

Fish Habitat Guideline FHG 004

**Mangrove nurseries:
Construction, propagation and planting**

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See also the Fish Habitat Management Operational Policy Series and Fish Habitat Codes of Practice Series.

These guidelines provide a technical information base to assist in the design, establishment and construction of a mangrove nursery, propagation techniques for selected mangrove species, and the planting out of mangroves. Development of these guidelines has been in response to a demand for information on Fisheries requirements for the running of a mangrove nursery and the undertaking of restoration works involving mangroves from natural resource managers, local government, developers, community groups and conservation agencies.

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Executive summary

Fisheries legislation in Queensland (*Fisheries Act 1994*) provides several mechanisms to manage fish habitats. These include providing for the protection of all marine plants¹ the declaration of Fish Habitat Areas² and the restoration of fish habitat(s).

Restoration of fish habitat may be directed by the Queensland Fisheries Service (QFS), Department of Primary Industries, under the provisions of the *Fisheries Act 1994* (Sections 124 and 125), which deal specifically with restoration. Restoration of fish habitats may also occur as a community, industry or government project.

This document, Fish Habitat Guidelines 004 (FHG 004), supports the marine wetland restoration process. These guidelines provide instruction on the design and establishment of a marine plant (specifically mangrove) nursery; outline specific growth characteristics of selected mangrove species; provide details of the impacts of pruning trials on nursery stock; and describe trial restoration methods for tidal fish habitats by selective use of nursery-reared mangrove stock.

The guidelines are based on the outcomes of a mangrove nursery project that was funded through various sources including the Queensland Fisheries Service, Natural Heritage Trust and mangrove permit mitigation. The mangrove nursery project evolved out of a perceived need to document specific mangrove growth rates and their reaction to various treatments.

The information used in FHG 004 is based on the outcomes of a QFS Natural Heritage Trust Project³. This project documented specific mangrove growth rates and their reaction to various treatments. The purpose of the project was to assist fish habitat management decisions and has contributed to the successful restoration of several degraded wetland areas. The main outcomes of the project included:

1. The documentation of growth conditions conducive to raising selected mangrove species in a nursery environment.
2. The documentation of the effects of pruning on regrowth rates in different mangrove species at different times of the year.
3. The provision of stock to wetland restoration projects and the documentation of their progress.
4. The provision of practical advice for groups intending to restore tidal wetlands.

Flowing from outcome 4 above, FHG 004 was formulated. It is envisaged that these guidelines will provide direction for community, industry and stakeholder

¹ Marine plants include mangroves, seagrasses, saltmarsh plants and algae.

² Fish Habitat Areas are declared under the *Fisheries Act 1994* over core areas of high value fish habitat.

³ The project was entitled “Investigation of Techniques to Improve Wetland Rehabilitation”.

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groups to enhance fish habitats and thereby fisheries productivity, in the following ways:

- (i) By describing the design and establishment of a mangrove nursery and its operating requirements.
- (ii) By outlining propagation and specific growth characteristics, including the effects of pruning, of selected mangrove species.
- (iii) By describing procedures for restoration of tidal fish habitats by selective use of nursery-reared mangrove stock ;
- (iv) By outlining the legal requirements and procedures for undertaking mangrove restoration and nursery propagation works.

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We would also like to thank Dr Barry Clough and Otto Delhouse of the Australian Institute of Marine Science for their advice in setting up the Queensland Fisheries Service Mangrove Nursery at Cairns, and the Natural Heritage Trust for funding assistance.

Please note that collection or propagation of marine plants, including seeds or cuttings, requires a Marine Plant Permit under Section 51 of the *Fisheries Act 1994* before any collection or propagation activities may take place. Establishment of a facility to commercially cultivate marine plants may only be undertaken by the authority of an Aquaculture Licence issued under the Act. Contact the Department of Primary Industries Call Centre (Tel:13 25 23) or your nearest DPI office for further information about obtaining permits and licences.

1.0 Introduction

Mangroves are known to provide important nursery, breeding and foraging grounds, and structural habitat [Alongi, 1998] for shelter from predators for mollusc, prawn, crab and fish species important to commercial, recreational and indigenous fisheries. Mangroves also have a role in improving water quality by removing nutrients from storm water (Langford and Mockeridge 1995) and controlling erosion from flooding and storm surge.

In recognition of the role of mangroves in fisheries productivity, the Department of Primary Industries Queensland Fisheries Service (QFS) is responsible for the management and protection of marine plants, including mangroves, under the *Fisheries Act 1994*. The Act prohibits the removal of mangroves unless a Marine Plant Permit has been issued.

While legislation and policy contribute to the protection and healthy functioning of mangroves and the associated fisheries, degradation of these fish habitats may still occur. Mangroves may be impacted through illegal clearing activities and inappropriate land use. This is in addition to the legal, but unavoidable, loss brought about through the issuing of permits for mangroves to be removed for public infrastructure or limited private development purposes.

The QFS has a lead agency role in advising how mangrove damage can be avoided, minimised or reversed where possible. The mangrove nursery evolved out of the need to improve this advice. In 1997, the Department of Primary Industries, Northern Fisheries Centre established a mangrove nursery to provide stock for the restoration of degraded tidal fish habitat, and to study specific mangrove growth characteristics. The plan was to use the outcomes of the mangrove nursery project to develop a set of fish habitat guidelines for mangrove nursery design, establishment and operation, and the use of nursery stock for restoration projects.

Nursery techniques were developed by applying standard propagation and rearing methods for terrestrial plants and using information from the Australian Institute of Marine Sciences (AIMS).

These guidelines can be applied to establish a reticulated or flow-through saltwater nursery using the Northern Fisheries Centre nursery as a model and provide information on tidal fish habitat restoration methods using mangroves. They will assist community groups or agencies that are interested in becoming involved in the restoration of marine fish habitats.

2.0 Mangrove nursery construction

The major components of a mangrove nursery⁴ are:

1. mechanisms to allow periodic inundation;
2. access to good quality salt and fresh water;
3. pumps for aeration and circulation of the water through the ponds;
4. power source;
5. shade regulation and;
6. good quality propagation stock.

2.1 Site selection

Ideally, the mangrove nursery should be sited in close proximity to tidal waters near good quality water and close to the intended restoration site to reduce pumping and transport costs. Adjacent land use should be considered for potential impact on the nursery and its operations.

2.2 Nursery ponds

The Cairns QFS nursery consisted of six ponds and was located on a one hectare cleared and gravelled area (Figure 1) at latitude 17° S. Each pond was 5.5 m by 2.3 m by 0.5 m deep with a 6.5 m³ capacity (for 4500 plants in 100 millilitre pots). Pond walls were constructed using 190 mm by 390 mm by 190 mm cement (*Besser*TM) blocks (76 blocks per pond).

Blocks were laid two courses high with each block filled with crusher dust to add stability and to protect the plastic liners from sharp edges of brickwork. Pond beds were laid on a foundation of crusher dust and river sand levelled to a 5° gradient towards the sump pumps. The gradient ensured efficient drainage of salt water to the sump pumps to avoid waterlogging of plant stock.

The ponds were lined with fibre-reinforced plastic (*Canvacon*TM), available in 4 m widths only. Two pieces were welded together to provide the required size for lining the ponds. *Canvacon*TM is UV stable and able to withstand nursery conditions for three years without breaking or tearing. Any durable UV stable plastic could be used for this purpose. The plastic should be at least 1 mm thick to withstand foot traffic while moving plants. The use of plastic liners also prevents loss of water through seepage, and contamination of the ground with sea water, and may also prevent problems with burrowing animals and other pests.

2.3 Shade

Three of the ponds were located under a 30% shade mesh structure (10 m by 5 m) to protect light-sensitive mangrove seedlings (e.g. *Bruguiera* species). The shade cloth was spread 2 m above the pond beds. Three other ponds

⁴ These guidelines describe the setting up of a mangrove nursery, based on experiences gained during the construction and maintenance of the Cairns QFS mangrove nursery. Local modification or further experimentation may be required, depending on the nature of the project being undertaken, site characteristics, number and type of mangroves required and production targets.

were located in full sun and contained seedlings and sun-hardened saplings of other species on trial (e.g. *Avicennia*, *Rhizophora* and *Ceriops* species). As the mangroves grow, shade requirements may vary. It is important to 'harden' plants before planting out by gradually increasing their daily exposure to the sun, to match the conditions at the planting out area. This is done prior to moving the seedlings to avoid heat stress on the plants.

2.4 Water reservoirs

Three 5000-litre fibreglass water reservoirs adjacent to the nursery ponds stored salt water (filtered to remove sediments) collected from the Trinity Inlet nearby. This seawater storage capacity was calculated to satisfy the pond area. Changes to pond size would require adjustments to the volume of water required. Flow-through systems are discussed in Section 2.7.

Water storage structures would not be required if salt water can be pumped directly to the ponds. In this case project funding did not permit the installation of pipe work from Trinity Inlet to the nursery. Nevertheless, an isolated water supply provided water quality control and can be used to regulate additional nutrients.

2.5 Pumps

Nursery pumps supplying the nursery ponds were connected to a 12-volt timer system. Two *Onga*™ 443 (constant pressure switch) pumps were used to pump the salt water into the ponds while 12-volt bilge pumps (*Rule*™) (800 gal/hr and 1100 gal/hr) were used to remove water from the ponds and recycle it to the reservoirs. Artificial tidal inundation was delivered through PVC pressure pipe of 25 mm diameter.

The bilge (or sump) pumps were installed in the corner of each pond within small depressions (Figure 1) to maximise water circulation and recycling. The sump pumps were connected to a timer system set to simulate local tidal cycles.

To minimise the risk of pump failure it is important to strictly maintain the filters within the sumps. This is particularly important immediately after pots containing new seedlings are added to the ponds as uncompacted sediments drift out of the pots. Sump depressions should also be kept clean, as soil escaping from pots can accumulate in these depressions.

2.6 Reticulated system

2.6.1 Simulated tidal regime

A simulated tidal regime was established using a system of pumps and timers to create inundation conditions similar to that of a natural mangrove environment. A time switch (MicroRex QT11™) was installed in a fuse box adjacent to the pumps and reservoirs and three timers were connected to the 6 *Rule*™ pumps. The switches were set to provide tide movements and regulate the frequency and volume of water moving in and out of the ponds.

A range of equipment for establishing a periodic inundation system is readily available. Advice should be sought from a nursery or pump supplier on the

type best suited to the proposed nursery layout, local conditions, operation and maintenance of the selected equipment.

All species were inundated for the same period each day although each pond filled at different times (one hour apart). The timers were set for the same times every day, filling and draining as per the regime outlined at 'Watering regime' in section 3 of these Guidelines.

The reticulated system chosen for the QFS nursery reflected site and financial constraints (i.e. distance from salt water and cost of installing piping). This system is likely to be more costly to establish and operate than a flow-through system but assists water quality management.

2.6.2 Water

Good quality salt and fresh water is important for optimum mangrove growth and to manage salinity levels.

Salt water was delivered by truck from Trinity Inlet to the QFS mangrove nursery reservoirs approximately three times per year. The salinity levels of sea water from Trinity Inlet averaged 33–35 ppt, depending on rainfall and flooding. The salt water supplied was diluted to a salinity of 17 ppt (approximately 50% salt water to 50% fresh water) following Clough's (1984) finding that salinities of 17 ppt optimise the growth of mangrove species within a nursery environment. Salinities were measured with a hand-held probe style pH-conductivity-salinity-temperature meter (*TPS*TM Model MC-81).

Although rainfall and evaporation processes influenced salinity levels in the ponds relatively constant salinity levels were maintained. Salinity was measured weekly and salt/fresh water added to adjust and maintain the salinity at 17 ppt. Fresh water was introduced during dry periods of high evaporation (i.e. August to November) and salt water was introduced during the wet season (December to March). It proved too difficult to maintain constant salinities during cyclonic rainfall events.

2.7 Flow-through system

A flow-through system would operate in a similar way to a reticulated system. Instead of pumping back to a tank, however, water would be discharged to the environment and not reused. Water would be brought in by pressure pump from a water source (creek, river or ocean) and pumped or gravity-fed back to the point of discharge. The pressure pump could be activated by a timer and cut off through the use of float switches similar to the reticulated system.

The flow-through system, if available, would avoid many of the problems associated with recycling water i.e. salinity fluctuations from evaporation and rain, a need for return pumps, potential high nutrient levels of stored water and vector control. However, natural fluctuations in the salinity of ambient sea water from rainfall and runoff may impact on the nursery requirements required for optimal growth and development of the mangroves.

The pond and plumbing design of this system would be almost identical to that of the reticulated system except tanks would not be required.

When planning to use either a flow-through or reticulated system, QFS advises that the proposed system be discussed with the Environmental Protection Agency prior to construction to check whether any approvals (e.g. Discharge Licence) are required.

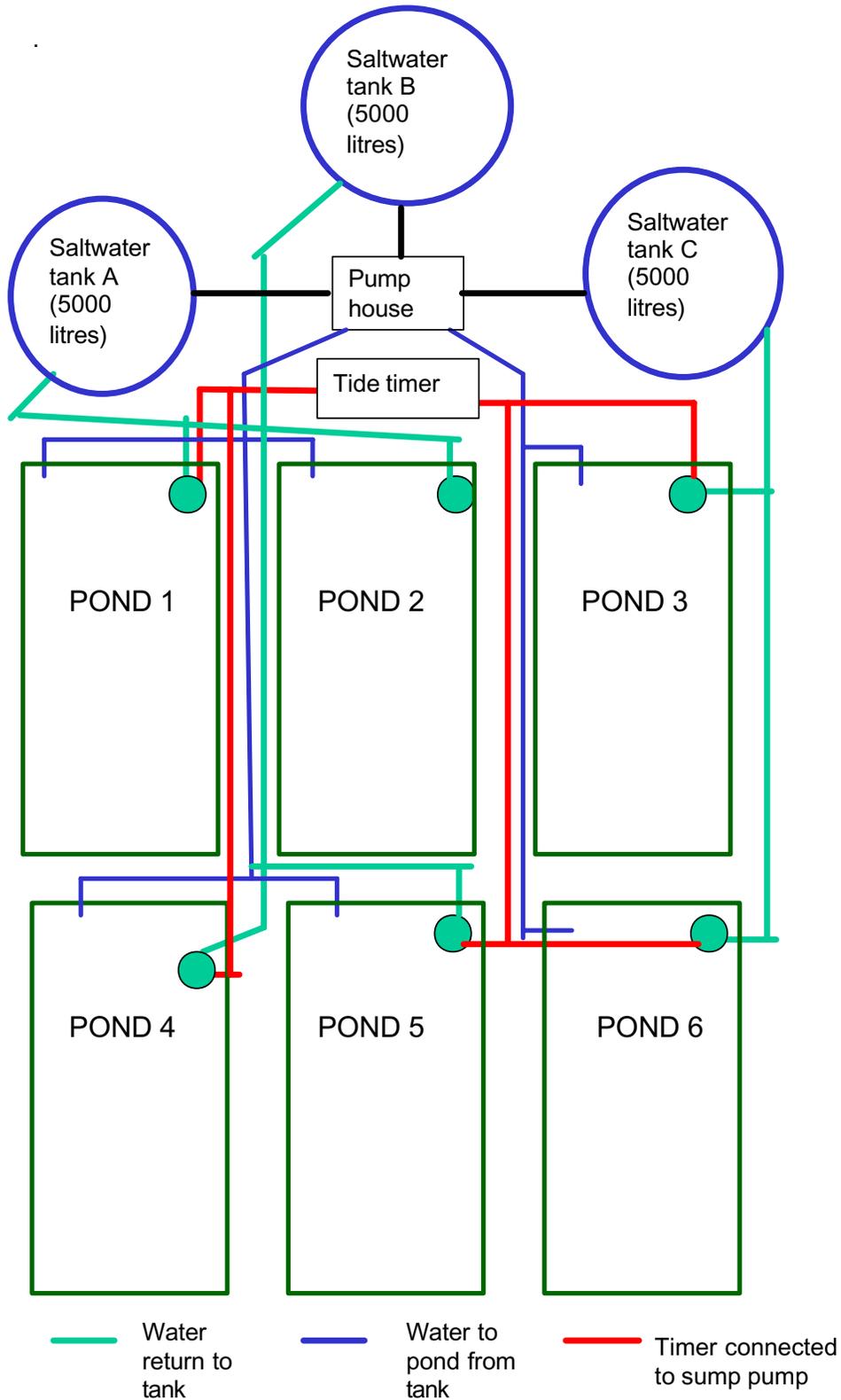
2.8 Pipes

Nursery plumbing consisted of 25 mm and 15 mm diameter PVC pressure pipes. The 25 mm pipe was used for moving the water from the reservoirs to the ponds while the 15 mm pipe was for the return to the reservoirs. Pipes were laid in 300 mm trenches around the ponds and covered by soil to reduce damage and minimise water temperature fluctuations during water transfer. The piping was designed to isolate certain ponds so that ponds could be operated independently (Figure 1).

2.9 Wiring

The nursery was supplied with a 240-volt electrical current. A fuse box containing timers and power points was erected adjacent to the tanks and ponds. This supply activated all of the pumps through a *MicroRex*™ QT11 tidal simulation timer. The incorporation of a 12-volt system seemed appropriate from a safety perspective (i.e. water and power don't mix) but was also problematical (high maintenance).

Figure 1. Nursery layout



3.0 Mangrove propagation

3.1 Location

For logistical reasons it is easier to grow propagules at or near the site identified for planting. Growing plants in similar environmental conditions to the final planting site also appears to minimise mortality rates.

3.2 Soils

When fully operational the NFC nursery held a maximum of 4500 mangrove plants in 100 mm pots in the six ponds. An estimated 10m³ of growing medium was required to fill 4500 pots. The growth medium consisted of 50% sand and 50% peat (based on recommendations from AIMS and nursery suppliers) and was purchased from a local nursery supplier. Fine mesh (i.e. flyscreen mesh) was placed at the base of the pots over the drainage holes to reduce the loss of fine sediments.

3.3 Watering regime

Saltwater inundated the ponds to a depth of approximately 20 cm twice each day and was kept at that level for approximately six hours each time. The watering regime was:

1. At 10am and 10pm the pressure pumps (Onga™) would start to fill the ponds and continue to fill for about 2 ½ hours.
2. Once the ponds reached the required level (covering the soil in the pots to approximately 20 cm), a float-operated switch in the pond was activated to automatically stop the pressure pumps. The float switch is critical to the operation of the ponds to prevent overflow.
3. At 2pm and 2am the ponds would begin to drain via the Rule™ pump (set on a timer) taking between 3–4 hours to return all the water back to the reservoirs.

The artificial tidal regime was fixed and did not progress the standard of approximately one hour each day with each high tide as occurs in the natural environment. It is not known if this artificial, fixed tidal regime had any effect on growth or survival rates.

3.4 Species selection

Species selection will depend on the nature of the restoration work to be undertaken and the characteristics of the site from which the propagules will be collected. QFS officers should be consulted prior to collection for technical and statutory advice.

For the QFS nursery, propagules of nine species of mangroves available locally (Caïms) were collected for propagation and rearing. Species were selected based on their ready availability, relatively wide distribution, capacity to act as colonisers of tidal lands, and ease of collection.

Note that Queensland Fisheries Service policy regarding propagule stipulates the collection of mangrove propagules should not exceed 10% of the actual annual yield in any one catchment nor should propagules be collected for

transplanting further than 100 km from the transplanting site due to potential impact on the local mangrove gene pool. Propagule collection levels for different species of mangrove are set subject to the seed production levels of each species.

3.5 Propagules

3.5.1 Collection

Propagules for the QFS mangrove nursery were collected (under a Fisheries Act authority issued to the Department) using dinghies and by hand from mangrove boardwalks, local beaches and boat ramps. Collection occurred at various locations along the far north Queensland coast, including Trinity Inlet, Barron River, Mourilyan Harbour and Maria Creek.

Different species of mangroves were collected depending on seasonal availability in north Queensland (refer Table 1). For assistance in identifying mangrove propagules refer to Lovelock (1993).

Collection occurred from the Highest Astronomical Tide (HAT) area and propagules collected often had roots clearly visible, e.g. *Avicennia*, or had first leaflets forming, e.g. *Rhizophora*.

It is important to gather propagules in good condition that are relatively unblemished to increase successful germination. Signs of a viable propagule include fullness of shape, intactness, and characteristic even colour. Propagules with visible physical damage, e.g. from crabs or from tidal wash, should be rejected. Signs of non-viability include withering, desiccation, parts missing or holes made by either crabs or larvae or as a result of wave action. In this study, germination rates for propagules collected after long exposure to sun (i.e. lying at High-Water Mark) were typically very poor.

3.5.2 Storage

Care should be taken with dry storage of certain propagules as borers can hatch under these conditions and irreversibly damage the seed. Caution should also be shown when storing propagules in plastic. Certain species of insect larvae will chew through plastic containers (Foster pers comm). Propagules may be attacked any time from flowering to after propagule formation. For optimal germination immediate propagation is recommended.

Considerable germination success was achieved with refrigerated storage of propagules or by leaving the propagules in buckets of fresh water until ready to plant. Treatment with a prophylactic to prevent insect attack was not undertaken.

3.5.3 Soaking and husk removal

Results from QFS trials indicated that propagules immersed in fresh water for 3-7 days enhanced germination. Soaking grey mangrove (*Avicennia marina*) seed in fresh water caused the outer sheath to split. This appeared to enhance the germination rate by about 50%. Soaking should occur in shade and in temperatures of less than 25 degrees Celsius to reduce the risk of fermentation. The *Avicennia* sheath should be removed prior to planting.

Rhizophora species can be planted without soaking with successful germination results.

Clough (pers comm, January 1997) advised that germination rates were improved in *Heritiera* species if the propagules were soaked in fresh water for between one and two weeks and the husk split off by hand prior to planting.

3.6 Potting

During the QFS nursery trials two separate procedures were followed for potting of the mangroves. The 160 propagules of the species assigned to the pilot pruning research project (see Appendix 1) were potted into the sand/peat mix in 200 mm diameter plastic pots as per the methodology outlined in Field *et al* (1996). Propagules collected for restoration purposes were potted into 100 mm plastic pots to conserve nursery space and maximise the total number of plants. For better root establishment or if the plants are to be held for an extended period (e.g. longer than six months) it is recommended that 200 mm pots be used.

As seedlings were removed from the QFS Nursery for various restoration projects and space increased, new seedlings were repotted into 200 mm pots (as per Field *et al*).

Strategies for stopping seeds floating out of the potting mixture include spearing the cigar-shaped propagules (e.g. *Rhizophora* spp., *Bruguiera* spp.) at least half way into the soil. Grey mangrove (*Avicennia marina*) seeds were germinated in a propagation tray containing 100% sand until four leaves were visible. They were then potted into 200 mm pots.

3.7 Fertilising

Mangroves grown in a nursery environment require fertilisation at approximately six months of age to maintain healthy growth and replace the 'food reserves' of the propagules. *Fish Emulsion*[™] (N 9%: P 2%: K 6%) can be applied at a dosage rate of one part fertiliser to 100 parts water in an 8 litre bucket every three months. Further fertilizer application advice can be obtained from a local nursery supplier and by checking the manufacturer's recommendations. This fertilizing protocol worked adequately for the QFS nursery.

Clough *et al* (1984) recommends a more specific fertiliser nutrient composition to optimise mangrove growth in a nursery environment.

3.8 Vector control

Within a mangrove nursery, brackish conditions may provide an opportunity for mosquitoes to breed. As mosquitoes pose a public health and safety issue, mosquito breeding in the QFS nursery was prevented by incorporating certain precautionary measures.

The outlets and lids of the reservoirs were completely covered with very fine fly screen to reduce mosquito larvae being introduced into the reservoir water.

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Fine filter socks in tank inlets collected mosquito larvae. Sump pumps were covered with mesh netting to prevent mosquitoes from breeding in the sump depressions after the ponds were drained. Netting also reduced the amount of suspended potting media that could clog the pumps and interfere with flow rates. Constant monitoring of the pond water during the wet season is recommended to control mosquito larvae outbreaks.



Plate 1. Northern Fisheries Centre (QFS) Mangrove Nursery



Plate 2. Seedlings for restoration, Cairns QFS nursery



Plate 3. Saltwater Reservoir tanks (5000 litre), Cairns QFS nursery



Plate 4. Mangrove trimming experimental pond, Cairns QFS nursery



Plate 5. Mangrove propagules in 100mm plastic pots, Cairns QFS nursery



Plate 6. Trimming mangroves, Cairns QFS nursery



Plate 7. High school students planting *Ceriops* seedlings at the Powerlink restoration site, Cairns.



Plate 8. High school students measure height and girth of mangroves, Powerlink restoration site, Cairns

3.9 Plant disease control

No explicit methods were used to prevent disease entry or disease control within the QFS mangrove nursery, although its relative isolation, (i.e. being located in the middle of one hectare of cleared and gravelled area) may have contributed to the absence of signs of disease. Mangroves are known to be susceptible to the fungus *Phytophthora/Halophytophthora* [Pegg and Forsberg, 1982]. Advice on plant diseases can be sought through DPI Animal and Plant Health Service or a local plant nursery.

3.10 Plant pest control

Herbivory is a major threat to successful mangrove propagation in an open nursery environment. Compared with the natural environment relatively few insect predators exist, making nursery conditions favourable for insect attack. Insects that attacked the mangrove seedlings at the QFS nursery included:

- The *Hypersilia* moth fed on mangrove leaves (particularly *Rhizophora* spp.) and has the potential to significantly reduce leaf mass, e.g. by 50% in a week (pers comm, Foster).

Prevention: TM*Otto (White)* or TM*Cheryl* are broad-scale pesticides that can be used to reduce plant pest numbers. These products should be applied according to directions.

NB. Given the relatively small numbers of plants at the QFS nursery, the most effective way of disposing of these pests was removal by hand.

- Borer species (identified as *Hypersilia robusta* Mahogany shoot borer – Horack *pers comm* CSIRO Entymology) often infested *Xylocarpus* species. Eggs are laid in the flowers of the tree and remain within the seed during germination.

Prevention: Prevention of infestation was almost impossible. However, by collecting propagules as soon as possible during the fruiting period then soaking them for at least one week in fresh water before planting, borer hatching may be prevented or reduced. Spraying of targeted seed mangroves at flowering may reduce the level of borer attack.

3.11 Short-term propagation

There may be occasions where greater numbers of propagules must be collected for revegetation of a large area within a short period of time.

Large numbers of *Rhizophora* or *Brugiera* species propagules that are to be kept for a short period of time prior to planting out can be propagated using polystyrene boxes filled with the growth medium and planted 10 cm apart. Overhead freshwater irrigation of the boxes every two to four days is a successful strategy for this method of mass planting in the short term.

Propagules reared in this way, reached an average height of 20 to 30 cm (a period of 4 to 12 weeks) before being used for restoration works. This technique has also been used successfully in South East Asia where space for propagating mangroves for restoration works can be limited.

For more information on mangrove nursery methodologies refer to:

- Field et al (1996)
- Siddiqi et al (1993)
- Clough (1984)
- Heylar (1980)

A full reference listing is provided in the Bibliography of this document.

4.0 Restoration procedures using nursery stock

This section describes the specifics of planting nursery-grown mangroves into the field. It should be read in conjunction with Fish Habitat Guideline *Restoration of Fish Habitats – Fisheries Guidelines for Marine Areas (FHG 002)* that describes general procedures for restoring degraded marine fish habitats.

Revegetation of degraded fish habitats may be beneficial for fisheries productivity and coastal stabilisation particularly where there is little natural seed stock in the region or where the degraded area is large. Artificial revegetation may also be appropriate in urgent situations where a site has been disturbed and erosion is occurring or threatens the integrity of adjacent marine plant communities.

Allowing unassisted revegetation through natural recolonisation may often be the most effective way of restoring a site. Natural recolonisation is most effective where there is a suitable accessible seed bank in the vicinity of the degraded area, the degrading impacts have been removed and where the contours and hydrology of the site have been restored.

4.1 Timing of propagation

Choosing which species to propagate in the nursery essentially depends on the proposed restoration location and the known colonisation capacity of each species. Table 1 indicates the various mangrove species that were propagated at the QFS nursery and their fruiting season (collection period) for northern Queensland.

Table 1. Mangrove species fruiting period (collection time).

Common name	Species name	Fruiting period
Grey mangrove	<i>Avicennia marina</i>	Feb to March
Cannonball mangrove	<i>Xylocarpus granatum</i>	June to Sept
Cedar mangrove	<i>Xylocarpus mekongensis</i>	Dec to Feb
Red mangrove	<i>Rhizophora species</i>	All year
Small-leafed orange mangrove	<i>Bruguiera parviflora</i>	Jan to Feb
Large-leafed orange mangrove	<i>Bruguiera gymnorhiza</i>	Apr–July
Yellow mangrove	<i>Ceriops australis</i>	Dec–May
Looking glass mangrove	<i>Heritiera littoralis</i>	Dec–March

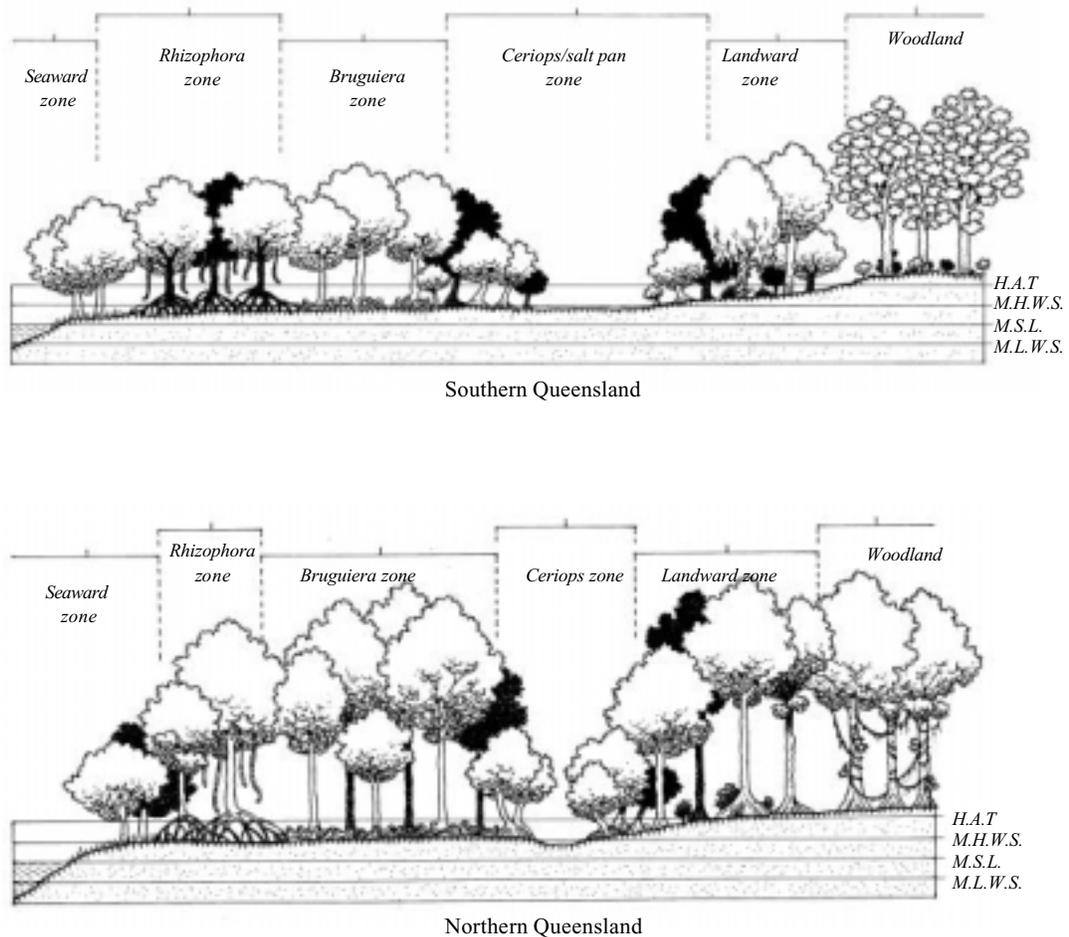
4.2 Species selection

Revegetation species should be selected on their ability to withstand the prevailing environmental conditions of the restoration site, particularly if the site is bare at time of planting. For example, *Avicennia* spp. and *Rhizophora* spp. are recognised as primary colonisers (pioneering species) while other species only colonise as the primary community establishes (e.g. *Bruguiera* spp.).

The position in the tidal range for which the plants are destined should also be taken into account. Adjacent mangrove communities should be assessed to determine the species distribution along the tidal range.

Figure 2. Zonation of mangroves.

Redrawn (P. Lennon, 2002) from *Mangroves of Australia*, Lear & Turner 1977 (Queensland University Press). Tidal level abbreviations: Highest Astronomical Tide (H.A.T.); Mean High Water Springs (M.H.W.S.); Mean Sea Level (M.S.L.); Mean Low Water Springs (M.L.W.S.).



The tidal character of the proposed planting site should also be taken into account to increase the success rate of restoration. If the site is at the outer edge of the mangrove fringe along a foreshore, then the use of appropriate pioneering species (e.g. *Avicennia* spp. and *Rhizophora* spp.) that are most likely to be able to sustain higher tidal inundation is recommended. If the area

to be planted is a disturbance path through the tidal profile (e.g. a transect from the foreshore to the landward edge of the mangrove area), then a variety of species according to their typical occurrence in the tidal range is recommended. A typical zonation arrangement for mangroves in north eastern Australia is shown in Figure 2.

4.3 Planting out

The QFS trials demonstrated that mangroves can be successfully planted out at any stage from propagule to seedlings up to three years old. Replanting success can be expected as long as both the plant and the site are in reasonable condition and the change from the nursery environment is not extreme in terms of light, salinity, temperature or hydrological conditions. Where there is a marked difference in any or all of the above conditions then a period of at least one month for gradual acclimatisation is recommended.

Planting out should coincide with the dormant season for the species — June to July in North Queensland (pers comm, N Duke). Generally, flowering and fruiting of mangroves (plant growth activity) is lowest during the cooler, drier months of April to August (dormant season).

4.4 Planting according to zone

Certain mangrove species will grow successfully in the more dynamic seaward edge. However, planting without added protection for stability is likely to be successful only in sheltered tidal zones. Where there is more wave and wind action (i.e. closer to the coastal edge) other methods of planting that reduce the effects of physical impacts may be required. One such method is the use of split PVC pipe around each mangrove seedling (*Riley encased method*). This protects the young seedling from the physical forces of wind and waves. The PVC pipe is removed when the tree reaches a suitable height. This has only been trialed with *Rhizophora* species, however, there is no obvious reason why stabilising methods could not be used with all species as long as the species characteristic zone is taken into account (see Figure 2).

4.5 Planting according to shade

Certain mangrove seedlings require more shade than is available in an open nursery or field environment. For example, the orange-leaved mangroves (*Bruguiera gymnorhiza* and *Bruguiera parviflora*) grow more successfully in a shaded environment. The QFS Nursery had a shade cover (roof only) of 30% shade cloth. This allowed the early, rapid growth of “sun sensitive” mangrove species, which could then be “sun hardened” at around 12 months of age prior to planting out.

4.6 Planting according to age

Conditions at each restoration site will dictate revegetation plant type, size and age. QFS found that seedlings between 6 to 12 months of age were optimal in terms of ease of transport, lower costs associated with propagation and greater ability to withstand the rigors of transplanting (i.e. root damage, environmental changes). Mangroves from the nursery up to three years of age were also successfully transplanted.

After about 18 months there is likely to be significant root growth in all species in the nursery environment. To increase the chances of successful planting the pot should be cut from the plant to reduce root damage. This may leave the plant vulnerable to possible *Phytophthora* invasion. Some root pruning, particularly of damaged roots, may be required but should be done in balance with foliage pruning. Less than 30% foliage removal is advisable, particularly with *Ceriops* and *Bruguiera* spp. The abilities of certain mangrove species to withstand pruning are shown in Appendix 1.

4.7 Field planting process

The following are suggestions to assist in the planting of mangroves in the field:

- Choose appropriate species for the site (i.e. correct tidal influence for species); check local distribution along the tidal profile (refer Figure 2).
- Use endemic species to avoid translocation problems (refer to Queensland Fisheries Service policy on mangrove collection and translocation)
- Assemble equipment:
 - ⇒ Long handled spades and shovels are useful to dig the initial hole;
 - ⇒ Small garden spades assist in returning the soil around the roots once the seedling has been placed in the hole;
 - ⇒ Stakes, tripods or PVC pipe may be used to stabilise seedlings;
 - ⇒ Stakes should be single, short and tied to the lower trunk only, with enough expansion of the tie to allow for growth;
 - ⇒ Wheelbarrows, with reduced tyre pressure, to carry plants to the site (if conditions allow);
- Ensure tides allow access below Highest Astronomical Tide (HAT) for the species to be inundated sufficiently (depending on species) or for the workers to access the planting site and plants;
- Dig a hole to an appropriate size for the seedling — at least 100 % more by volume than the pot size so that less compacted soils will be placed around the seedlings roots;
- Dislodge the seedling from the pot with minimal disturbance by placing one hand over the top of the soil and inverting the pot into the other hand;
- Gently place the plant into the hole with the roots below ground level — potting media should be level with surrounding soils;
- Cover the base with surrounding soil and press until upright stability is achieved;
- Stake the plant with a single, short stake, if required (or use other protective measures).

4.8 Planting densities

Experience has shown that planting young seedlings at a density of at least one seedling per 0.5m² is successful. This allows room for the seedling to grow and allows access if thinning is required. Dr Barry Clough (pers com.) suggests a planting density of one to 1.5 m.

For more information on restoration techniques refer to:

- Duke N.C., Dalhaus O. & Clough B. (1997)
- Field C.D. (Editor), 1996.
- Hopkins E., White W. & Clarke A. (1998)
- Quinn, R.H. & Beumer, J.P. (1984)

5.0 Legal requirements and contacts

All marine plants in Queensland are protected under the *Fisheries Act 1994* and a permit is required for their disturbance. The collection of mangrove propagules and planting out of seedlings requires a permit under Section 51 of the Act. Initial enquiries for all marine fish habitat restoration works should be directed to your closest Queensland Fisheries Service office. Alternatively, you can contact the DPI Call Centre on 13 25 23 for further information. The DPI website and Fishweb – www.dpi.qld.gov.au/fishweb also provide information on the permitting process and requirements.

WARNING

Marine fish habitat restoration works should not occur without the appropriate approvals. Substantial fines and court costs may be incurred. Consideration will be given to reducing fees for approved restoration projects undertaken by community groups.

Contacts

The DPI Call Centre

Open Mon – Fri from 8am to 6pm except public holidays.

Ph 13 25 23 Queensland callers only.

07 3404 6999 Interstate callers

+61 7 3404 6999 International callers

Email: callweb@dpi.qld.gov.au

Habitat Manager South Region (NSW/Qld border to Sarina)

Department of Primary Industries

Southern Fisheries Centre

PO Box 76

Deception Bay Qld 4508

Ph 07 3817 9500

Email: habitat.sfc@dpi.qld.gov.au

Habitat Manager North Region (Sarina to Qld/NT border)

Department of Primary Industries

Northern Fisheries Centre

PO Box 5396

Cairns Qld 4870

Ph 07 4035 0100

Email: beverley.gibbs@dpi.qld.gov.au

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DPI Queensland Fisheries Service Translocation Policy.

Duke, N.C., Dalhaus, O. & Clough, B. (1997) Restoration and planting of mangroves at Oyster Point during 1996. Final report to GBRMPA, Australian Institute of Marine Science, Townsville.

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Fisheries Regulation 1995

Heylar, K.R. (1980) Growing plants in recirculating nutrient solutions. NSW Sept. Agriculture Bulletin No. 6.

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Pegg, K.G. & Forsberg, L.I. (1982) *Phytophthora* in Queensland mangroves. Wetlands (1):2–3.

Quinn, R.H. & Beumer, J.P. (1984) Wallum Creek – A study on the regeneration of mangroves. In: *Focus on Stradbroke.* Stradbroke Island Management Organisation, Amity Point, Boolarong Publications, Brisbane, pp. 238–259.

Siddiqi, N.A., Islam, M.R., Khan, M.A.S. & Shahidullah, M. (1993) Mangrove nurseries in Bangladesh. ISME Mangrove Ecosystems Occasional Papers No. 1.

Thorhaug, A. (1990) Restoration of mangroves and seagrasses – economic benefits for fisheries and mariculture. In: Environmental Restoration: Science and Strategies for Restoring the Earth. J.J. Berger (ed) Island Press, Washington pp. 265–281.

APPENDIX 1 Mangrove nursery project descriptions

Project One: Mangrove growth in a nursery environment.

The objective of this project was to provide both an education resource and an ensuing set of guidelines for groups taking an active interest in fish habitat rehabilitation e.g. Councils, Landcare and other community groups, rehabilitation contractors, other government agencies. The Fisheries guidelines for Mangrove nursery construction, propagation and planting FHG 004 are an outcome of this project. The guidelines detail techniques and procedures refined during the life of the project.

Location

The DPI mangrove nursery was constructed adjacent to the Northern Fisheries Centre in Cairns, Australia (16.944°S, 145.772°E). The nursery covered an area of approximately 200 m² and was located approximately 500 m from Trinity Inlet. Exposed to a typical tropical environment, nursery conditions included distinct seasonal variation in rainfall (wet/dry) of up to 3500 mm per year with most of this falling over the wet season (October to April), temperatures ranging between 14°C – 34°C, high humidity, and exposure to cyclonic activity.

Funding

The Northern Fisheries Centre received funding (\$10 000) from the State Government to establish the mangrove nursery for the purpose of studying mangrove growth and the effects of pruning on mangroves. National Heritage Trust–Fishcare funding (\$11 000) was obtained to provide staff support for nursery work, workshops, formulation of education material and for constructed tidal fish habitat research. Further support was obtained through the marine plant permitting process as mitigation to unavoidable fisheries resource loss (\$10 000).

The total cost of the mangrove nursery project construction and ongoing maintenance was \$31 000 over a three-year period, from June 1997 to June 2000.

Project Two: Pruning research project

This project was to study the effects of pollarding, pruning on growth rates and survival of selected mangrove species.

Advice on the timing and effects of pruning on various species is required by groups that undertake trimming of mangroves for maintenance of public infrastructure (e.g. to provide safe sight along transport corridors and to allow access for drainage works and maintenance of powerlines).

The pruning pilot research project was conducted in Pond 2 of the mangrove nursery. Within this pond, mangroves were grouped according to age, class and species. There were eight plants in each species group. A once-only pruning was given to two different year classes (one and two years old) for five different mangrove species.

Fisheries Guidelines for Mangrove Nursery Construction, Propagation and Planting

Half of the mangroves in each age class/pruning time group (four plants) were pruned at 30 % and the other half were pruned at 50%. The pruning technique involved cutting the plant at the primary stem with secateurs on a 45° angle. Plant height was measured from the apex of the propagule to the tip of the apical shoot. Percentage cut was measured from the tip of the apical shoot down. Callipers were used to measure the girth at the top of the propagule.

All plants were measured, including the control group, to coincide with the new pruning event (every six months). The experiment ran for three years. This data was entered, validated and statistically analysed.

Table 2. Species studied in pruning research project

Common name	Species name
Grey mangrove	<i>Avicennia marina</i>
Cedar mangrove	<i>Xylocarpus mekongensis</i>
Yellow mangrove	<i>Ceriops australis</i>
Red mangrove	<i>Rhizophora stylosa</i>
Large-leafed orange mangrove	<i>Bruguiera gymnorrhiza</i>

Results

Table 3. Percentage of survival at end of three-year experiment.

Common name	Species name	Summer		Winter		Control
		30%	50%	30%	50%	
Percentage trimmed						nil
Grey mangrove	<i>Avicennia marina</i>	100%	100%	100%	100%	100%
Cedar mangrove	<i>Xylocarpus mekongensis</i>	100%	100%	100%	100%	100%
Yellow mangrove	<i>Ceriops australis</i>	100%	50%	25%	25%	100%
Red mangrove	<i>Rhizophora stylosa</i>	100%	75%	100%	100%	100%
Large-leafed orange mangrove	<i>Bruguiera gymnorrhiza</i>	0%	25%	50%	0%	100%

Table 4. Percentage difference in rates of growth from control.

Common name	Species name	Summer		Winter	
		30%	50%	30%	50%
Percentage trimmed					
Grey mangrove	<i>Avicennia marina</i>	-62%	-31%	114%	2%
Cedar mangrove	<i>Xylocarpus mekongensis</i>	-4%	-20%	-106%	-51%
Yellow mangrove	<i>Ceriops australis</i>	-194%	-108%	304%	-18%
Red mangrove	<i>Rhizophora stylosa</i>	0%	0%	138%	-160%
Large-leafed orange mangrove	<i>Bruguiera gymnorrhiza</i>	-100%	0%	-75%	-100%

As outlined in Table 1 there was 100% survival rate of control individuals for all species in summer and winter. Individuals treated with two pruning intensities during the summer or winter responded in various ways outlined below.

Avicennia marina

Avicennia marina survival was not affected by foliage removal at any time of the year or by percentage pruned. The growth rate declined in summer after pruning and increased in winter only when 30% of the foliage was removed.

Xylocarpus mekongensis

This species survived when pruned during summer or winter at both pruning regimes. The growth rate decreased as a result of pruning more significantly in winter than summer.

Ceriops australis

In winter, survival was decreased by 75% when individuals were pruned at both intensities and by 50% when half the foliage was removed during summer. Growth rates declined in summer for both percentages and also in winter for 50% pruning.

Rhizophora stylosa

Survival of this species decreased by 25% when 50% of the foliage was removed during winter. Pruning of this species to 30% in winter increased growth rates. Pruning in summer decreased growth rates at both the 30% and 50% pruning levels.

Bruguiera gymnorrhiza

There was no survival after pruning in summer and winter at both 30% and 50% pruning regimes respectively. There was 75% decreased survival in this species when 50% pruned in summer and a 50% survival for 30% pruning in winter. There seems to be no clear pattern here although death of the trees

indicates low tolerance to pruning. The growth rate declined for both seasons and at both pruning levels.

Conclusion

From this initial study it is clear that certain mangrove species can tolerate pruning whilst others do not. Both *Avicennia* and *Xylocarpus* species appear to tolerate pruning of both 30% and 50% at both times of year tested. It appears that *Bruguiera* species are most sensitive to pruning with death occurring at 50% pruning for both times of year. The *Ceriops* species used in this trial appears to also suffer from pruning but seems more tolerant of summer pruning. *Rhizophora* species appear tolerant of pruning except where 50% pruning occurred in summer.

The effect of pruning on growth rates shows a pattern of increased growth rates with pruning in winter in all species except *Xylocarpus* species. This difference between species could be due to the deciduous nature of *Xylocarpus*. Growth rates were also higher in plants pruned to only 30% of the original height.

These results will assist Queensland Fisheries Service Officers in offering advice and developing trimming or maintenance regimes for clients requesting Section 51 Permits to trim mangroves. Advice to clients is on a case-by-case basis and would take into consideration species present. It would incorporate long-term strategies for the pruning of mangroves that has the least impact on tree health.

Project three: General tidal wetland restoration

The objective of this project was to promote fisheries productivity in degraded or created fish marine habitats as well as to provide advice to groups interested in carrying out their own restoration of these areas.

The QFS nursery contained stock that was used for restoration projects. Mangroves taken from the nursery were replaced to continue the on-going process of restoring coastal wetlands. Once the mangroves reached an optimal age or height they were removed from the nursery and transported to the restoration site (see Plates 2, 7 & 8).

Various groups, such as local governments, schools and people restoring wetlands as part of developments have been assisted by QFS staff with technical and on-site advice in regard to marine fish habitat restoration.

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