Careel Bay, New South Wales. At Towra Point, Botany Bay (New South Wales), 35 species were found (Australian Littoral Society, 1977). Forty two species were collected from Trinity Bay, Cairns (Hegerl and Davie, 1977), and 56 species in Corio Bay, near Rockhampton (Ellway, 1974). Far fewer species (6) have been recorded from South Australia (Butler *et al.*, 1977). These few observations do not allow for many generalizations.

The diversity of spiders associated with mangroves increases rapidly from temperate to tropical zones, but all the spiders recorded from mangroves also occur in other terrestrial habitats. McCormick (1978) suggests that spiders in mangroves may be highly seasonal in occurrence and in areas subjected to regular flooding the fauna may be severely restricted. From the information available, it appears that the spider fauna of mangroves may be recruited from adjacent habitats.

Of the spiders found in mangroves the orb web building spiders are the most evident. This group includes both the slant orb web weavers of the genus *Tetragnatha* (the large jawed spiders) which elsewhere are associated with stream or lake-side habitats and the vertical orb web weavers of the genus *Eriophora*. Both are adapted for catching flying prey. Foliage dwelling spiders seem to be rather uncommon.

Other groups of spiders occur on the ground or on the lowest vegetation. Most evident in these situations are the wolf spiders (*Geolycosa* sp,) and allied hunting spiders of the family Pisauridae (*Dolomedes* sp.). Presumably these are opportunistic hunters, foraging on the exposed mud at low tide. *Dolomedes*, however, is often associated with aquatic habitats and has been observed to move underwater to avoid predators or take prey (Gray, pers. comm.).

Scorpions and mites have been reported from Hinchinbrook Island (Bunt, pers. comm.).

*Aquatic Invertebrates*

This review is restricted to macro-invertebrates. Although microfauna such as nematodes and protozoa is abundant in mangroves, its presence has been poorly documented in Australia. Only a single study has been carried out on the nematode fauna. Dacraemes and Coomans (1978) collected 25 species of nematodes from a single sample in the mangroves at Lizard Island, Great Barrier Reef, suggesting that a rich fauna is awaiting study. Overseas, more attention has been directed to the microfauna (see Newell, 1974, for review).

The aquatic invertebrates of mangroves are primarily marine in origin with some fresh water animals occurring at the freshwater, marine interface in the upper reaches of the estuaries. In addition there is a group of marine pulmonate molluscs which is probably related to terrestrial and freshwater pulmonate gastropods. However they have had a long history of independent evolution (Zilch, 1959).

Within the intertidal zone, the mangrove fauna is dominated by polychaetes, crustaceans and molluscs (Appendices 1,2,3). In addition to the intertidal fauna, tide pools and channels with permanent water have a characteristic estuarine subtidal fauna. Again this is dominated by polychaetes, crustaceans and molluscs, but echinoderms, ascidians, coelenterates and sponges may be present (Saenger *et al.*, 1980). Sponges and ascidians are also associated with sea grasses. This subtidal fauna is arguably part of the mangrove system, but for the purposes of this review, we consider only the intertidal fauna.

According to where they live, there are five distinct groupings of marine invertebrates within the intertidal of mangrove forests: encrusting epifauna, mangrove epifauna, substrate epifauna, substrate infauna and wood-boring infauna. The composition of the fauna within each of these categories is determined by the physical environment and there are distinct patterns of zonation (Hutchings and Recher, 1974). Zones are determined by sediment structure, tidal and salinity regimes and period of inundation. The distribution of mobile animals will also vary according to the time of day and night. Thus the intertidal fauna changes through time and is patterned on both a horizontal and vertical scale in space. Little of this complexity has been quantified and the summary which follows must be accepted as a simplification of an exceedingly complex situation. Studies which provide information on relative abundances of marine invertebrates within mangrove habitats are limited to Butler *et al.* (1974, 1975) (South Australia), Hutchings and Recher (1974), Hutchings et al. (1977), Weate (1975), McCormick (1978) (New South Wales), Shine *et al.* (1973) (Queensland) and Hegerl *et al.* (1979) (Northern Territory).

*Epifauna*

The epifauna consists of sessile and mobile animals which live on the surface of the forest floor, on mangrove trunks and on mangrove roots and pneumatophores.

*Encrusting fauna*

Throughout most of Australia, the encrusting fauna is dominated by the oyster *Saccostrea commercialis* and barnacles. The dense mass of these animals provides a sheltered environment for a rich and mobile fauna of errant polychaetes, crustaceans and gastropods. Encrusting animals occur throughout the mangroves, but require inundation on each tide and are best developed at the edges of the mangrove forest where the flow of water is high and prolonged inundation occurs. As in other intertidal environments (e.g. rocky foreshores), barnacles tend to dominate in the upper reaches and oysters or mussels at lower tide levels.

In New South Wales, encrusting fauna has a similar pattern of zonation irrespective of locality (McCormick, 1978). The greatest concentration of animals occurs in the frontal areas. McCormick (1978) suggests that frequency of tidal inundation and shade are the most critical factors affecting the abundance of this fauna. In areas of low light intensity, epiphytic algae (*Bostrychia* sp., *Caloglossa* sp., *Catenella* sp.) grow over the pneumatophores of *Avicennia* and around the base of tree trunks. These algae provide a microhabitat for small gastropods and amphipods. The algae, together with oysters may in some places retain enough moisture for spionid and nereid polychaete worms to occur. Broadly similar patterns and communities of encrusting organisms have been reported from South Australia, Victoria and Queensland.

The barnacle *Elminius modestus* and the serpulid *Galeolaria caespitosa* occur on the pneumatophores and lower trunks of *Avicennia marina* in the upper part of Spencer and St Vincent Gulf and at Ceduna in South Australia (Womersley and Edmonds, 1958). In Victoria, the fauna on *Avicennia* is characterized by the snail *Bembicium melanostomum,* the mussel *Mytilus edulis planulatus,* and the barnacle *Chamaesipho columna* (Smith *et al.,* 1975). The Sydney rock oyster *Saccostrea commercialis* and the barnacle *Balanus amphitrite* dominate the encrusting epifauna on *Avicennia* in New South Wales (Dakin *et al.*, 1952; Hutchings and Recher, 1974; Hutchings *et al.,* 1977). The snail *Littorina scabra* and the isopod *Ligia australiensis* are also typical of this community.

Weate (1975) working on the lower Myall River on the central coast of New South Wales (32°S) recorded ten species of molluscs and four crabs living on mangroves. Some, such as the gastropods *Salinator solida* and *Melosidula zonata,* grazed both on the trunks of *Avicennia* and the surface of the mud substrate. Other molluscs, including *Patelloida mimula, Xenostrobus securis, Tatea rufilabris* and *Lasaea australis* occurred only on the encrusting oyster *Saccostrea commercialis.* On the central coast of New South Wales, Hutchings and Recher (1974) recorded 26 species of molluscs and crabs living on or in the mangroves at Careel Bay (Appendices 2 and 3). The mangrove epifauna at Brooklyn, also on the Hawkesbury River estuary but upstream from Careel Bay, has a less diverse fauna, although the total number of individuals appears similar (Hutchings *et al.,* 1977; pers. obs.). Species such as *Balanus amphitrite, Paragrapsus laevis, Austrocochlea constricta* and *Melosidula zonata* are absent at Brooklyn, but common at Careel Bay. The difference is probably the result of lower salinities and possibly of higher silt loads at Brooklyn.

One of the most conspicuous animals in the mangrove epifauna is the gastropod *Littorina scabra. L. scabra* occurs throughout the mangrove forest and can be extremely abundant. In Queensland and northern Australia, *L. scabra* occurs with a second species of *Littorina,* n. sp., (Ponder, pers. comm.). Other molluscs on mangrove trunks include *Cerithidea obtusa* and *Nerita lineata. Oncis* sp., a pulmonate slug, is also present.

Several studies in Queensland mangroves have not recorded the precise habitat where species were collected (e.g. Hegerl and Davie, 1977; Shine *et al.,* 1973). However, the mangrove epifauna seems to be more diverse with decreasing latitude.

Saenger *et al.* (1979) studied subtidal fouling organisms in the Calliope River, Queensland. Several of the species which colonized their settlement plates also occur on pneumatophores and tree trunks in the frontal zone of mangroves. These include such species as the barnacle *Balanus amphitrite,* the serpulid polychaete *Ficopomatus* *uschakovi* and the oyster *Saccostrea commercialis.* They found that *Balanus, Ficopomatus* and the bryozoan *Electra* sp. characterize a pioneer community which is replaced by a community dominated by *Saccostrea, Xenostrobus, Balanus* and *Ficopomatus.* A mosaic of pioneer and climax phases is the common condition found on naturally occurring substrates such as mangrove pneumatophores and tree trunks in the study area.

Two species of oysters (*Saccostrea commercialis* and *S. echinata*) have been recorded from mangroves adjacent to the coral reef at Low Isles. The gastropod *Morula* was a common associate (Stephenson *et al.*, 1958). A recent survey of the fauna of mangroves in the Kakadu National Park, Northern Territory, by Hegerl *et al.* (1979) does not indicate specific habitats for the molluscs collected, although the encrusting oysters *Saccostrea echinata* and *S. commercialis* were collected. Barnacles were common on the trunks of *Sonneratia, Camptostemon* and *Rhizophora,* but were not identified.

*Substrate Epifauna*

The animals which live on the surface of the forest floor are mainly molluscs. Crabs are also common, but the majority live in burrows, coming out only to forage and are discussed under infauna.

The molluscs are dominated by gastropods which are zoned in relation to tidal inundation. McCormick (1978) found that the frontal zone of the mangroves is the most diverse, although the diversity varied at the six sites he studied along the New South Wales coast. He found no trend towards increasing diversity from southern to northern New South Wales. However the sites varied greatly in their salinity regimes and mangrove structure which may explain these findings. Except for McCormick's (1978) study seasonal fluctuations in substrate epifauna have been almost completely neglected. He found maximum densities during the winter and spring.

Five families of molluscs dominate the epifauna, the Neritidae, Littorinidae, Potamididae, Cerithiidae and Ellobiidae (MacNae, 1968). Scattered information exists on the preferred habitats within the mangroves for some species. The two species of *Terebralia, T. palustris* and *T. sulcata,* prefer muddy substrates whereas species of *Cassidula* occur among decaying vegetation. The pulmonate slugs *Onchidium* sp. are cryptic, burying themselves in mud or hiding under debris. Stephenson *et al.* (1958) found *Onchidium, Quoyia* and *Bembicium* concentrated among shingle under *Bruguiera* bushes at Low Isles. Many gastropods occur throughout the mangroves, on the surface of mud, on pneumatophores and in association with logs.

The number of molluscs in the surface epifauna increases from the temperate zone to the tropics. Although almost certainly underestimates, 16 species have been recorded in South Australia, 24 in Victoria, 33 in New South Wales and 57 in northern Queensland (Appendix 3). There are distinct temperate and tropical elements to this fauna.

*Conuber melanostoma* and *C. sordida* (Naticidae) are restricted to temperate mangroves and are absent from central Queensland and further north. In contrast *Cassidula augulifera* (Ellobiidae) is restricted to tropical mangroves although *C. augulifera* does extend as far south as southern Queensland. In the family Neritidae, 6 species are restricted to tropical or sub-tropical mangroves and only *N. atramentosa* occurs in temperate mangroves and southern Queensland. As more information on the molluscs becomes available the distribution patterns will become clearer and will probably continue to substantiate the pattern of greater diversity of molluscs in tropical mangroves than in temperate systems (Fig. 3).

MacNae (1968) hypothesized that the molluscs occurring in temperate mangroves such as Westernport Bay and the gulfs of South Australia are typical

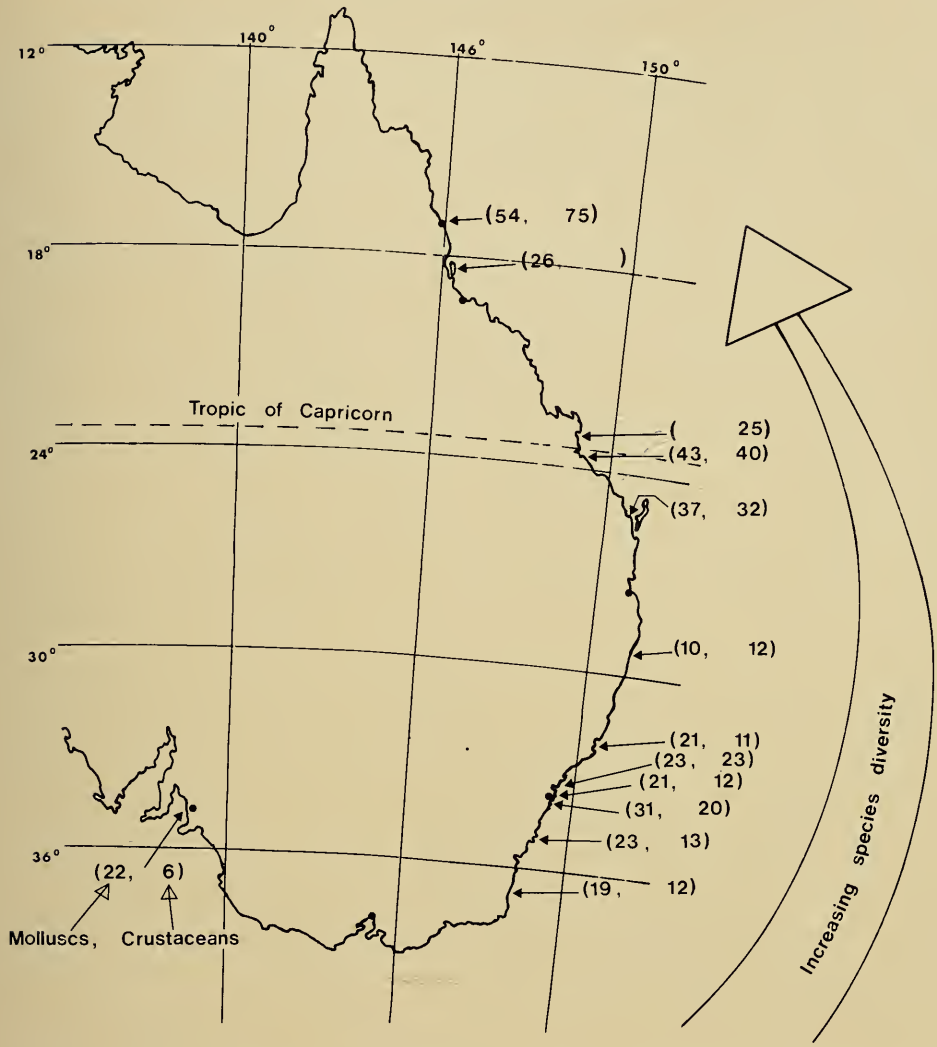



*Fig. 3.* Several groups of marine invertebrates appear to be more abundant and richer in species in the tropics than in the temperate zones. Data on molluscs and crustaceans are most complete and are used here to illustrate this point for Australian mangrove forests.

estuarine species and that specialized mangrove species are restricted to tropical areas. MacNae (1966) also suggested that the fauna associated with Sydney Harbour mangroves is a depauperate tropical one with all the species derived from Queensland. However he based this statement on incomplete species lists provided by Dakin *et al.* (1952). The mangrove mollusc fauna near Sydney is in fact quite rich and is a mixture of tropical and temperate forms.

There is relatively little information on the abundance of any of these animals. Hutchings *et al.* (1977) recorded densities of 0.4 individuals per m$^2$ for *Littorina scabra* and 55.5 individuals per m$^2$ for a species of *Tatea* in the mangroves at Brooklyn on the Hawkesbury River. Numbers of *Tatea* can exceed 10,000 individuals per m$^2$ in salt marsh at the edge of mangroves (Ponder, pers. comm.). Butler *et al.* (1975)

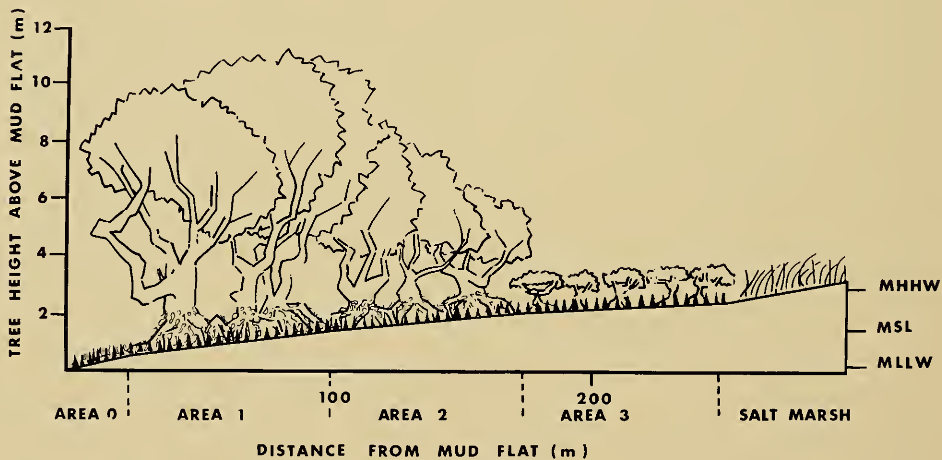
provide a list of macrobenthic animals found in mangrove areas at different locations in South Australia and rank these by relative abundance.

Except for McCormick's (1978) work in New South Wales, there are no measures of the seasonal change of the substrate epifauna. McCormick (1978) found that maximum densities occur in winter and spring at Towra Point on Botany Bay and Patonga Creek on Broken Bay, Hawkesbury River (Fig. 4).

*Substrate Infauna*

This fauna includes animals that live in the sediment for all or part of their lives. It is restricted to the upper layers of mud and consists of sedentary and mobile animals. The mobile species such as crabs feed on the surface of the mud. The majority of the fauna live in semi-permanent or permanent burrows. Burrows penetrate through the oxygenated layers of mud into the anaerobic layers, where they are restricted in depth by the fibrous matted root systems of the mangroves. Some of the terrestrial fauna such as ants may trap air in their burrows during high tide and marine animals such as crabs trap water during low tide.

The infauna has been neglected in mangrove faunal studies and well-planned, long term collecting throughout Australian mangroves is needed. The sedentary animals are represented by sipunculans, echiuroids, polychaetes and nemerteans. There is a single species of sipunculan, *Phascolosoma arcuatum*. It occurs in tropical




**PATONGA CREEK**; 33° 32′ S, 151° 16′ E, (JANUARY)

| | AREA 0 | | | AREA 1 | | | AREA 2 | | | AREA 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | C | P | M | C | P | M | C | P | M | C | P |
| EPIFAUNA | 8 | 10 | 2 | 8 | 9 | 2 | 8 | 7 | 1 | 6 | 0 | 0 |
| INFAUNA | 1 | 6 | 5 | 1 | 4 | 3 | 1 | 4 | 4 | 1 | 2 | 0 |
| TREE FAUNA | - | - | - | 7 | 10 | 1 | 7 | 4 | 0 | 5 | 2 | 0 |

*Fig. 4.* McCormick (1978) studied the horizontal distribution of animals in several areas of mangroves in New South Wales. These data on species number for the mangrove stands at Patonga on the Hawkesbury River are presented in this figure. Both epifauna and infauna are richest in species at the lower tide levels where there is regular inundation by the tides. The terrestrial invertebrate fauna is most abundant in the middle zones where refuges during high tide occur and absent from frontal areas (area 3) which are covered by high tides.

mangroves in Australia and extends into South East Asia (Edmonds, 1980). *Phascolosoma* occurs throughout the mangroves, constructs extensive galleries in the substrate, and may occur in large numbers. The echiuroid *Ochetostoma australiense* occurs on the mud flats in front of the mangroves from northern New South Wales to southern Queensland. This species has a commensal crab, bivalve and gastropod associated with it in Queensland (Ponder, pers. comm.).

Polychaetes probably occur in all mangrove areas in Australia although they have rarely been collected systematically. The species which have so far been recorded are listed in Appendix I but many more species probably occur. Polychaetes are restricted to the wetter seaward margins of the mangroves or near regions of permanent water (Hutchings, pers. obs.). They occur in the less consolidated sediments where burrowing is easy. Burrows do not extend into the dense root systems of the mangroves. Several families are represented but nereids, spionids and capitellids are the most abundant groups. From the data available it appears that the polychaete fauna is more diverse in tropical regions. Most of the species occurring in temperate mangrove systems also occur in other estuarine habitats. An exception is the terebellid *Hadrachaeta aspeta* which occurs only in mangroves or on mud flats immediately adjacent to the mangroves (Hutchings, pers. obs.). Whether more mangrove specialists occur in the tropics remains to be investigated. Some of the species such as the nereids and spionids construct semi-permanent mucous-lined tubes. Many of the species occurring in the substrate also occur in rotten logs or in pockets of water trapped among the encrusting epifauna on pneumatophores, prop roots and tree trunks.

There are limited data on the abundance of polychaetes in mangroves. Hutchings *et al.* (1977) and McCormick (1978) have some data for New South Wales. In general densities of polychaetes appear low with less than one individual per $m^2$. However, McCormick (1978) found that numbers changed seasonally and more extensive sampling could reveal higher population sizes. Numbers of polychaetes in Queensland mangroves appear to be higher than in New South Wales.

Nemerteans occur in frequently-inundated areas of mangroves where sediments are relatively unconsolidated. A tropical species, *Pantinonemertes winsori,* occurs beneath bark and in cavities in rotten wood of *Avicennia marina* and *Ceriops tagal* (Moore and Gibson, 1981). At Careel Bay, *Tubulanus polymorphus* occurs in sea grass beds (*Zostera* sp.) adjacent to the mangroves and probably extends into the frontal zone of the mangrove forest (Hutchings and Recher, 1974). Turbellarians also occur in mangroves throughout New South Wales (Hutchings and Recher, pers. obs.), but have not been identified.

Molluscs are represented in the substrate of mangrove habitats by large numbers of bivalves. McCormick (1978) reported up to four species from his sites in New South Wales. *Glauconome plankta, Arthritica helmsii* sp., *Laternula* sp., *Tellina deltoidalis* and *Venerupis crenata* were the most abundant species. Species diversity is higher in tropical mangroves and a number of species may be restricted to mangrove habitats (Fig. 3).

MacNae (1968) suggested that some mangrove bivalves literally form a 'cocoon' among the matted roots of the mangroves. Bivalves are most abundant along the seaward fringe of the mangrove forest and decrease in abundance and diversity with decreasing tidal inundation (McCormick, 1978).

Crustaceans are a conspicuous component of the substrate fauna (Appendix 2). Crabs are the most obvious. The snapping shrimp *Alpheus* and the burrowing prawn or nipper *Callianassa* as well as isopods and amphipods are less visible, but are probably equally abundant. Certainly one of the most characteristic sounds of mangrove environments at low tide is the 'snapping' of alpheids in their burrows. Crabs are represented by large numbers of species in several families (Appendix 2) and are among the best known of the mangrove fauna (Fig. 3).

In tropical mangroves the burrows of the mud lobster *Thalassina anomola* and the mud crab *Scylla serrata* are conspicuous. Juvenile *Scylla* are particularly common in mangroves although they also occur among sea grasses and the retention of extensive mangrove forests may be critical for the management of this commercially-important species. Once the juveniles reach a carapace width of 60-80 mm they tend to move into subtidal areas, but continue to forage among the mangroves on the rising tide (Hill, 1979, 1980, and pers. comm.). The use of mangroves is accentuated in places where the density of sub-tidal benthic animals is low, perhaps as a result of freshwater conditions during the wet season, such as in far north Queensland.

There is a distinct zonation of crab species within the mangrove forest. In Western Australia, George and Jones (in press) correlated the distribution of fiddler crabs *Uca* with sediment grain size. Elsewhere zonation appears to be determined largely by period of tidal inundation. Yates (1978) studied the ecology of crabs in mangroves at Patonga Creek on Broken Bay, New South Wales (33°S). Two ocypodids *Heloecius cordiformis* and *Australoplax tridentata*, are most abundant on the seaward fringe of the mangroves with numbers decreasing towards land. *Heteropanope serratifrons* and *Ilyograpsus paludicola* occur only on the seaward margins. By contrast *Sesarma erythrodactyla* is most abundant in the highest zones with numbers decreasing towards the seaward edge. Similarly, *Helograpsus haswellianus* occurs only on the landward margins. *Paragrapsus laevis* is restricted to the middle regions of the mangroves. *Helice leachi*, which occurs only in small numbers, is restricted to the higher levels of the shore.

At Patonga there are only two species of mangrove, *Avicennia marina* and *Aegiceras corniculatum*. The distribution and abundance of crab species cannot be correlated with either species (Yates, 1978). In the tropics some species of crab are restricted to particular zones and may be dependent on the species of mangrove. According to MacNae (1968), *Uca lactea* is associated with *Avicennia*, especially when it is growing in sand. If the sand is very fine *U. bellator* occurs and is also common in areas shaded by outermost bushes of *Ceriops*. However, George and Jones (in press) disagree with MacNae's identifications and the precise nature of the distribution of his *Uca* species in Australian mangroves must now be viewed with caution. The larger sesarmids, being mainly herbivores, occur in areas of seedlings of *Avicennia, Bruguiera* and *Ceriops*. Whereas *Macrophthalmus depressus*, an omnivore, is restricted to sandy substrates in drainage channels (MacNae, 1968).

Yates (1978) recorded seasonal changes in the abundance of crabs. Maximum densities of most species occur during summer. *Paragrapsus laevis* is most abundant in winter. Some species, such as *Sesarma erythrodactyla* and *Paragrapsus laevis*, move to lower zones in the mangroves to spawn. Crabs also show daily activity patterns. During the day, at low tide, crabs tend to remain in their burrows. Hutchings and Recher (1974) recorded maximum concentrations of crabs at night on a rising tide. Many of the crabs were climbing pneumatophores and trees to forage.

*Wood Infauna*

The fauna associated with dead and living wood is not restricted to mangroves, but because logs tend to be trapped and accumulate in mangrove habitats, mangroves have a rich wood-boring fauna. In Australia, the wood-boring fauna is dominated by the teredinid molluscs of which 31 species in eight genera have been described (Turner *et al.*, 1972; Turner and McKay, 1979). Holdich and Harrison (1980) have recently described several species of isopods *Gnathia* from dead wood found in Queensland mangroves.

Animals such as the ship worms (Teredinidae) and gnathid isopods are important in the breakdown of wood in marine habitats. However, there is some evidence that the wood must first be invaded by fungi before it can be colonized by wood boring animals (Cragg and Swift, 1980). Leightley (1980) has found marine fungi in the wood of the five species of Australian mangrove so far examined. The succession of marine fungi in wood has been extensively studied in Florida by Newell (1974) and similar patterns can be expected in Australia. In Papua New Guinea, Cragg and Swift (1980) have drawn analogies between terrestrial decomposers such as termites and beetles and the marine timber borers.

The wood-boring fauna is not restricted to dead wood. In Florida, an isopod *Sphaeroma terebrans* attacks the live prop roots of *Rhizophora mangle*. Simberloff *et al.* (1978) suggest that the damage by isopods coupled with insect attack on aerial roots may stimulate root branching. For every root produced by the tree, 1.4 roots reach the substrate thereby providing greater support for the plant. There is no information for Australia on the wood-boring fauna of live mangroves.

Associated with these wood-boring organisms is a range of animals seeking protection from predation, desiccation, etc., such as barnacles, limpets, crabs, amphipods, nemerteans and polychaetes. This fauna is most diverse in logs trapped in the frontal margins of the mangroves which are frequently inundated. Under logs, small pockets of water are often trapped which provide suitable microhabitats for many of these animals. In temperate mangroves the crab *Sesarma erythrodactyla* commonly occurs under logs (Yates, 1978). Graham *et al.* (1975) found 34 species of molluscs associated with logs in Trinity Bay, Cairns. These molluscs often use the tunnels and cavities created by the wood-boring teredinids. Also, some species such as *Ellobium aurisjudea* seek refuge in the log during the day, and feed on the muddy substrates in the *Rhizophora* and *Bruguiera* zones at night or on cloudy, rainy days. One species of nemertean *Pantinonemertes winsori* has been recorded from tropical mangroves (Moore and Gibson, 1981). It occurs beneath bark or in cavities in rotten fallen timber of *Avicennia marina* and *Ceriops tagal* in the upper tide levels.

At Gladstone, central Queensland (23°S), many species of molluscs including *Melampus castaneus, M. striatus, Ellobium aurisjudea, Onchidium* sp., *Bactranophorus* sp., *Nerita lineata, Isognomon ephippium* have been collected from logs (Saenger, pers. comm.). Microgastropods (e.g. *Assiminae* spp. and *Iravadia* sp.) are also found on logs in tropical mangroves (Ponder, pers. comm.). Ponder has evidence that differences in the mollusc fauna can be attributed to differences in the moisture content of the log and the frequency of inundation.

In the Northern Territory several species of crab utilize rotting logs in the mangroves of Kakadu National Park (Hegerl *et al.,* 1979). Hegerl *et al.* (1979) found that *Metopograpsus quadridentatus, Metopograpsus* sp., and *Clistocoeloma merquiensis* were most abundant in logs in the upper part of the tidal range. *Nannosesarma batavicum* and *Sesarma* sp. occur in logs in the *Rhizophora* zone. *S. kraussi borneensis* is restricted to sites which are frequently inundated and *Epixanthus dentatus* occurs in *Rhizophora, Sonneratia/Camptostemon* zones. *S. darwinensis* commonly occurs under decaying logs. Saenger (pers. comm.) collected the crabs *Clistocoeloma merguiense, Sesarma molluccensis* and *S. elongata* from logs among mangroves at Gladstone.

## Patterns

It helps to understand the ecology of mangrove ecosystems if it is realized that mangroves are essentially forests with a muddy intertidal substrate. The abundance of animals, their distribution within the mangrove forest, and their adaptations to the physical and biological environment can then be explained in the same ways that one would discuss a terrestrial forest or estuarine mudflat. For much of the fauna, mangroves are no more than an extension of their 'normal' habitat. Relatively few animals are restricted to mangroves or show specific adaptations to the mangrove environment.

Mangrove endemics have probably evolved in response to a limited array of unique features. Mangroves are flooded regularly by the tide, for varying periods depending on the tidal cycle, and at varying times during the day. For terrestrial organisms, this restricts movement and limits the amount of time available for foraging on the forest floor. McCormick (1978) has suggested that the canopy fauna in mangroves which is subject to partial or complete flooding of the canopy is depauperate for this reason. High tannin content and concentrations of salt on or within the leaves of mangroves cause special problems for herbivores. The resistance of mangrove leaves to breakdown may also limit the ability of marine detritivores to use them.

The mangrove community reflects the merging of the marine and terrestrial systems. In temperate areas, at their most complex, mangroves form fairly open forests with a simple canopy; in the tropics, mangroves may be open or closed and are often layered with distinct zonation. The terrestrial fauna is largely restricted to the forest canopy, and the marine fauna to the forest floor and lower levels of trees. Thus there is a horizontal partitioning of these two parts of the mangrove community.

Within the two faunal groups, subdivisions occur. For terrestrial animals, these divisions may be related to the horizontal zonation of the mangroves. For example, stands of *Rhizophora* may provide vertical complexity, nesting sites or shelter for a particular species of bird, whereas stands of *Avicennia* may not offer these advantages. As mangroves are often a continuation of nearby forest, the partitioning within these forests should be compared with that occurring in mangroves. Such comparisons may explain, for example, why some birds which occur in adjacent habitats are absent from mangroves.

For the marine fauna, mangroves provide additional habitat to that found on muddy shores. The dense canopy of the forest provides protection against desiccation and may offer cover against predators. Mangrove conditions are less rigorous in terms of salinity and temperature change than those on an exposed mudflat. The less rigorous environment and the firm substrates provided by roots, stems and logs enable some animals to survive which might otherwise be absent from the intertidal environment of estuaries.

As a generalization, most of the marine fauna occurring in temperate mangroves also occurs on adjacent muddy or rocky shores. Mangrove specialists or endemics are by and large restricted to the tropics (e.g. Figs 2 and 3). Either the tropical mangrove forest offers habitats not available in tropical estuaries (e.g. solid substrates) or the cooler conditions, high humidity and shelter from the sun within the mangrove forest are critical for survival.

For the marine fauna, zonation horizontally across the substrate from low to high water mark and vertically up roots and trunks and within the substrate, occurs in response to the periodicity of tidal inundation (Fig. 4). This may be modified by drainage patterns and tidal creeks within the mangroves. Behavioural, physiological and morphological adaptations to water loss will largely determine the tide levels at which particular species can live. The distribution of animals may vary during a tidal cycle or during their life cycle; some species for example migrate seawards to spawn. Like the terrestrial fauna, the distribution of the marine fauna may be determined by the zonation of the mangroves themselves. For example, the prop roots of *Rhizophora* and the buttress roots of *Bruguiera* may provide different microhabitats for marine animals in comparison to the pneumatophores of *Avicennia*. The density of pneumatophores, the amount of debris on the floor, and fallen logs are important for cryptic species and wood fauna, in providing refuges and protection from desiccation. Zonation of sediment within the mangroves is important to infaunal species. Also the density of seedlings and the canopy cover which provide shade, affect animals living on the surface of the mud. Salinity gradients along a river will determine how far each species penetrates upstream.

Superimposed upon all these factors are latitudinal gradients along the coast. The number of mangrove species increases from south to north with the greatest diversity occurring in northeastern Queensland and northwestern Western Australia (Lear and Turner, 1977) (Fig. 1). Coincident with the increasing number of species, the extent of mangrove forests and their structural complexity also increase. Although data are lacking for most tropical mangroves and for Western Australia in particular, there appears to be a precipitous increase in the diversity of the mangrove fauna which parallels that of the forest (Figs 2 and 3). As in the case of birds (Schodde *et al.,* 1982), the increased diversity of species is accompanied by an increased number of mangrove specialists and endemics (Fig. 3). The three major groups of marine animals, polychaetes, crustaceans and molluscs (Fig. 3), all increase in species number from south to north (Appendices 1, 2, 3) and similar patterns can be expected for other groups.

Pianka (1978) and others have reviewed the many theories advanced to explain the increased diversity of tropical animal communities relative to those in similar habitats within the temperate zones. It is not possible to separate completely the different factors which may have led to the greater diversity of tropical systems. In the case of mangroves, the greater structural complexity of the tropical forests, the increased number of plant species and larger areas are all related to increased faunal diversity. The area of mangroves and the distance between stands, in particular, may explain the much greater numbers of birds which use mangroves as a primary habitat in the tropics when compared to temperate mangrove forests. This is simply a logical extension of the theories of island biogeography (see MacArthur and Wilson, 1967). The increased structural complexity and greater number of plant species would also permit a greater number of bird species to co-exist (Recher, 1971). Schodde *et al.* (1982) provide examples of resource apportionment among closely related birds co-existing in northern mangrove forests. The white-breasted whistler *Pachycephala lanioides* apparently forages extensively on the muddy forest floor where it takes various marine invertebrates while the co-occurring mangrove golden whistler *P. melanura* forages for insects in the canopy. Two co-habiting kingfishers *Alcedo azurea* and *A. pusilla* differ in size (28 to 35 grams versus 10 to 13 grams) and would be expected to take different sized prey. Other examples given by Schodde *et al.* (1982) include flycatchers *Myiagra,* fantails *Rhipidura,* and warblers *Gerygone.* Similar patterns are evident among marine invertebrates with various crabs separated within the mangroves by size of sediment particles (*Uca* spp.), type of food or capacity to withstand desiccation.

As data become available, it is likely that significant regional differences in community composition and diversity will be evident between tropical mangrove forests in northern Australia. Stands of mangroves in northwestern Australia are apparently much more uniform in species composition than those in northeastern Australia. Historical events related to recent glacial periods and the separation of northeastern and northwestern marine environments by the Torres Strait land bridge have probably had a significant effect on the evolution of distinctive mangrove communities in these regions. During the time the land bridge existed there were enhanced opportunities for plants and animals to move between mangrove forests in eastern Australia and eastern New Guinea. These were isolated from mangroves occurring along the western fringes of the continent.

Schodde *et al.* (1982) discuss the origins of the mangrove avifauna in the context of the Torres Strait land bridge. They suggest that northwestern Australia was linked to New Guinea by a mangrove-rich land connection, Arafura Land. This, they argue, was the centre of evolution for mangrove bird specialists. In addition, the mangroves in this area are geologically older and have been stable over geological time. Those in northern Queensland have been affected by fluctuations in sea levels which periodically eliminated mangrove areas (Coventry *et al.,* 1980). Cape York was connected to the Gulf of Papua which had relatively few mangrove forests and hence fewer mangrove birds.

Whether similar patterns exist for other groups of mangrove animals is unknown. As is evident from the material presented in this review, information on mangrove fauna is sketchy. There is a particular need for quantitative studies of fauna and for work in tropical mangrove forests. Until such information is available it will not be possible to evaluate fairly the theories of Schodde and his colleagues or those of MacNae (1968) regarding the evolution and dispersion of mangrove animals in Australia. Nor, we submit, will it be possible to develop sound management and conservation strategies for what must be regarded as one of Australia's richest ecosystems.

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## Appendix 1

### POLYCHAETES RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld | | | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| | | Nth | Cent. | Sth | | | | |
| POLYCHAETA | | | | | | | | |
| Polynoidae | | | | | | | | |
| *Lepidonotus* sp. | | | | | X | | | |
| Sigalionidae | | | | | X | | | |
| Amphinomidae | | | | | | | | |
| *Eurythoe complanata* (Pallas) | | X | | | | | | |
| Phyllodocidae | | | | | | | | |
| *Phyllodoce duplex* McIntosh | | | | | X | | | |
| *P. malmgreni* Gravier | | X | | X | | | | |
| *P. novaehollandiae* Kinberg | | | | | X | | | |
| *Phyllodoce* sp. | | | X | | | | | |
| Nereididae | | | | | | | | |
| *Australonereis ehlersi* (Augener) | | | | X | X | | X | |
| *Ceratonereis erythraeensis* Fauvel* | | | X | X | X | | | |
| *C. mirabilis* Kinberg | | | | X | | | | |
| *Namalycastis abiuma* Mueller | | | | X | | | | |
| *Namalycastis* sp. | | | | | X | | | |
| *Namanereis quadraticeps* (Blanchard) | | | | | X | | | |
| *Neanthes cricognatha* (Ehlers) | | | | | | | X | |
| *N. vaalii* Kinberg | | | X | X | X | | X | |
| *Nereis uncinula* (Russell) | | | | X | | | | |
| *Nereis* sp. | | | | | X | | | |
| *Perinereis vallata* (Grube) | | | | | | | X | |
| *Platynereis* cf. *dumerilii antipoda* Hartman | | | | X | | | | |
| *Pseudonereis rottnestiana* (Augener) | | | X | | | | | |
| Nephtyidae | | | | | | | | |
| *Nephtys australiensis* Fauchald | | | X | X | X | | | |
| Glyceridae | | | | | | | | |
| *Glycera americana* Leidy | | | X | | | | | |
| *Glycera* sp. | | | X | | | | | |
| *Goniada* sp. | | | X | | | | | |
| Eunicidae | | | | | | | | |
| *Eunice antennata* (Savigny) | | X | | | | | | |
| *Marphysa sanguinea* Montagu | | | | X | X | | | |
| *Marphysa* sp. | | | | | X | | | |
| Lumbrineridae | | | | | | | | |
| *Lumbrineris* sp. | | | | | X | | | |
| Onuphidae | | | | | | | | |
| *Diopatra dentata* Savigny | | | | X | | | X | |
| Orbiniidae | | | | | | | | |
| *Leitoscoloplos* sp. | | | X | | | | | |
| *Scoloplos (S.) simplex* (Hutchings) | | | | | X | | | |
| *Scoloplos* sp. | | | X | | | | X | |
| Spionidae | | | | | | | | |
| *Boccardia* sp. | | | | | X | | | |
| *Polydora* sp. | | | X | | | | | |
| *Prionospio* sp. | | | X | | | | | |
| *Scolecolepis indica* Fauvel | | X | | | | | | |
| Spionidae spp. | | | | | X | | | |
| Magelonidae | | | X | | | | | |
| Chaetopteridae | | | | | | | | |
| *Chaetopterus* sp. | | X | | X | X | | | |

## APPENDIX 1

POLYCHAETES RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld | | | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| | | Nth | Cent. | Sth | | | | |
| *Mesochaetopterus minutus* Potts | | X | | | | | | |
| Cirratulidae | | | | | | | | |
| *Cirriformia tentaculata* Montagu | | | | | X | | | |
| Opheliidae | | | | | | | | |
| *Armandia intermedia* Fauvel | | | | | X | | | |
| Capitellidae | | | | | | | | |
| *Barantolla lepte* Hutchings | | | X | | X | | | |
| *Capitella capitata* (Fabricius) | | | | | X | | | |
| *Notomastus torquatus* (Hutchings & Rainer) | | | | X | X | | | |
| *Notomastus* sp. | | | X | | X | | | |
| Maldanidae | | | | | | | | |
| *Euclymene* sp. | | | X | | | | | |
| Oweniidae | | | | | | | | |
| *Owenia fusiformis* Delle Chiaje | | | | X | X | | | |
| Terebellidae | | | | | | | | |
| *Hadrachaeta aspeta* Hutchings | | | | | X | | | |
| *Lysilla pacifica* Hessle | | | | | X | | | |
| *Pista* sp. | | | | | X | | | |
| *Rhinothelepus* sp. | | | | | X | | | |
| *Thelepus setosus* (Quatrefages) | | | | | X | | | |
| *Amphitrite rubra* (Risso) | | | | | X | | | |
| *Terebella ehrenbergi* | | | | | | | *X* | |
| Sabellidae | | | X | | | | | |
| *Laonome* sp. | | | | X | | | | |
| Serpulidae | | | | | | | | |
| *Ficopomatus uschakovi* (Pillai) | | | | X | | | | |
| *Galeolaria caespitosa* Savigny | | | | | | | X | |
| *Salmacina* sp. | | X | | | | | | |

*This species has recently been split into several species, by Hutchings and Turvey (manuscript) and Hutchings and Glasby (in press). *Ceratonereis erythraeensis* probably does not occur in Australia.

*Sources of references:*

Butler *et al.*, 1977; Hutchings and Recher, 1974; Hutchings *et al.*, 1977; McCormick, 1978; Queensland Museum (unpublished report), 1974; Saenger *et al.*, 1977; also unpublished data of Hutchings.

## Appendix 2

### CRUSTACEANS RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld Nth | Qld Cent. | Qld Sth | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| CIRRIPEDIA | | | | | | | | |
| Iblidae | | | | | | | | |
| *Ibla cumingi* Darwin | | X | | | | | | |
| Balanidae | | | | | | | | |
| *Balanus amphitrite* Darwin | | X | X | X | X | X | X | X |
| *Elminius modestus* Darwin | | | | | X | | | |
| Tetraclitidae | | | | | | | | |
| *Tetraclita coerulescens* (Splenger) | | X | | | | | | |
| *T. squamosa* (Bruguière) | | X | | | | | | |
| *T. vitiata* Darwin | | X | | | | | | |
| Chthamalidae | | | | | | | | |
| *Chamaesipho columna* (Spengler) | | | | | | X | | |
| *Chthamalus caudatus* Pilsbury | X | X | | | | | | |
| *C. malayensis* Pilsbury | X | X | | | | | | |
| Tanaidacea | | | | | | | | |
| Paratanaidae | | | | | | | | |
| *Paratanais* sp. | | | | | X | | | |
| Isopoda | | | | | | | | |
| Anthuridae | | | | | | | | |
| *Cyathura* sp. | | | | | X | | | |
| *Haliophasma* sp. | | | | | X | | | |
| Cirolanidae | | | | | | | | |
| *Cirolana* sp. | | | | X | | | | |
| Limnoriidae | | | | | | | | |
| *Limnoria lignorum* (Rathke) | | | | | X | | | |
| *Limnoria* sp. | X | | | | | | | |
| Sphaeromatidae | | | | | | | | |
| *Amphroidella* sp. | | | | | X | | | |
| *Eubranchiata* sp. | | | | | X | | | |
| *Exosphaeroma alii* Baker | | | | | X | | | |
| *E. alata* Baker | | | | X | X | | | |
| *Exosphaeroma* sp. | | | | X | | | | |
| *Pseudosphaeroma* sp. | | | | | X | | | |
| *Sphaeroma quoyanum* Milne-Edwards | | X | X | X | X | | | |
| *S. terebrans* Baker | | | | X | X | | | |
| *S. walkeri* Stebbing | | | | | X | | | |
| *Sphaeroma* sp. | | X | | X | X | | | |
| *Chitonopsis* sp. | | | | | X | | | |
| Ligiidae | | | | | | | | |
| *Ligia australiensis* (Dana) | | | | | X | | | |
| *Ligia* sp. | | X | | | | | | |
| Amphipoda | | | | | | | | |
| Cheluridae | | | | | | | | |
| *Chelura terebrans* Philippi | | | | | X | | | |
| Corophiidae | | | | | | | | |
| *Corophium* sp. | | | | | X | X | X | |
| *Ericthonius* sp. | | | | | X | | | |
| Gammaridae | | | | | | | | |
| *Victoriopisa australiensis* (Chilton) | | | | | X | | | |
| Talitridae | | | | | | | | |
| *Orchestia* sp. | | | | | X | | | |
| *Talorchestia* sp. | | | | X | | | | |

## APPENDIX 2

CRUSTACEANS RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld Nth | Qld Cent. | Qld Sth | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| Hyalellidae | | | | | | | | |
| *Parhyallela* sp. | | | | | X | | | |
| Indet sp. | | X | | | | | | |
| DECAPODA | | | | | | | | |
| Penaeidae | | | | | | | | |
| *Metapenaeus macleayi* (Haswell) | | | | | X | | | |
| *Penaeus latisulcatus* Kishinouye | | | | | | | X | |
| *P. plebejus* Hess | | | | | X | | | |
| Alpheidae | | | | | | | | |
| *Alpheus edwardsi* (Andouin) | | X | | | X | | | |
| *Alpheus* sp. | | | | | X | | | |
| Atyidae | | | | | | | | |
| *Paratya* sp. | | | | | X | | | |
| Palaemonidae | | | | | | | | |
| *Leander intermedius* Stimpson | | | | | | | X | |
| *L. littoreus* McCulloch | | | | | | | X | |
| *Macrobrachium intermedium* Stimpson | | | | | X | | | |
| *Palaemon serenus* Heller | | | | | X | | | |
| Callianassidae | | | | | | | | |
| *Callianassa australiensis* Dana | | | X | X | X | | | |
| Laomediidae | | | | | | | | |
| *Laomedia healyi* Yaldwyn & Wear | | | | | X | | | |
| Grapsidae | | | | | | | | |
| *Eriocheir spinosa* Milne-Edwards | | | | | | | X | |
| Xanthidae | | | | | | | | |
| *Pilumnopaeus serratifrons* Kinahan | | | | | X | | | |
| Ocypodidae | | | | | | | | |
| Scopimerinae | | | | | | | | |
| *Ilyoplax dentata* Ward | | X | X | X | | | | |
| *Ilyoplax* sp. | X | X | X | X | | | | |
| *Scopimera inflata* Milne-Edwards | | X | X | X | X | | | X |
| *Scopimera* sp. | | | | | | | | X |
| *Tmethypocoelis* sp. | X | | | | | | | |
| *Heloecius cordiformis* (Milne-Edwards) | | | | X | X | X | | |
| *Ocypode ceratophthalma* (Pallas) | | X | X | X | X | | | X |
| *O. convexa* Quoy & Gaimard | | | | | | | | X |
| *O. cordimanus* Desmarest | | X | X | X | X | | | X |
| *O. fabricii* Milne-Edwards | X | | | | | | | X |
| *Uca capricornis* Crane | X | X | X | | | | | X |
| *Uca* sp. A | X | | | | | | | X |
| *Uca* sp. B | X | | | | | | | X |
| *Uca* sp. C | X | | | | | | | X |
| *Uca dussumieri* (Milne-Edwards) | | X | X | | | | | |
| *U. australiae* Crane | | | | | | | | X |
| *U. coarctata* Milne-Edwards | X | X | X | X | | | | |
| *U. flammula* Crane | X | | | | | | | X |
| *U. signata* (Hess) | X | X | X | X | | | | X |
| *U. longidigita* (Kingsley) | | | X | X | X | | | |
| *U. seismella* Crane | X | X | X | X | | | | X |
| *U. polita* Crane | X | X | X | X | | | | X |
| *U. tetragonon* (Herbst) | | X | X | | | | | |

## Appendix 2

### CRUSTACEANS RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld | | | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| | | Nth | Cent. | Sth | | | | |
| *U. dampieri* Crane | X | | | | | | | X |
| *U. vomeris* McNeill | X | X | X | X | X | | | |
| *U. triangularis* (Milne-Edwards) | X | X | | | | | | |
| *U. mjobergi* Rathbun | X | X | X | | X | | | X |
| *U. perplexa* (Milne-Edwards) | | X | X | | X | | | |
| Macrophthalminae | | | | | | | | |
| *Australoplax trindentata* (Milne-Edwards) | | X | X | X | X | | | |
| *Cleistostoma wardi* Rathbun | | X | X | X | | | | |
| *Leipocten sordidulum* Kemp | | X | X | X | | | | |
| *Macrophthalmus abercrombiei* Barnes | | X | | | | | | |
| *M. boscii* Audouin & Savigny | X | X | X | | | | | X |
| *M. convexus* Stimpson | X | X | X | | | | | Nth |
| *M. crassipes* Milne-Edwards | X | X | X | X | X | | | Nth |
| *M. darwinensis* Barnes | X | | | | | | | X |
| *M. japonicus* (De Haan) | | | | | | | | X |
| *M. latifrons* Haswell | | | | | | X | | |
| *M. latreillei* (Desmarest) | X | X | X | X | | | | X |
| *M. pacificus* Dana | X | X | X | X | | | | Nth |
| *M. punctulatus* Miers | | X | X | X | X | | | |
| *M. setosus* Milne-Edwards | | | X | X | X | | | |
| *M. telescopicus* (Owen) | X | X | X | X | | | | X |
| *Paracleistostoma mcneilli* (Ward) | | X | X | X | | | | |
| Mictyridae | | | | | | | | |
| *Mictyris livingstonei* McNeill | | X | X | X | X | | | |
| *M. longicarpus* Latreille | X | X | X | X | X | X | | X |
| *M. platycheles* Milne-Edwards | | | | X | X | X | | X |
| Grapsidae | | | | | | | | |
| Grapsinae | | | | | | | | |
| *Metopograpsus frontalis* Miers | X | X | X | X | | | | X |
| *M. latifrons* (White) | X | X | | | | | | |
| *M. quadridentatus* Stimpson | X | | | | | | | |
| *Metopograpsus* sp. | X | X | X | X | | | | |
| *Ilyograpsus paludicola* (Rathbun) | | | | X | X | | | |
| *?Ilyograpsus* sp. | | | | X | | | | |
| Varuninae | | | | | | | | |
| *Varuna litterata* (Fabricius) | X | X | X | X | | | | |
| Sesarminae | | | | | | | | |
| *Clistocoeloma merguiense* De Man | X | X | X | X | | | | |
| *Helice leachii* Hess | | X | X | X | X | X | | |
| *Helograpsus haswellianus* (Whitelegge) | | X | X | X | X | X | X | |
| *Nannosesarma* sp. A | | | | | | | | X |
| *Nannosesarma* sp. B | X | X | X | X | | | | |
| *Nannosesarma* sp. C | | X | X | X | | | | |
| *Paragrapsus gaimardii* Milne-Edwards | | | | | | X | X | |
| *P. laevis* (Dana) | | | | X | X | X | | |
| *P. quadridentalus* Milne-Edwards | | | | | | X | | |
| *Sarmatium crassum* Dana | | X | X | X | | | | |
| *Sesarma (Chiromantes) brevicristatum* Campbell | | X | | | | | | |
| *S. (Chiromantes) darwiniensis* Campbell | X | | | | | | | |

## Appendix 2
### MOLLUSCS RECORDED FROM AUSTRALIAN MANGROVES

| | NT | | Qld | | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| | | Nth | Cent. | | | | | |
| *S. (Chiromantes) lividum* Milne-Edwards | | X | | | | | | |
| *S. (Chiromantes) messa* Campbell | | X | X | X | | | | |
| *S. (Chiromantes) semperi longicristatum* Campbell | X | | X | X | X | | | |
| *S. (Chiromantes) semperi ?semperi* Burger | | | | | | | | X |
| *S. (Holometopus)* sp. 1 | | | | X | Nth | | | |
| *S. (Holometopus)* sp. 2 | | X | | | | | | |
| *S. (Holometopus)* sp. 3 | | X | | | | | | |
| *S. (Parasesarma) erythrodactyla* Hess | | X | X | X | X | X | | |
| *S. (Parasesarma) leptosoma* Hilgendorf | | X | X | X | | | | |
| *S. (Parasesarma) ?moluccensis* De Man | X | X | X | X | | | | |
| *S. (Parasesarma)* sp. 1 | | | | | | | | X |
| *S. (Parasesarma)* sp. 2 | X | | | | | | | |
| *S. (Bresedium)* sp. (aff. *brevipes*) | | X | X | | | | | |
| *S. (Bresedium)* sp. | X | | | | | | | |
| *S. (Neoepisesarma)* sp. (aff. *brockii*) | X | X | X | X | | | | |
| *S. (Neoepisesarma)* sp. | X | | | | | | | |
| *S. (?Neoepisesarma)* sp. | X | | | | | | | |
| *S. (Neosarmatium) fourmanoiri* Sérène | | X | | | | | | |
| *S. (Neosarmatium) meinerti* De Man | X | | | | | | | |
| *S. (Neosarmatium)* sp. | | X | X | X | | | | |
| *S. (Neosesarma)* sp. | | X | | | | | | |
| *S. (Sesarmoides) kraussi borneensis* Tweedie | X | X | X | X | | | | |
| *S. (Tiomanium) indica* Milne-Edwards | | X | | | | | | |
| Xanthidae | | | | | | | | |
| *Epixanthus dentatus* (White) | X | X | X | | | | | X |
| *E. frontalis* Milne-Edwards | X | | | | | | | |
| *Heteropanope glabra* Stimpson | X | X | X | X | | | | |
| *H. serratifrons* (Kinahan) | | | | X | X | X | X | |
| *?Heteropilumnus* sp. | | | | X | | | | |
| *Myomenippe fornasinii* (Bianconi) | | X | | | | | | X |
| Unident. sp. | | X | | | | | | |
| Goneplacidae | | | | | | | | |
| *?Rhizopa* sp. | | X | | | | | | |
| *Speocarcinus* sp. | | X | | | | | | |
| Portunidae | | | | | | | | |
| *Scylla serrata* (Forskål) | X | X | X | X | X | | | X |
| Hymenosomatidae | | | | | | | | |
| *Elamenopsis aspinifera* Lucas | | X | | | | | | |
| *E. lineata* Milne-Edwards | | X | X | X | | | | |
| *E. octagonalis* (Kemp) | | | | X | | | | |
| *E. torrensica* Lucas | X | X | | | | | | |
| *Elamenopsis* sp. 3 | | X | | | | | | |
| *Elamenopsis* sp. 4 | | | X | | | | | |
| *Halicarcinus bedfordi* Montgomery | | X | X | X | | | | X |

## APPENDIX 2 (continued)

| | | | | | |
|---|---|---|---|---|---|
| *Amarinus laevis* (Targioni Tozzetti) | | | X | X | |
| *A. paralacustris* (Lucas) | | X | X | X | X |
| *A. latinasus* Lucas | X | | | | |
| *Hymenosoma hodgkini* Lucas | | X | X | X | X |

*Sources of References:*
Aust. Litt. Soc., 1977; Barnes, 1967, 1971; Butler, 1973, 1974; Butler *et al.*, 1975, 1977; Campbell, 1967; Campbell and Griffin, 1966; Crane, 1975; Davie (unpub.); Ellway, 1974; George and Jones (in press); George and Knott, 1965; Graham *et al.*, 1975; Hale, 1927; Hegerl and Tarte, 1974; Hegerl *et al.*, 1979; Holdich and Harrison, 1980; Hutchings and Recher, 1974; Hutchings *et al.*, 1977; Lucas, 1980; McCormick, 1978; McNeill, 1926; Shanco and Timmons, 1975; Shine *et al.*, 1973; Saenger, 1977; Ward, 1933; Weate, 1973 (unpub.), 1977; Wescott, 1976.
Davie in his unpublished manuscript has verified many of the decapod identifications but the other crustaceans are based entirely on the literature. So some of the identifications and their distributions may be inaccurate.

## APPENDIX 3

MOLLUSCS RECORDED FROM AUSTRALIAN MANGROVES

| | NT | Qld Nth | Qld Cent. | Qld Sth | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| POLYPLACOPHORA | | | | | | | | |
| *Acanthozostera gemmata* Iredale & Hull | X | X | | | | | | X |
| GASTROPODA | | | | | | | | |
| Fissurellidae | | | | | | | | |
| *Montfortula rugosa* (Quoy & Gaimard) | | | | X | X | | | |
| Patellidae | | | | | | | | |
| *Cellana tramoserica* (Sowerby) | | | | X | X | X | X | |
| Acmaeidae | | | | | | | | |
| *Patelloida mimula* (Iredale) | X | X | X | X | X | | | |
| Trochidae | | | | | | | | |
| *Astrocochlea adelaidae* (Philippi) | | | | | | | X | |
| *A. concamerata* (Wood) | | | | | X | X | X | X |
| *A. constricta* (Lamarck) | X | X | X | X | X | X | X | |
| *A. torri* Cotton & Godfrey | | | | | | | X | |
| *Euchelus atratus* (Gmelin) | X | X | X | X | | | | |
| *Montodonta labio* (L.) | X | X | | | | | | |
| *Phasianotrochus* sp. | | | | | | | X | |
| *Prothalotia comtessi* Iredale | | | X | X | X | X | | |
| Neritidae | | | | | | | | |
| *Nerita atramentosa* Reeve | | | | X | X | X | X | X |
| *N. albicilla* L. | | | X | X | | | | X |
| *N. chamaeleon* L. | X | X | X | X | | | | X |
| *N. lineata* Gmelin | X | X | X | X | | | | X |
| *N. planospira* Anton | X | X | X | X | | | | |
| *N. plicata* L. | X | X | | X | | | | |
| *N. ualenensis* Lesson | | X | | | | | | X |
| *Neritina crepidularia* Lamarck | | X | X | X | | | | |
| Littorinidae | | | | | | | | |
| *Bembicium auratum* (Quoy & Gaimard) | X | X | X | X | X | X | X | |
| *B. melanostomum* (Gmelin) | | | | | X | X | X | |
| *Littorina acutispira* Smith | | | | X | X | | X | |
| *L. irrorata* Say | | | | | | | | X |
| *L. scabra* (L.) | X | X | X | X | X | | X | X |
| *L. undulata* Gray | X | X | X | X | | | | X |
| *Peasiella tantilla* (Gould) | X | X | | | | | | |
| Hydrobiidae | | | | | | | | |
| *Hydrobia buccinoides* (Quoy & Gaimard) | | | | X | X | X | X | X |
| *Posticobia brazieri* (Smith) | | X | | X | X | | | |
| *Tatea kesteveni* Iredale | | | | | X | X | X | |
| *T. rufilabris* (Adams) | | | | | X | X | | |
| Stenothyridae | | | | | | | | |
| *Stenothyra* sp. | X | X | X | | | | | |
| Iravadiidae | | | | | | | | |
| *Iravadia* sp. | X | X | X | | | | | |
| Assimineidae | | | | | | | | |
| *Assiminea relata* Cotton | | X | | X | | | | |
| *A. tasmanica* (T. Woods) | | | | | X | | | |
| *Assiminea* sp. | X | X | | | | | | |
| Turritellidae | | | | | | | | |
| *Turritella terebra* (L.) | X | X | | | | | | |
| Planaxidae | | | | | | | | |
| *Planaxis sulcatus* (Born) | X | X | X | X | | | | X |
| *Quoyia decollata* (Quoy & Gaimard) | X | X | | | | | | |
| Rissoidea | | | | | | | | |
| *Rissoina* sp. | | X | X | | | | | |
| Vitrinellidae | | | | | | | | |

APPENDIX 3 (continued)

| | NT | Qld | | | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| | | Nth | Cent. | Sth | | | | |
| *Pseudoliota* sp. | | | | | X | | | |
| Potamididae | | | | | | | | |
| *Cerithidea largillierti* (Philippi) | X | X | X | X | | | | |
| *C. obtusa* (Lamarck) | X | X | | X | | | | X |
| *C. cingulata* (Gmelin) | | X | | | | | | X |
| *Pyrazus ebeninus* (Bruguière) | X | X | X | X | X | X | | |
| *Telescopium telescopium* (L.) | X | X | X | X | | | | X |
| *Terebralia palustris* (L.) | X | X | | | | | | X |
| *T. sulcata* (Born) | X | X | X | X | | | | X |
| *Velacumantus australis* (Quoy & Gaimard) | X | X | X | X | X | X | X | |
| Cerithiidae | | | | | | | | |
| *Clypeomorus carbonarius* (Sowerby) | | | | X | X | | | |
| Strombidae | | | | | | | | |
| *Lambis lambis* (L.) | X | X | | | | | | |
| *Strombus luhuanus* (L.) | X | X | | | | | | |
| Naticidae | | | | | | | | |
| *Polinices conicus* (Lamarck) | X | X | X | X | X | X | X | X |
| *P. melanostoma* (Swainson) | | | | X | X | X | | |
| *P. sordida* (Swainson) | | | X | X | X | X | | |
| Muricidae | | | | | | | | |
| *Bedeva hanleyi* (Angas) | X | X | | X | X | X | X | |
| *Cronia aurantiaca* (Hombron & Jacquinot) | | | | X | X | | | |
| *Homalocantha secunda* (Lamarck) | X | | | | | | | |
| *Lepsiella vinosa* (Quoy & Gaimard) | | | | | | | X | |
| *Morula marginalba* (Blainville) | X | X | X | X | X | | | |
| *Naguetia capucina* (Lamarck) | | | | | | | | X |
| Buccinidae | | | | | | | | |
| *Cominella eburnea* (Reeve) | | | | | | | X | |
| *C. lineolata* (Lamarck) | | | | | | | X | |
| Melongenidae | | | | | | | | |
| *Volema cochlidium* (L.) | X | | | | | | | X |
| Nassariidae | | | | | | | | |
| *Nassarius burchardi* (Dunker *in* Philippi) | | | X | | X | X | X | |
| *N.* cf. *dorsatus* (Röding) | X | | | | | | | X |
| *N. olivaceus* (Bruguière) | | X | | X | | | | |
| *N. melanioides* Reeve | | | X | | | | | |
| *N. pauperatus* (Lamarck) | | | | | | | X | |
| *N. jonasii* (Dunker) | | | | | X | | | |
| *N. pullus* (Linné) | | | X | X | | | | |
| Collumbellidae | | | | | | | | |
| *Columbella duclosiana* | | | | | | | | X |
| *Pyrene scripta* (Lamarck) | | X | | | | | | |
| *Zafra* sp. | X | | | | | | | |
| Mitridae | | | | | | | | |
| *Mitra retusa* Lamarck | | | | X | | | | |
| Bullinidae | | | | | | | | |
| *Bullina lineata* (Gray) | X | X | | | | | | |
| Haminoeidae | | | | | | | | |
| *Atys naucum* (L.) | X | X | | | | | | |
| *Haminoea* sp. | X | X | X | X | | | | |
| Ellobiidae | | | | | | | | |
| *Cassidula angulifera* (Petit) | X | X | X | X | | | | X |
| *C. nucleus* (Gmelin) | X | X | X | | | | | X |
| *C. rugata* Menke | X | X | X | | | | | |
| *C. sowerbyana* (Pfeioffer) | | X | | | | | | |
| *Melampus striatus* (Pease) | | X | X | X | | | | |

APPENDIX 3 (continued)

| | NT | Qld Nth | Qld Cent. | Qld Sth | NSW | Vict. | SA | WA |
|---|---|---|---|---|---|---|---|---|
| *M. castaneus* (Muehlfeldt) | | X | | | | | | |
| *Ellobium aurisjudae* (L.) | X | X | X | X | | | | X |
| *Melosidula granulosa* Iredale | | | | X | | | | |
| *M. zonata* (Adams & Adams) | | X | | X | X | | | |
| *Ophicardelus ornatus* (Férussac) | | | | X | X | X | X | |
| *O. quoyi* (Adams & Adams) | | X | X | X | X | X | | |
| *O. sulcatus* (Adams & Adams) | X | X | X | X | X | X | | |
| *Pythia scarabaeus* (L.) | X | X | | | | | | |
| Amphibolidae | | | | | | | | |
| *Salinator burmana* (Blanford) | | | | | | | | X |
| *S. fragilis* (Lamarck) | X | X | X | X | X | X | X | X |
| *S. solida* von Martens | X | X | X | X | X | X | X | X |
| Siphonariidae | | | | | | | | |
| *Siphonaria bifurcatus* Reeve | | | | X | | | | |
| *S. denticulata* Quoy & Gaimard | X | X | | | | | | |
| *S. marza* (Iredale) | X | X | | | | | | |
| Onchidiidae | | | | | | | | |
| *Onchidina australis* Semper | X | X | | X | X | X | | |
| *O. beutschlii* Stantschinsky | X | X | | | | | | |
| *O. daemelii* Semper | | | X | X | X | | | X |
| *O. verruculatum* Cuvier | X | X | X | X | X | | | |
| *Oncis chameleon* (Brazier) | | | X | X | | | | |
| *Oncis* sp. | | X | | X | | | | |
| Aplysiidae | | | | | | | | |
| *Aplysia* sp. | | X | | X | X | | | |
| *Bursatella leachi* (Blainville) | | | | X | | | | |
| BIVALVIA | | | | | | | | |
| Solemyidae | | | | | | | | |
| *Solemya teraereginae* (Iredale) | | X | | | | | | |
| Arcidae | | | | | | | | |
| *Anadara trapezia* (Deshayes) | | | | X | X | | | X |
| *Arca* sp. | | X | | | | | | |
| *Barbatia* sp. | X | X | | | | | | |
| Mytilidae | | | | | | | | |
| *Amygdalum beddomei* Iredale | | X | | | | | | |
| *Modiolus inconstans* (Dunker) | | | | | | X | X | |
| *Musculus variocosus* (Gould) | | | | X | | | | |
| *Mytilus edulis* L. | | | | | X | X | X | |
| *Trichomya hirsuta* (Lamarck) | | X | | X | X | | | |
| *Xenostrobus pulex* (Lamarck) | X | X | | X | X | X | X | X |
| *X. securis* (Lamarck) | | X | | X | X | | | |
| Isognomonidae | | | | | | | | |
| *Isognomon isognomon* (L.) | | | | X | | | | |
| *'Isognomon' nucleus* (Lamarck) | X | X | | | | | | |
| *Isognomon* cf. *vitrea* (Reeve) | | | | | | | | X |
| *Isognomon* sp. | X | | | | | | | |
| Pinnidae | | | | | | | | |
| *Pinna bicolor* (Menke) | X | X | X | | | | | |
| Pteriidae | | | | | | | | |
| *Pinctada margaritifera* (L.) | X | X | | | | | | |
| Ostreidae | | | | | | | | |
| *Ostrea nomades* Iredale | | | | X | | | | |
| *Saccostrea amasa* (Iredale) | X | X | | X | | | | |
| *S. cucullata commercialis* (Iredale & Roughley) | | | X | X | X | X | | X |
| *S. echinata* (Quoy & Gaimard) | X | | | | | | | |
| Anomiidae | | | | | | | | |

## APPENDIX 3 (continued)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Enigmonia aenigmatica* (L.) | | X | | | | | | X |
| *Patro australis* (Gray) | X | | | | | | | |
| Lucinidae | | | | | | | | |
| *Arthritica helmsii* (Hedley) | | | | | X | | | |
| *Cavatidens omissa* Iredale | | | | | X | | | |
| Leptonidae | | | | | | | | |
| *Lasaea australis* (Lamarck) | | | | | X | | | |
| Geloinidae | | | | | | | | |
| *Batissa violacea* (Deshayes) | X | X | | | | | | |
| *Geloina coaxans* (Gmelin) | X | X | X | X | | | | |
| Veneridae | | | | | | | | |
| *Circe tumidum* (Bolten) | X | X | | | | | | |
| *Paphia hiantina* (Lamarck) | X | X | X | | | | | X |
| *Tapes watlingi* Iredale | | | | X | X | | | |
| *Venerupis crenata* (Lamarck) | | | | | X | | X | |
| *V. crebrelamellata* Tate | | | | | | | X | |
| Tellinidae | | | | | | | | |
| *Tellina deltoidalis* Lamarck | | | | | X | | | |
| *T. australis* Deshayes | | X | | | | | | |
| *T. capsoides* Lamarck | | X | | | | | | |
| Mesodesmatidae | | | | | | | | |
| *Mesodesma altenai* de Rooij Schuiling | X | | | | | | | |
| Mactridae | | | | | | | | |
| *Notospisula trigonella* (Lamarck) | X | | X | X | X | X | X | |
| Glauconomidae | | | | | | | | |
| *Glauconome* cf. *cumingi* (Prime) | | | | | | | | X |
| *G. virens* (L.) | | | | X | | | | |
| *G. plankta* (Iredale) | X | X | | | X | | | |
| Teredinidae | | | | | | | | |
| *Bankia australis* (Calman) | | | X | X | X | X | X | X |
| *B. campanelata* Moll & Roch | | X | | | | | | |
| *B. carinata* (Grey) | X | X | X | | X | X | X | X |
| *B. bipalmulata* (Lamarck) | | X | X | X | | | | |
| *B. gracilis* Moll | | | X | X | | | | |
| *B. nordi* Moll | | | | | | | | X |
| *B. rochi* Moll | | | X | X | | | X | X |
| *Bactranophorus thoracities* (Gould) | X | X | X | | | | | X |
| *Bactranophorus* sp. | | | | X | | | | |
| *Dicyathifer manni* (Wright) | X | X | X | X | | | | X |
| *Lyrodus massa* (Lamy) | X | X | X | | | | | |
| *L. medilobata* (Edmonson) | X | X | X | X | X | X | X | X |
| *L. pedicellatus* (Quatrefages) | | X | X | X | X | X | | X |
| *L. bipartita* (Jeffreys) | X | X | X | X | X | X | X | X |
| *Nausitora dunlopei* Wright | | X | X | X | X | | | X |
| *N. globosa* Sivickis | | X | | | | | | |
| *Nototeredo edax* (Hedley) | | | | X | X | | X | X |
| *Teredo bartschi* Clapp | | | X | X | X | X | | X |
| *T. johnsoni* Clapp | | | X | | | | | |
| *T. navalis* (L.) | | | | | X | X | X | X |
| *T. furcifera* Von Martens | X | X | X | X | | X | X | X |
| *T. clappi* Bartsch | | X | X | X | X | | | X |
| *T. poculifer* Iredale | | X | X | X | | | | |
| *T. princessae* (Sivickis) | X | X | X | | | | | X |
| *T. trianularis* Edmonson | | | | | | | | X |
| Hiatellidae | | | | | | | | |
| *Fluviolanatus armarus* Laseron | | | | | X | | | |
| Pholadidae | | | | | | | | |

## APPENDIX 3 (continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Martesia striata* L. | | X | | | | | |
| Laternulidae | | | | | | | |
| *Laternula creccina* Reeve | | | | | | X | X |
| *L. tasmanica* (Reeve) | | | | X | | | |
| *L. vagina* (Reeve) | X | X | | | | | |

*Sources of references:*
Aust. Litt. Soc., 1977; Butler, 1973, 1974, *et al.* 1975, 1977; Ellway, 1974; Graham *et al.,* 1975; Hegerl and Davie, 1977, *et al.* 1979; Hutchings and Recher, 1974; Hutchings *et al.,* 1977; McCormick, 1978; Shine *et al.,* 1973; Saenger *et al.,* 1976; Turner *et al.,* 1972; Weate, 1973 (unpub.), 1975; Wells and Slack-Smith, 1981; also unpublished data of Hutchings and Australian Littoral Society. The species in this appendix are based entirely on the literature and the material has not been verified so some of the identifications and their distributions may be inaccurate.