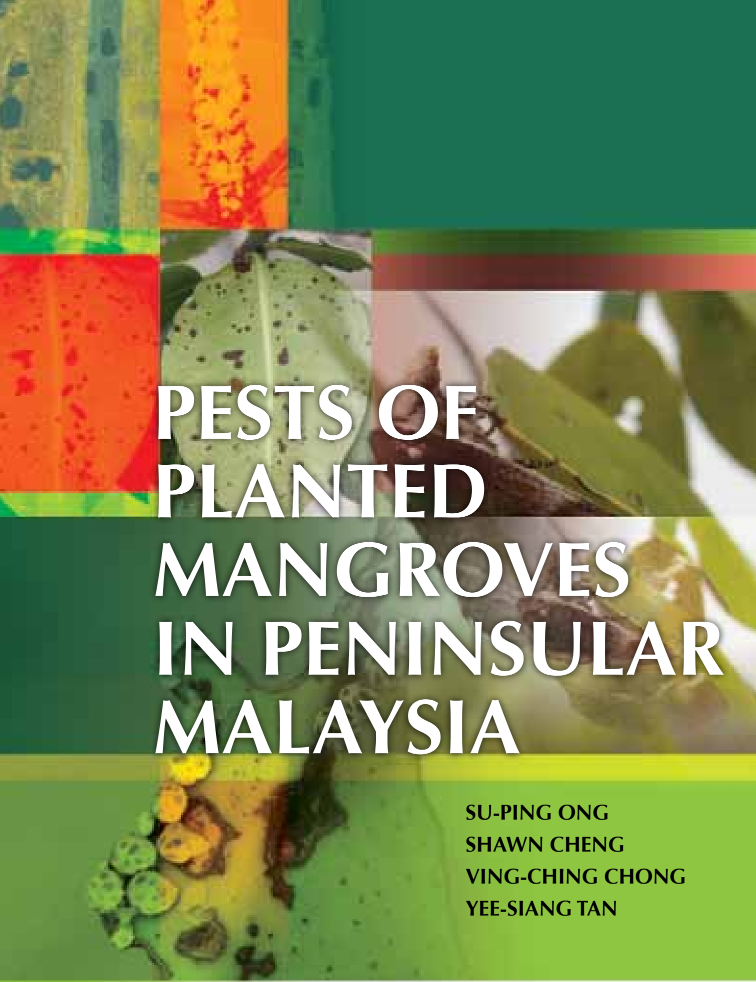

PESTS OF PLANTED MANGROVES IN PENINSULAR MALAYSIA

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2010

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Contents

Foreword

In recent years mangrove forests have received renewed attention, much of it due to the realisation of the impact it had in reducing the effects of a devastating tsunami which hit several Indian Ocean countries, post-Christmas 2004.

However, the state of mangroves is as such—they lie in derelict because man has converted these areas for crop production or aquafarming and found them unsuitable and unsustainable. Shortly after the tsunami in 2004, the Forestry Department Peninsular Malaysia started replanting mangrove forests in the country. It also engaged scientists from Forest Research Institute Malaysia (FRIM), University of Malaya (UM), National Hydraulic Research Institute Malaysia (NAHRIM) and other governmental agencies to find better and improved methods of replanting mangroves through research and development.

In replanting mangroves we have encountered invertebrate and vertebrate pest attacks. This field guide documents them along with recommendations on the prevention and control measures. The field guide is aimed at foresters and documents what is known of the pests of planted mangroves. We hope the publication will serve as a useful tool for foresters and those involved in the replanting of mangroves.

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Introduction

Mangrove forests occur between mudflats and riverbanks in tropical and subtropical areas, reaching their maximum growth in parts of Southeast Asia (Macnae, 1968). About 70 species of mangrove plants are recognised throughout the world, with the highest species concentration in Southeast Asia and Australia. The dominant mangrove species in Peninsular Malaysia are from the Avicenniaceae (*Avicennia marina, A. alba* and *A. officinalis*), Rhizophoraceae (*Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *B. parviflora*, *B. cylindrica* and *Ceriops tagal*) and Sonneratiaceae (*Sonneratia alba*, *S. caseolaris* and *S. ovata*).

Mangroves provide a habitat for a variety of animals. The waters surrounding mangroves are especially rich in shellfish and fish, and provide a livelihood for fishermen who depend on mangroves for cockle farming, fishing, cage culture and oyster harvesting. Apart from this, mangroves also yield timber, tannins and other ecological goods and services. Timber from mangrove forests are used as building material (including for the construction of jetties) and charcoal while tannin from the bark of *Rhizophora* trees has been used for dying fishing nets, sails and leather. Mangroves also play an important role in the functioning of closely related ecosystems such as terrestrial wetlands, seagrass beds and coral reefs.

The coastlines of many countries throughout the world are heavily populated and are often void of coastal vegetation that provides protection from storms, cyclones and tsunamis. Following the aftermath of the Indian Ocean tsunami, large-scale replanting of mangrove forests were carried out in countries such as Malaysia, Indonesia, Sri Lanka and Thailand. In parts of the world such as Florida, mangrove replanting has also been done because of the benefit it provides in terms of shoreline stabilisation and protection from storms and hurricanes (Riley & Kent, 1999).

In the replanting of mangroves in Peninsular Malaysia, seedlings have been observed to come under attack from invertebrate and vertebrate pests. Pests that attack crops or trees are native species that occur in the wild (Khoo, 1986). In the wild, their populations are kept in check by the non-uniform distribution of host plants, competition or predation by other insects and organisms. Planting trees in uniform stands allows insect pests to quickly locate host plants and enables multiple generations of their population to survive. The microclimate in an artificial environment also makes trees more susceptible to minor changes unlike trees in natural settings. In natural mangrove forests, wildings that grow among mature trees are protected from the effects of wave action, sunlight and are less susceptible to pests.

The main insect feeding guilds or groups found on planted mangrove seedlings are: 1) defoliators, 2) sap feeders, 3) bark- and wood-feeders, and 4) seed borers. The first feeding guild, the defoliators, damage mangrove seedlings by feeding on leaves directly through chewing, mining, eating away leaf tissues and leaving behind leaf veins, and feeding within shelter constructed from rolled leaves. The sap feeders, mostly the Hemiptera or plant bugs, suck sap from leaves, stems and other plant parts. Bark- and wood-feeding insects are another guild infesting replanted mangrove trees. Lepidoptera, specifically larva of the wood moth *Zeuzera conferta*, damages trees by tunnelling through the stem. Fruit- and seed-borers such as beetles from the family Scolytidae, on the other hand, bore through propagules rendering them weakened even before they are planted out in the mudflats.

At least 16 species of marine and estuarine faunas have been found to naturally attach onto mangrove trees or crawl on them above the soil surface (Berry, 1972). These sessile or mobile animals, such as barnacles, mussels, oysters and periwinkle snails that occur on the aerial roots, lower stems and leaves bring no apparent ill effects on the large host plant. However, on young mangrove seedlings or saplings, their occurrence and growth (called biofouling) may cause variable leaf and stem damage, stunting and even death of the young plant. The actual damage caused by these animals, all invertebrates, depends on the species, their growth and mode of nutrition. For example, barnacles do not feed on mangrove but their rapid growth weigh down and deform the young plant, while grazing periwinkle snails damage the young plant surface exposing it to insidious disease.

The incidence of heavy biofouling on replanted mangrove seedlings has become a major problem in that serious stunting of growth and mortality have been reported. This is not only experienced in the country but elsewhere such as Hong Kong. Biofouling control is necessary to enhance mangrove replanting and restoration. Because such serious biofouling on mangrove propagules is not commonly observed in nature, it may be a phenomenon associated with mangrove replanting in man-made or artificially modified environments which enhance biofouling. These enhancers include artificial shoreline protection structures that significantly reduce current flow and, being themselves substrates for colonization, function as huge larval sources. Another is the method of planting mangrove seedlings with supporting stakes, and on unsuitable slope height that does not allow for a period of plant emersion. In fact, exposure to air, light, heat and rainwater removes many biofouling species that would normally be present if there is permanent cover of water, leaving only species that could tolerate the exposed condition.

Only those species that could damage or potentially cause ill effects to young replanted mangrove plants are described here, with a mention of other pests but non-biofouling in the strict sense, such as snails. Although these animals are closely associated with replanted young mangrove plants, reports on their destructive role have not been fully elucidated except in the case of certain grapsid crabs. For instance, *Neosarmatium meinerti* (Sesarminae) predates very heavily on mangrove propagules in Kenya, with no distinct preference for mangrove species, and the crab has been suggested to be a threat to mangrove restoration (Dahdouh-Guebas *et al*. 1997). Peninsular Malaysia has the largest diversity of grapsid crabs, with 51 species, of which 44 are sesarmines (Lee, 1998).

In the following pages, pests that affect replanted mangrove plants will be introduced in greater detail with information on their distribution, biology, host plants and recommendations for their control. The use of insecticides to control insects or anti-fouling paints to control barnacles on seedlings, like they do in ships, are not suitable for use in this environment due to the effects it may have on the marine environment. Most of the recommendations given focus on cultural practices such as pruning infested plant limbs, collecting propagules during seasons when damage by scolytid beetles is low, manual removal of barnacles on seedlings, and planting seedlings on higher ground. For seedlings to have a good chance of surviving, practices such as using healthy seedlings, planting saplings instead of seedlings, and using suitable species are important.

Invertebrate Pests

INSECTS PESTS

Poecilips fallax Eggers, 1927

COMMON NAME	Pin-hole borer
ORDER & FAMILY	Coleoptera, Scolytidae
DISTRIBUTION	Southeast Asia
HABITAT	Usually found in mangrove forests.
BIOLOGY	The females lay eggs within tunnels created in the propagules. The life cycle of the scolytid beetle is between 39 and 53 days (Lapis & Valentin, 1982). The adult is dark brown in colour and measures about 3 mm in size. They have several generations in a year and different developmental stages of the beetle can be found throughout the year (Lapis & Valentin, 1982).
DAMAGE	Seeds in distress are usually more prone to be attacked, but fresh fallen propagules are also viable. Frass can be observed exuding from entry hole on propagules. *Poecilips fallax* is a common seed predator in mangroves and has been recorded on *Rhizophora* spp., *Bruguiera gymnorhiza* and *Ceriops* sp. (Browne, 1961).

CONTROL METHODS

Timing of collecting and planting propagules is to be considered as well. Infestation level has been found to be higher during the dry season, from January to April, in the north-western states of Peninsular Malaysia (Murphy, 1990). Thus, collection of propagules for planting purposes should be done during wet periods to reduce infestation of the beetles. Checking propagules for signs of pin-hole borers when collecting is important to ensure that only the healthiest seeds are selected for planting. Raising beetle-infested seeds in the nursery only increases the chance of spreading the infestation to other seeds.

Elsewhere in the Philippines, it has been shown that air-drying seedlings for one to two weeks resulted in higher survival rate (Lapis & Valentin, 1982).

Plate 1 *Poecilips fallax*, a pin-hole scolytid beetle.

Plate 2 Lateral view of *P. fallax*.

Plate 3 Frass on a *Rhizophora* propagule at a nursery (Kuala Sanglang, Perlis).

Plate 4 Tunnelling by adults and larvae of *P. fallax* in a *Rhizophora* propagule.

Streblote lipara Tams, 1928

COMMON NAME	Snout moth
CLASS, ORDER & FAMILY	Insecta, Lepidoptera, Lasiocampidae
DISTRIBUTION	The genus is most diverse in Africa, but has a number of species in the Middle East, India and Southeast Asia (Holloway, 1987).
HABITAT	Specimens have been collected mainly from mangroves.
BIOLOGY	Females have been recorded to lay up to 241 eggs in the laboratory (Plate 5). Eggs are deposited on the surface and sometimes on the underside of leaves, or even on old cocoon cases. Eggs are cylindrical and hatch in 9–14 days (Plate 7). Larvae start feeding upon hatching (Plate 8). The larval stage lasts up to 40 days. Lasiocampid caterpillars live and forage together for defence purposes (Chung *et al.* 2008). They are often found aggregating on shoot tips (Plate 9). It is the larval stages that cause most damage, as they feed voraciously on the leaves. Larvae, when found on plant stems or leaves, appear rather flattened (Holloway, 1987) and are covered with poisonous spines to protect themselves from predators.

BIOLOGY *(continued)*

When disturbed, part of the thorax is raised, revealing short spiny hairs, black in colour, which can embed into the skin when touched (Holloway, 1987) (Plate 10). Pupae are enclosed in cocoons (Plate 11). The adults emerge 10–17 days later and have a wingspan of about 3–6 cm. Female adult moths are usually larger than males (Plate 6). The adults are inactive during day and can be observed resting on leaf tips.

DAMAGE

The larvae of the moth cause serious defoliation on replanted mangrove seedlings, and weave silken webs on the plant stems. Repeated attacks can weaken and eventually lead to death in seedlings. *Streblote lipara* has been found on *Rhizophora* seedlings in Lekir (Perak) and Byram (Penang).

CONTROL METHODS

An implement such as a pair of forceps can be used to remove eggs, larvae and pupae from infested trees. The spiny hairs on larvae and pupae can cause skin irritation therefore, precaution must be taken. Manual removal is recommended because spraying insecticides may cause harm to the marine environment. A parasitic wasp was recorded emerging from a pupa of *S. lipara* (Plates 12–13).

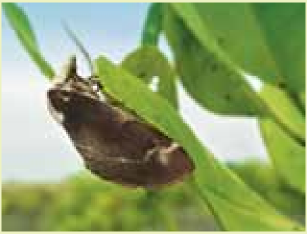

Plate 5 An adult female moth, *Streblote lipara*, getting ready to oviposit on the *Rhizophora* leaves.

Plate 6 Pinned specimen of *S. lipara* female (top) and male (bottom).

Plate 7 *S. lipara* eggs laid on the underside of a leaf. Several eggs have already hatched. The eggs are white and have brown markings on the surface.

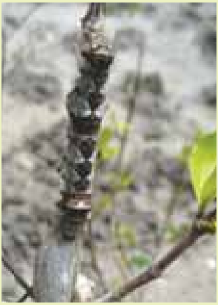

Plate 8 Mature larva of *S. lipara*.

Plate 9 Young larvae of *S. lipara* aggregate on the shoot tip during high tide.

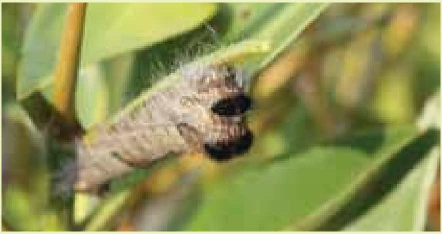

Plate 10 *S. lipara* raising tufts of hair, when provoked.

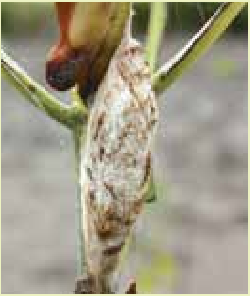

Plate 11 Pupa of *S. lipara*.

Plate 12 Pupa of *S. lipara* attacked by a parasitic wasp. Diameter of the exit hole made by the wasp measured 0.5 cm.

Plate 13 A parasitic wasp that emerged from a pupa of *S. lipara*.

Zeuzera conferta *Walker,* 1856

COMMON NAME	Stem borer
CLASS, ORDER & FAMILY	Insecta, Lepidoptera, Cossidae
DISTRIBUTION	Northeast Himalaya, Indochina, Sundaland, Sulawesi, Molluccas, New Guinea
HABITAT	Prefers lowlands especially mangroves. Other records are on *Barringtonia* (Lecythidaceae), *Ochroma* (balca, Bombacaceae) and *Theobroma* (cacao, Sterculiaceae) in Java (Holloway, 1986).
BIOLOGY	Very little is known of the biology of the insect. In our studies we have only recorded their pupae and adults (Plates 14 & 15). Adult females are larger than males and have a long ovipositor at the end of the abdomen, which enables them to position their eggs into bark crevices. The larva bores into the nearest twig and constructs tunnels as they feed (Plate 16). The tunnels enlarge as the larvae grow. The larva metamorphoses into a pupa while inside the hollowed-out stem. The pupa will move partially out of the tunnel at the exit hole when it is ready to emerge and after emerging, the exuvia is left in the openings (Solomon, 1995) (Plate 17).

DAMAGE

Broken twigs and branches with dead brown foliage are symptoms of stem borer infestation (Solomon, 1995). Sawdust or frass from the tunnelling activity of the borer, expelled through the entry and exit hole, can be observed on the ground below the infested tree (Solomon, 1995). Sometimes ants and spiders can be found occupying the abandoned stem for refuge.

In Kg. Baru Pulau Sayak (Kedah), they have been found infesting three-year-old *Rhizophora apiculata* seedlings. Elsewhere in Bangladesh, they have been recorded infesting *Sonneratia apetala* (Saenger & Siddiqi, 1993), and in Indonesia, *Avicennia* spp. (Hardi, 1997).

CONTROL METHODS

Knowledge on natural enemies of the moth is poor. Cultural methods like pruning and removing dead trees and branches to contain the attack should be carried out. Elsewhere, a study has shown that mass trapping of male moths by using pheromones of the females was effective in reducing their numbers in a walnut orchard (Patanita & Vargas, 2007).

Plate 14 *Z. conferta* pupa inside stem.

Plate 15 Adult specimen of *Z. conferta*.

Plate 16 *R. apiculata* stem hollowed out by *Z. conferta*.

Plate 17 Exuvia of *Z. conferta* protruding from exit holes on the tree stem.

Bagworms

CLASS, ORDER & FAMILY	Insecta, Lepidoptera, Psychidae
DISTRIBUTION	Paleotropical (Tropical countries like Africa, Asia and Oceania)
HABITAT	Plantations, forest trees, mangroves
BIOLOGY	The complete lifecycle of a bagworm can take anywhere between several months to a year. Larvae construct protective bags made of twigs, leaves and small stones bound together with silk immediately after hatching. The bags are constructed in various shapes e.g. conical and pagoda shapes and are sometimes used to distinguish between bagworm species (Plates 18–21). Bagworms live and feed within this thin protective casing, with only their head and thorax protruding from the bag, which can retract completely into the casing when disturbed. The size of the casing grows as the larva increases in size or matures. Larvae disperse by hanging from their bags on a slender silk thread to become windborne. When pupating, the larva attaches the bag to a substrate and positions its head downwards in the bag (Rhainds *et al*. 2009).

BIOLOGY *(continued)*

Males have wings whilst females are flightless and it is the males which fly out to seek the females during mating. Females continue to remain in their cases when mating and laying their eggs. The adults do not feed and are short-lived.

DAMAGE

Bagworms cause damage by feeding on the underside of leaves resulting in brown blotches on the leaves (Plate 23). Leaves are often left riddled with small holes. During heavy infestation, bagworms can cause severe defoliation on seedlings (Plate 22).

Bagworms have been recorded infesting mangrove trees in Sri Menanti Laut (Johor), Lekir (Perak), Kg. Baru Pulau Sayak (Kedah), Jimah (Negeri Sembilan) and *Casuarina equisetifolia* in Kerteh (Terengganu).

CONTROL METHODS

Foliage damage caused by bagworms is however not a serious problem in mangroves. Natural enemies help keep bagworm populations in check. Wet conditions can accelerate the growth of entomopathogenic fungi, a natural biological control agent which is detrimental to the larvae (Rhainds *et al*. 2009). Bagworms can also be handpicked and destroyed from trees if they are present in small numbers.

Plate 18 Conical shaped bagworm in Lekir (Perak).

Plate 19 Bagworm cases made from plant material.

Plate 20 An abandoned bagworm case on a casuarina tree (Kerteh, Terengganu).

Plate 21 The pagoda bagworm, *Pagodiella sp.*, excises round-shaped discs from *R. apiculata* leaves and uses it to build protective bags (Lekir, Perak).

Plate 22 Severe defoliation by bagworms.

Plate 23 Brown blotches on *Rhizophora* leaves caused by bagworms.

Leaf miners

CLASS, ORDER & FAMILY	Insecta, Diptera or Lepidoptera, Agromyzidae or Gracillariidae
DISTRIBUTION	Temperate and tropical countries
HABITAT	Forest trees, plantations, mangroves
BIOLOGY	Not much is known of the biology of leaf miners on mangroves. We have only recorded abandoned tunnels within leaf tissues. Feeding tunnels on the leaves are unique to each species and can be used to identify the species responsible for the damage. Leaf miners either belong to the micromoth group or the diptera. Their larvae are grub-like and dorso-ventrally flat (Speight & Wylie, 2001), and have evolved to accommodate confined living spaces. The miners feed within the leaf mesophyll which contains photosynthetic cells. Damage can affect photosynthetic rates and other leaf processes, depending on the intensity of attack and type of leaf tissues that are infested (Parrella *et al*. 1985), and can also lead to premature leaf shedding (Raimondo *et al*. 2003).
DAMAGE	Serpentine-like mining patterns are often observed on leaf surface as a result of the tunnelling and feeding activity of leaf miners (Plate 24). Loss of green leaf area is conspicuous on surfaces infested with mines.

DAMAGE *(continued)*

Leaf miners were recorded infesting *Avicennia* seedlings in Balik Pulau (Penang), Lekir (Perak) and mature mangrove trees in Kuala Selangor Nature Park (Selangor).

CONTROL METHODS

No control is needed as leaf miners are minor pests and natural biological control maintains the pest population at tolerable levels. Premature leaf shedding by trees causes the highest larval mortality for this moth (Simberloff & Stiling, 1987). Leaves with multiple mines abscise early, killing the larva living within (Simberloff & Stiling, 1987). The abscission however, will not kill miners in the pupal stage.

Plate 24 Abandoned tunnels of a leaf miner on *Avicennia* in Balik Pulau, (Penang).

Mealybugs

CLASS, ORDER & FAMILY	Insecta, Homoptera, Margarodidae
DISTRIBUTION	Widely distributed
HABITAT	On stems of *Casuarina equisetifolia*, forest plantations, crops, fruit trees.
BIOLOGY	Mealybugs are soft-bodied insects that belong to the scale insect group. The lifecycle of mealybugs, from egg to adult, takes about several weeks to months (Dreistadt, 2001). Active infestation usually occurs during the immature stage of the mealybug as the immatures can crawl or disperse by wind to nearby trees. The immature form resembles the adults. Females are wingless and do not move once they settle on plant parts. Males have wings and leave the case to mate.
DAMAGE	Mealybugs suck sap from plants with their sharp piercing-sucking mouthparts. Mealybugs secrete a powdery wax layer to protect themselves while feeding on plants. Feeding causes yellowish spots on the leaves. Sooty mould fungus also grows from the honeydew excreted by the mealybugs and covers the stem and leaf surface (Plate 25). Ants may sometimes be present together with mealybugs as they both share a close relationship (Plate 26).

DAMAGE *(continued)*

The ants obtain honeydew, a by-product excreted from the mealybug, and in return the ants provide protection to the mealybugs from predators.

Mealybugs have been found infesting *Casuarina* trees in Kerteh (Terengganu) and Kampung Anak Air (Pahang). They were also found on *Avicennia* sp. trees in Lekir (Perak).

CONTROL METHODS

Natural enemies of mealybugs are birds, lizards, parasitic wasps, ladybird beetles and green lacewings. Oil emulsion sprays are effective against mealybugs. They are cheap, environmentally-friendly and useful against soft-bodied insects (e.g. mealybugs, young scale insects and aphids). Oil emulsion spray is a mixture of oil and water with soap added as an emulsifier. It kills mealybugs by blocking their spiracles and causes them to suffocate. As oil emulsion sprays have no residual effect, repeated application is necessary to prevent recurrence of mealybug infestations. Forceful jets or stream of water can also be used to reduce the infestation of mealybugs on trees (Dreistadt, 2001), however mealybugs occurring on the underside of the leaves or stems may not be removed. Manual removal by hand is necessary to get rid of persistent mealybugs.

Plate 25 Infestation of mealybugs on *Avicennia* sp. with sooty mould on the stems. Ants tending to mealybugs for honeydew.

Plate 26 Ants tending to mealybugs for honeydew on casuarinas.

MARINE PESTS

Balanus amphitrite Darwin, 1854

COMMON NAME	Striped barnacle, Purple acorn barnacle
CLASS, ORDER & FAMILY	Maxillopoda, Sessilia, Balanidae
DISTRIBUTION	Worldwide in warm and temperate waters. The species is the predominant barnacle of ports worldwide and is believed to be introduced by ships and ballast water (Cohen, 2005).
HABITAT	Commonly found in estuarine and coastal waters as biofouling organism on hard substrates such as rocks, seawalls, pilings, ship hulls, shoreline protective structures (e.g. riprap, geo-tube), and on living surfaces of molluscs, crabs and mangroves trees. The barnacles grow on all parts of the replanted mangrove seedling and sapling, but more on the roots and lower region of stems (Plate 27).
BIOLOGY	Maximum shell diameter of 30 mm. A filter-feeding maxillipodan crustacean, protected and living within its shell of six triangular, hard calcareous plates which are directly attached by its base to solid substratum. The plates are marked by distinct purple vertical stripes (Plate 28).

BIOLOGY *(continued)*

The diamond-shaped opening on the top is protected by two pairs of movable hard plates that flex out to the sides when the animal extends out its feeding appendages to filter organic suspension during high tide.

The animal is hermaphroditic. Individuals release as many as 10,000 eggs per brood, with as many as 24 broods per year (El-Komi & Kajihara, 1991). Eggs are brooded before free-swimming planktonic larvae (nauplius) are released into the seawater. Nauplii (Plate 29) soon transform into cypris larvae which then seek out suitable hard substratum to settle on (Plate 30). The settled cypris larva cements itself to the substrate by secreting adhesive proteins. The species is both eurythermal and euryhaline, tolerating low temperatures (12°C) and low salinities (4 ppt), but breeding requires warmer optimum temperature of 23°C and salinities of above 15 ppt (Vaas, 1978; Desai *et al*. 2006).

DAMAGE

Two main factors that influence barnacle infestation leading to growth retardation, damage or death of replanted mangrove seedlings are tidal inundation (exposure) and salinity. Barnacle infestation increases with the duration of inundation since the cypris is planktonic.

DAMAGE *(continued)*

Hence, the lower the mangrove seedlings are planted on the shore, the longer the plants are immersed in water for barnacle settlement. Also, plant emersion during ebb tide will expose settled barnacles to irradiation, high temperature and rainwater. Our experiments have shown that *Avicennia marina* seedlings planted on the lower shore (160 cm above chart datum, CD) sustained substantially higher barnacle infestation as compared to *Rhizophora apiculata* seedlings on the upper shore (220 cm above CD). Plants on the lower shore received heavy barnacle settlements during the first 10 days, but settlement and population numbers (1000 or more individuals) stabilised after a month. On the upper shore, the number of settled barnacles over one month did not exceed 20, while the highest of 40 was obtained after two months; in all cases, the highest numbers were found on the lower part of the stem not exceeding 10 cm from the soil.

Although barnacles are tolerant of a wide range of salinities, the data on barnacle growth on mangrove seedlings and other surfaces (e.g. fish cage nettings), indicate that low salinity reduces infestation. This could be related to their reproductive requirement.

DAMAGE *(continued)*

Barnacle infestation of more than 30% cover on the leaf and the stem has a negative effect on the seedlings. The fouled plants appear unhealthy, e.g. bearing less leaves and leaves turning yellowish. Barnacle growth causes direct leaf damage if the larvae settle on the edge of small lacerations or pin holes on the leaf. The growth of the barnacles will soon break up the leaf (Plate 31). The hard and sharp plates of attached adult barnacles on the swaying leaf or stem could cut and damage the plant (Plate 32) if the wind or water current is strong. More common, the young plant is eventually weighed down by the increasingly heavy burden of barnacles (Plate 33). For instance, the load weight of barnacles could exceed six times the weight of the plant. Barnacle growth on the stem nodes obstructs new leaves from sprouting (Plate 34). If the leaf could sprout out between the crowded cover of barnacles, the leaf becomes twisted and deformed. Heavy barnacle growth on the lower part of the stem obstructs the growth of support roots thus weakening the support system of the young sapling.

CONTROL METHODS

One good way to reduce barnacle settlement and survival on newly planted seedlings is simply to plant them on higher ground. Planting mangrove seedlings at least two metres above CD is recommended so that they are not completely immersed during high neap water. Nevertheless, consideration in terms of mangrove plant species tolerance to immersion or emersion has to be met.

Any new innovative method vis-à-vis the conventional method (stake method) that could raise the planting 'height' of the seedlings could potentially reduce barnacle infestation. In this regard, seedlings planted on coir-logs or comp-pillows and raised to the height as suggested should be effective in reducing barnacle settlement, although cost-effectiveness is an important consideration. The conventional stake method but without a long stake to anchor the propagule may be equally effective against fouling because any "grooves" between stake and seedling provide safe places for the heaviest barnacle infestation. Free swaying of the mangrove saplings in a swift current field will reduce cypris settlement since it has been documented that larvae did not settle when the current speed exceeds 21 cm s^{-1} (Qian *et al*. 2000).

CONTROL METHODS *(continued)*

Within two weeks of barnacle settlement or attachment, a soft brush could be used to remove the young soft juveniles. The larger hard barnacles could be physically removed using a pair of forceps every 1–2 months interval. Although a tedious operation, the pickings will allow the young seedlings some respite and to grow quickly without any ill effects for the first few months.

Certain anti-fouling chemical agents may be considered but toxicity to mangrove seedlings and the environment must be completely evaluated before extensive use.

Plate 27 Heavy encrustations of striped barnacles on replanted mangrove seedlings.

Plate 28 *Balanus amphitrite*, diameter 10–15 mm, height 8–10 mm.

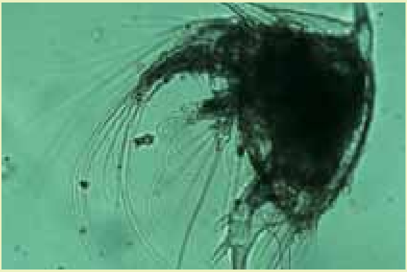

Plate 29 Nauplius larva of barnacle, 0.5 mm. Note characteristic frontal horns.

Plate 30 Settled cypris larva (length, 0.55 mm) resembling a small rice grain on mangrove leaf.

Plate 31 Young growing acorn barnacles breaking up mangrove leaf.

Plate 32 Leaf cut and split induced by sharp plate of acorn barnacle

Plate 33 Barnacle growth causes deformed stem of mangrove seedling.

Plate 34 Barnacle growth on the stem nodes obstructs new leaves from sprouting.

Euraphia withersi (Pilsbry, 1916)*, formerly Chthamalus withersi* Pilsbry, 1916

COMMON NAME	Whither's barnacle
CLASS, ORDER & FAMILY	Maxillipoda, Sessilia, Chthamalidae
DISTRIBUTION	Indo-West Pacific distribution
HABITAT	Whither's barnacles are found in similar habitats as the striped barnacles, but on the higher and drier regions of the substratum, usually between high- to mid-tide levels. They are found on coastal hard structures, river mouths and mangrove swamps. On mangrove seedlings and saplings, they are found more on the upper parts of the plant, on the adaxial leaf surface (top) and near the shoots.
BIOLOGY	Shell diameter of 7–13 mm, height 4–5 mm; 5–10 mm on mangrove saplings. The roughly oval body has a wavy outline formed by six flattened capitulum plates that have few, broadly jagged and ribbed bases (Plate 35). The dorsal opercular plates of the orifice are diamond-shaped. The suture lines of these plates are straight distinguishing it from *Chthamalus malayensis*, which are wavy.

BIOLOGY *(continued)*

Plate colour is brown, light grey to ash grey. Unlike *Balanus amphitrite*, which can settle and pile on top of each other, *E. withersi* settle close to but rarely on each other (Plate 36). The species is tolerant of salinity and turbidity fluctuations. Larval development of reported chthamaloids from nauplius to cypris stage just before settlement is about two weeks at 28°C (Yan & Chan, 2001).

DAMAGE

As generally described above but not as serious as *B. amphitrite* since *E. withersi* is smaller and lighter. The shell plates of the latter are less sharp.

CONTROL METHODS

As described above.

Plate 35 *Euraphia withersi*, diameter 5–10 mm.

Plate 36 Non-piling distribution of star barnacles on the upper leaf surface.

Littoraria scabra (Linnaeus, 1758)

COMMON NAME	Rough periwinkle
CLASS, ORDER & FAMILY	Gastropoda, Hypsogastropoda, Littorinidae
DISTRIBUTION	Wide distribution in tropical and subtropical areas, largely in the Indo-Pacific region from eastern Africa to Polynesia, including northern Australia and southern Japan.
HABITAT	Lives on the lower trunk of mangrove tree and its prop roots, as well as on the leaves (up to 2 m above soil). On replanted mangrove propagules and saplings (30 cm to 1 m height), the snail is observed on the roots (above mud), stems and leaves, as well as on attached barnacles.
BIOLOGY	Shell height 25–35 mm, ribbed, with strong peripheral keel, colour pale with dark brown or black oblique axial stripes (Plate 37). Sexually dimorphic, males being smaller with lower spire and larger aperture (Reid, 1986). Snails of the genus *Littoraria* occur on mangrove trees, and show both vertical and horizontal patterns of zonation that result from their behavioural responses and physiological tolerance (Reid, 1986). Both *Littoraria scabra* and *L. melanostoma* are mainly found on the seaward edge of mangrove forests (Berry, 1972).

BIOLOGY *(continued)*

The snail moves up the tree to avoid flood water and predation, and downward during ebb tide to feed. It is a generalist herbivore, feeding preferentially on microalgae and bacteria, but easily shifts its diet by feeding on a variety of foods such as leafy macrophytes, filamentous algae, mangrove tissues and even zooplankton (Alfaro, 2008). The snail is ovoviviparous; eggs developed within the mantle cavity and released at the late veliger stage.

DAMAGE

No serious outbreak of snail damage has been observed, although snails are reported to graze on mangrove bark and leaves. Load burden may damage delicate stems due to large snail aggregations (Plate 38).

CONTROL METHODS

Disposal by hand.

Plate 37 *Littoraria scabra*, height 10 mm.

Plate 38 Large aggregation of *L. scabra* on top of planted stake.

Littoraria melanostoma (Gray, 1839)

COMMON NAME	Black-mouth mangrove periwinkle
CLASS, ORDER & FAMILY	Gastropoda, Hypsogastropoda, Littorinidae
DISTRIBUTION	Tropical and subtropical region from east India to Southeast Asia, southern China and Taiwan.
HABITAT	The snail occurs mainly at the lower level of mangrove tree trunks up to 2 m above soil, staying above the high tide level. Juveniles occur mainly on leaves. On mangrove propagules and saplings, the snail is found in the same regions as *L. scabra*.
BIOLOGY	Shell height 20–30 cm, spire tall with straight outline, colour pale yellow with brown or gray dots arranged in spiral pattern (Plate 39). Shell opening pale yellow with black patch. During the day, it is inactive, but during night, it crawls downwards. The snail is a generalist grazer, ingesting mangrove bark, epidermal plant cells, fungi, microalgae and cyanobacteria (Lee *et al*. 2001). The snail apparently releases egg capsules into the sea every two weeks during the spring tides.

DAMAGE Grazing damage unknown. Load burden to young plants may occur.

CONTROL METHODS Manual disposal.

Plate 39 *Littoraria melanostoma*, height 15 mm. Note dark patch on the edge of the shell opening.

Plate 40 *L. melanostoma* on terminal leaf of mangrove seedling. Note a hole on the leave.

Xenostrobus mangle Ockelmann, 1983

COMMON NAME	Small black mussel
CLASS, ORDER & FAMILY	Bivalvia, Mytiloida, Mytilidae
DISTRIBUTION	Based on described materials, the species has been recorded from Malaysia and Thailand. The type-locality or site of collection of the holotype is Jeram, Klang, west coast of Peninsular Malaysia (Ockelmann, 1983).
HABITAT	An epifauna that uses its fine byssus threads to attach itself onto hard substrates such as stones, concrete boulders, pilings, mangrove trees and cage fish nettings. In young mangrove saplings, this small mytilid mussel is observed to grow amongst the thick growth of barnacles (see Plate 41).
BIOLOGY	The thin shell of the adult is dark violet to bluish-black (Plate 42), while the juvenile shell has a brownish coloration. A maximum size of 13.1 mm x 7.4 mm x 5.5 mm was observed (Ockelmann, 1983). Sexes are separate, with individuals reaching sexual maturity at 2–3 mm shell length. Larval development is planktotrophic, and developed spats settle gregariously amongst adults.

DAMAGE

Amassed mussels increased the load burden on the young mangrove seedling, as well as prevent new leaves and roots from sprouting.

CONTROL METHODS

The byssus threads of the mussel are very strongly attached to the stem or barnacle mass. Manual removal (together with barnacle mass) without plant damage is possible but tedious.

Plate 41 The small black mussel, *Xenostrobus mangle*, growing amongst acorn barnacles.

Plate 42 Detached *Xenostrobus mangle* showing characteristic hinged bivalves, length 10 mm.

Vertebrate Pests

Macaques

Long-tailed macaques or crab-eating macaques, *Macaca fascicularis* (Primates: Cercopithecidae) are widely distributed throughout Southeast Asia and are common inhabitants of tropical rainforests, mangrove forests and plantations (Plate 44). In the wild, they often forage in groups and feed on leaves, fruits, crabs and insects. Long-tailed macaques are also known to cause damage to property as well as crops. They are opportunists as they often forage near human habitats.

In Byram Forest Reserve, Penang, planted *Rhizophora* seedlings were damaged by long-tailed macaques which fed on the shoots of seedlings (Plate 43). Seedlings planted alongside roads adjacent to oil palm plantations were usually more prone to damage by macaques. The problem has not been observed in areas where seedlings were planted directly on mudflats and at the sea front.

Plate 43 Broken shoots caused by resident long-tailed macaques in Byram, (Penang).

Plate 44 A long-tailed macaque in a mangrove forest.

Cattle/Livestock

Casuarina equisetifolia seedlings planted on sandy beaches on the east coast of Peninsular Malaysia, were damaged by livestock (cows and goats) from nearby settlements. The same was observed to happen in Kerteh (Terengganu) and Pantai Mek Mas (Kelantan). In Perlis and Pahang, seedlings were protected from strong winds and grazing animals by wind-break nettings and fences (Plate 45–46).

Local awareness on the importance of replanting mangroves is important. Coastal land use affects the livelihood of coastal communities, thus participation or prior consent from villagers can ensure support and cooperation in mangrove replanting projects and may help reduce vandalism and livestock grazing on plantings.

Plate 45 Fenced-up casuarina seedlings in Pantai Bukit Batu Putih (Perlis).

Plate 46 Fence surrounding a new site, ready to be planted with casuarinas in a beach front in Pahang.

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Glossary

No.	Term	Definition
1	Abscise	Shedding of leaves.
2	Brood	Sac-like pouch containing eggs.
3	Byssus	Bunch of strong protein threads secreted by bivalves for attachment.
4	Calcareous	Made of calcium carbonate material.
5	Capitulum	Major part of the body containing only the head and thorax.
6	Chart datum	Commonly referring to the mean lower low water or lowest astronomical tide.
7	Chthamaloids	Small barnacles belonging to the genus *Chthamalus*.
8	Coir-log	Interwoven coconut fibres bound together with biodegradable nettings in the form of a log.
9	Comp-pillows	Pillow-shape planting structures using coir-log materials.
10	Dimorphic	Two different forms of one sex.
11	Dorso-ventral	Back and front part of the body.
12	Ebb tide	Tide that recedes after high water.
13	Emulsion	A stable mixture of two or more liquids.
14	Entomopathogenic	A fungus that can parasitise and kill insects.

No.	Term	Definition
15	Euryhaline	Adaptable to a wide range of salinity.
16	Eurythermal	Adaptable to a wide range of temperature.
17	Frass	Sawdust and excrement left by wood-boring insects.
18	Geotube	A large polypropylene or polyethylene tube filled with suitable heavy materials (e.g. sand).
19	Grapsid	Those belonging to the Grapsidae family of crabs.
20	Guild	Group of insects with similar feeding behaviour.
21	Hermaphroditic	Containing both male and female sexual organs.
22	Larva/larvae (pl.)	The immature stage of an insect / caterpillar.
23	Maxillipodan	Belonging to a group of small crustaceans with short abdomen, feeding usually with their maxillae.
24	Mesophyll	Layer of leaf tissue between upper and lower epidermis of a leaf.
25	Mytilid	Bivalves belonging to the genus *Mytilus* or related species.

No.	Term	Definition
26	Neap water	Occurring about every two weeks when the moon is either at the first- or third-quarter phase.
27	Ovipositor	An egg-laying organ in the female adult.
28	Planktotrophic	Feeding on plankton (drifting small organisms in the water).
29	Propagule	Fruits of mangrove trees from the family Rhizophoraceae.
30	Pupa/pupae (pl.)	Non-feeding stage in the lifecycle of an insect.
31	Riprap	Any large block of material used to protect coastal structures.
32	Serpentine	Resembling snakelike pattern.
33	Spats	Young of bivalve molluscs.
34	Spiracle	Small openings on the body that are part of the ventilatory system.
35	Spire	Pointed structure on the shell's apex.
36	Substratum	Base to which organism is attached.
37	Veliger	Second stage of development of certain molluscs.

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