EFFECTS OF BARNACLES ON MANGROVE SEEDLING TRANSPLANTATION AT BAN DON BAY, SOUTHERN THAILAND

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The study examined the survival of *Avicennia alba, Rhizophora mucronata* and *Sonneratia caseolaris* seedlings planted in new mudflat at Ban Don Bay, Surat Thani Province. Four months after transplantation in July 1995, three species of barnacles attached to the stems of seedlings. *Balanus* sp.1 was the most dominant (99%), followed by *Balanus amphitrite* Darwin and *Chthamalus* sp. The ranges of individual barnacle attached on *A. alba, R. mucronata* and *S. caseolaris* were 94.3 ± 12.1- 170.3 ± 24.6, 91.6 ± 13.6 - 275.1 ± 40.1, and 244.7 ± 29.8 - 329.8 ± 45.6 individual per seedling, respectively. Most barnacles were <2 mm in length. The entire group of *A. alba* and *S. caseolaris* seedlings died within eight months of transplantation, and *R. mucronata* seedlings died within a year. Very low water salinity during September to December inhibited barnacle reproduction. Only during brackish water periods (two to three months each period) barnacle larvae establish settlement and experience rapid growth on mangrove seedlings which were immersed in seawater.

Introduction

Several studies have reported that the majority of barnacles can be found attached to substrates such as ships, marine constructions, stones, shells, crabs, timbers, bamboos, buoys and mangrove trees (Achituv 1984, Henry and McLaughlin 1975). In Thailand as well as in the other places, barnacle communities are generally regarded as just an unpleasant part of the coastal scene. To date there have been very few studies on barnacles in Thailand. Studies have included Limpsaichol and Parnrong's (1986) study on the influence of tar on the settling of *Balanus amphitrite* and Rawangkul *et al.* (1995) study showing that in the last few years, barnacles have destroyed *Rhizophora mucronata* seedlings in plantations in Nakorn Si Thammarat Province. Although some seedlings have been attacked by grapsid crabs and hermit crabs (Havanond & Maxwell 1993), the phenomenon of barnacle damage constitutes a new problem for mangrove forest plantations which have otherwise been successful.

The present study aimed to examine what mangrove species (*Avicennia alba, Rhizophora mucronata* and *Sonneratia caseolaris*) would survive from barnacle attachment after transplantation on the new mudflat at Ban Don Bay.

Material and methods

Site studied

Experiments were conducted at Ban Don Bay (9°19'20" E, 99°14' N) Surat Thani Province (Figure 1). Ban Don Bay is a large estuarine mangrove system. The forest is dominated by *Sonneratia caseolaris,* followed by sparse populations of *Avicennia alba, Kandelia candel, Rhizophora mucronata* and *Rhizophora apiculata.* Rapid sedimentation at mangrove ground developed the new mudflat which had not been occupied by any plant species yet. The new mudflat was affected by freshwater from the Phunphin Canal and was flooded whole day only in the heavy rainy season (October-January). Back mangroves have been converted for shrimp farming since 1982.

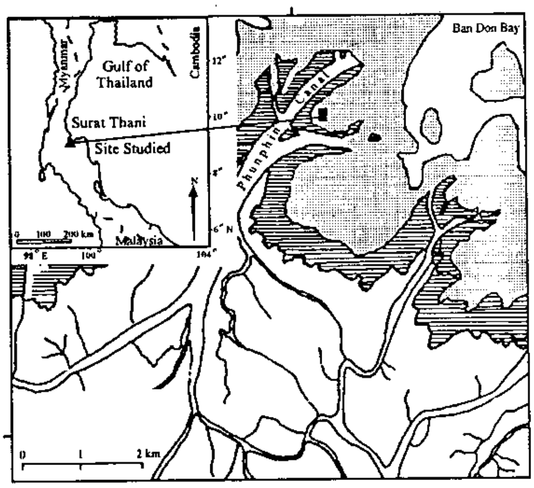

Figure 1. Map of Ban Don Bay, showing the location of site studied (☐ mudflat, ▤ mangrove).

Experimental design for mangrove transplantation

Seedlings of *A. alba, R. mucronata* and *S. caseolaris* were transplanted in the new mudflat in July 1995. Each species was planted with a spacing of 1.5 x 1.5 m in a 20 x 30 m^2 experiment plot. Three plots of each species were randomly arranged at three intertidal levels: high-tidal (H), mid-tidal (M) and low-tidal (L) (Figure 2). Two-hundred and eighty (20 x 14 rows) seedlings of each species were planted in each plot. The distance between seedlings of each species was 0.5 m.

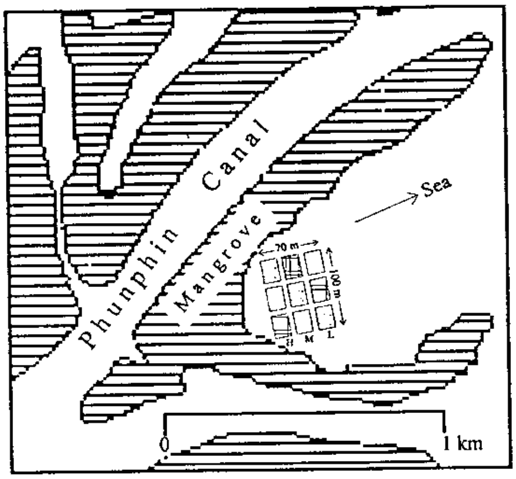

Figure 2. Experiment plots of the transplantation of *A. alba* (□), *R. mucronata* (▤), and *S. caseolaris* (▦) at three intertidal levels on the new mudflat.

Barnacle investigation on seedlings

The investigation of barnacle attachment on seedlings was carried out every four months after transplantation of seedlings. Twenty-four seedlings were randomly harvested in each plot. Barnacle attachment distance and total height of the seedlings were measured. After cleaning with a brush, barnacles attached to the collected seedlings were removed and preserved in 70% alcohol solution. Barnacles were identified to the genus level by examining shell color and structure, operculum (tergum and scutum) and mouth (labrum), following the providing keys of Pope (1965), Henry and McLaughlin (1975), Jones (1987b) and Foster & Newman (1987).

The abundance of barnacles on each seedling was determined by counting the number of each species in three size classes: <2 mm, 2-4 mm and >4 mm. The length from carina to rostrum was the measurement used. In addition, water salinity was also measured monthly using a salinometer during high tide.

Results and discussion

Three species of barnacles, i.e. *Balanus* sp.1, (unidentified species), *Balanus amphitrite* Darwin and *Chthamalus* sp. were identified from 230 collected seedlings. *Balanus* sp.1 was the most abundant (more than 99%) while the other two species comprised the remaining one percent (Table 1). Most barnacles attached were <2 mm in length. The tergum, scutrum and body shape of *Balanus* sp.1 are very similar to *Balanus kondakovi* Tarasov & Zevina but its larval stages were similar to the larval stages of *Balanus reticulatus* Utinomi (Lee and Kim 1991, Kado, unpublished data), which was collected from *Rhizophora mucronata* seedlings transplanted at Ban Pakpoon Nakorn Si Thammarat Province (Rawangkul *et al.* 1995). Rainbow *et al.* (1989) reported that the intertidal barnacle *Balanus kondakovi* Tarasov & Zevina, 1957, are widely distributed in eastern Asia but little is known of their intertidal ecology. The morphometric variation of the opercular plates of several species of acorn barnacles may be related to chemical factors. Furman (1990) showed that *Balanus improvisus* at low salinity had relatively small opercular openings compared to individuals from high salinity. Barnacles exposed to the highest copper levels had the largest opercular plates (Royo-Gelabert & Yule 1994). However, the Ban Don *Balanus* sp.1 is in the process of being identified to the species level.

Four months after transplantation (November 1995) the settlement of barnacles on seedlings occurred from the sediment level to the top part of seedling. The height of barnacle attachment ranged from 16.3 ± 1.3 to 46.0 ± 2.2 cm (Table 2). *A. alba* and *S. caseolaris* seedlings were attached by barnacles not only on their stem surface but also on the leaves which was different from attachments on *R. mucronata*. This may have been due to the higher initial height of *R. mucronata* seedling used for transplanting. It is noteworthy that although the initial height of *A. alba* and *S. caseolaris* seedlings planted were the same size, *S. caseolaris* had more barnacles attached.

Balanus sp.1 attached extensively on pneumatophores of *S. caseolaris* trees, which was the dominant species in Ban Don Bay (personal observation) the same occurrence as found in its seedlings. Therefore, it may imply

Table 1. The abundance of various sizes of *Balanus* sp.1 attached on three species of mangrove seedlings four months after transplanting on a new mudflat at Ban Don Bay, Surat Thani Province ($\bar{x}$ ±SE)

Seedling species/ Plantation levels	Size class of *Balanus* sp.1 attached (ind/seedling)			*Balanus* sp.1 (%)	Total of 3 barnacle species (ind/seedling)
	<2 mm	2-4 mm	>4 mm		
Avicennia alba					
high-tidal level	84.3±14.2	26.8± 4.9	4.0± 1.0	98.5	116.9±19.3
mid-tidal level	66.7± 8.3	23.4± 4.0	3.4± 0.9	99.2	94.3±12.1
low-tidal level	132.5±19.6	35.0± 5.5	2.8± 0.8	100.0	170.3±24.6
Rhizophora mucronata					
high-tidal level	74.6±11.8	14.8± 2.5	2.2± 0.5	100.0	91.6±13.6
mid-tidal level	97.2±10.1	46.3± 6.0	7.0± 1.0	100.0	150.5±16.1
low-tidal level	169.7±23.5	80.0±11.3	25.4±13.0	100.0	275.1±40.1
Sonneratia caseolaris					
high-tidal level	146.9±17.9	87.5±11.6	10.3±1.2	100.0	244.7±29.8
mid-tidal level	205.7±21.7	87.9±11.3	16.1±1.7	100.0	309.7±32.7
low-tidal level	273.9±44.1	49.9± 4.2	5.5±0.6	99.8	329.8±45.6

Table 2. The averages height of mangrove seedlings and height of barnacle attachment on three species of seedlings, four months after transplanting ($\bar{x}$ ±SE)

Seedling species/ Plantation levels	Seedling height (cm)	Height of barnacle attachment (cm)
Avicennia alba		
high-tidal level	24.2±1.7	17.0±1.8
mid-tidal level	21.9±1.3	16.3±1.3
low-tidal level	25.7±2.3	21.0±2.5
Rhizophora mucronata		
high-tidal level	130.2±8.4	38.2±2.0
mid-tidal level	122.1±5.9	46.0±2.2
low-tidal level	119.5±7.4	45.6±2.0
Sonneratia caseolaris		
high-tidal level	25.4±1.5	22.3±1.6
mid-tidal level	22.5±1.4	20.4±1.5
low-tidal level	32.3±3.9	29.8±3.7

that its seedlings are an attractive host. Therefore, *S. caseolaris* cannot be successfully planted in this new mudflat even though it is a dominant species here. *Sonneratia* trees are able to be resistant barnacle attachment, but its seedlings are too soft and small to withstand barnacle attachment. Most seedlings looked as if they were growing well during the first four months after transplantation. However, most *A. alba* and *S. caseolaris* disappeared from the experiment plots within eight months (March 1996) (Table 3). Some seedlings were found to have remained on the sediment floor where they had fallen. This may have been due to the heavy growth of barnacles attached. Fourteen percent of the *R. mucronata* seedlings planted on the high-tidal level survived after eight months of the experiment period. More than 1,000 barnacles per seedling were found on their stems (Figure 3). The average rostrum-carina length of these barnacles was 5 cm. *R. mucronata* seedlings seemed to stand longer because of their strong-stem, but they were actually dead within one year of transplantation.

Table 3. The percentages of dead mangrove seedlings which contained >100 individual barnacles at various periods after transplantation

Seedling species/ Plantation levels	% dead seedlings after transplanting intervals		
	4 months (Nov 1995)	8 months (Mar 1996)	12 months (Jul 1996)
Avicennia alba			
high-tidal level	0	100	
mid-tidal level	4	100	
low-tidal level	0	100	
Rhizophora mucronata			
high-tidal level	0	86	100
mid-tidal level	17	100	
low-tidal level	29	100	
Sonneratia caseolaris			
high-tidal level	0	100	
mid-tidal level	0	100	
low-tidal level	8	100	

The seedlings of all species planted at the low-tidal position tended to carry the greatest number of barnacles. The lower the intertidal zone, the longer the period of seawater immersion. This may increase the incidence of *Balanus* cyprids attachment. *Balanus* spp. were capable of settling at both high and low intertidal levels, with the highest settlement occurring at lower levels (Perry 1988).

The average reduction from one naupliar stage to the next, up to the cypris, regardless of barnacle species, is about 96%; this means that only 4 of 100 larvae complete their larval cycle (Geraci and Romairone 1986). The numerous settlements of barnacles on mangrove seedlings in Ban Don Bay within a short period (four months after transplantation) indicate the abundance of cyprids and the high potential for attachment. Moreover, the various sizes of *Balanus* sp.1 found on seedlings tends to show that they may produce larvae several times during a four-month period. Both live and dead barnacles were found directly attached to mangrove seedlings and indirectly via attachment to other barnacles at the side (not on the operculum).

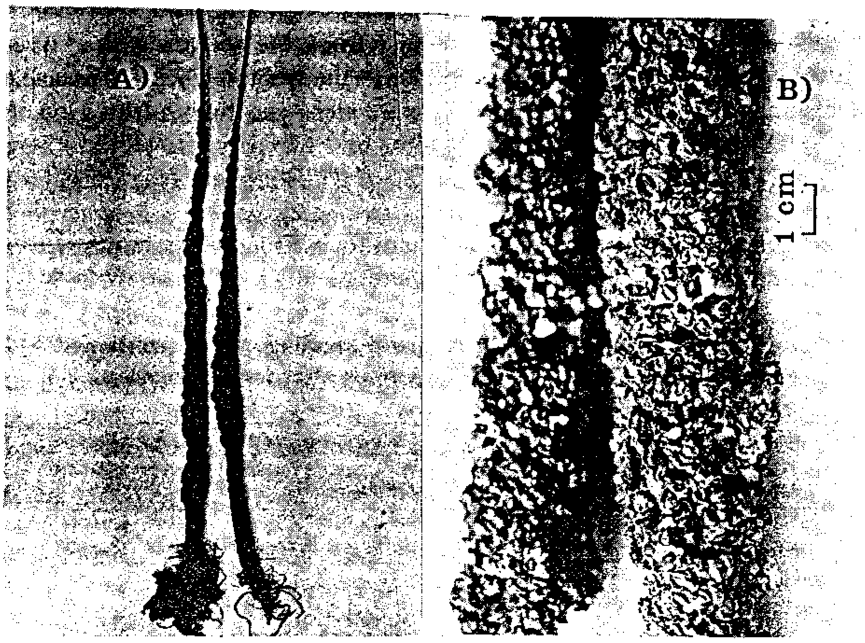

Figure 3. (A) Barnacle attached to one meter long *Rhizophora mucronata* seedlings after 8 months of transplanting (B) magnifying of barnacle attachment.

Although high variations of water salinity (Figure 4) occurred at the experiment plots, the low salinity tolerance was observed from the dominance of *Balanus* sp.1. Tolerance to fluctuating salinity varies among barnacle species. When *Semibalanus balanoides* is immersed in diluted seawater or freshwater, it closes its operculum tightly and switches to anaerobiosis (Harris 1990). Thus, some barnacles may be found in coastal areas where environmental conditions are stressful, such as in mangrove estuaries. Barnacles in mangrove are found on the trunks and twigs, rhizophores, pneumatophores and even on the leaves. Several environmental factors govern the settlement of cirripedes on mangroves and limit the variety of barnacles to those species capable of withstanding the environment of the mangrove: fluctuating salinity, turbidity and low wave action (Achituv 1984). Achituv further pointed out that the amount of silt carried by rivers increases the turbidity of the water, which disturbs and blocks the fine cirrial net of cirripedes. *B. amphitrite* and *Balanus variegatus* communities began to show signs of physiological stress when salinities dropped below 15‰ and prolonged of low salinities (10% or less) resulted in death (Jones 1987a).

Therefore, the number of cirripedes adapted to life in a mangrove environment is limited (Achituv 1984). In the present study, three species of barnacles were found in mangrove plantations, but there are no reports on the diversity of barnacle species in coastal areas of Thailand.

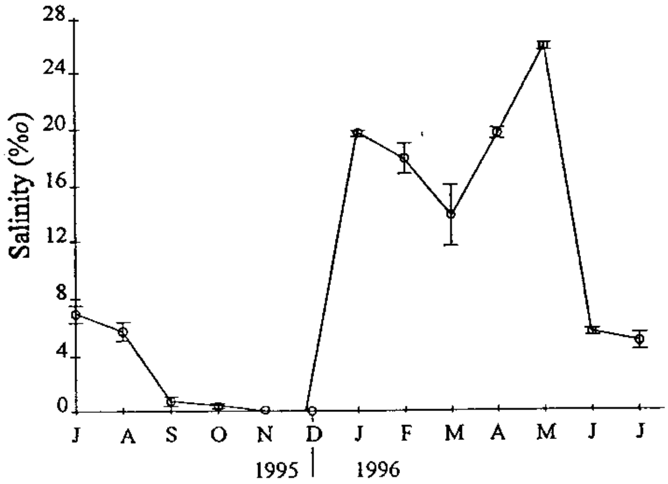

Figure 4. Water salinity in the experiment plots, Ban Don Bay.

Transplantation during the low salinity period may inhibit only some barnacle species for which low salinity is a settlement limitation. For example, a sharp drop in salinity during the wet season prevents successful settlement of *B. amphitrite* (Pillai 1958 cited in Egan & Anderson 1986). *Balanus* sp.1 was also inactive during September to December when water salinity ranged from 1 to 4‰. But its nauplii took only two to three months before the wet season to settle and grow rapidly on seedlings. These seedlings all died. Therefore, new mudflats, immersed in seawater for long periods, are not suitable for transplantation of these three mangrove species if the seawater contains large numbers of barnacle nauplii. The transplantation should be prolonged until the mudflat deposition is thicker or immersion in seawater less frequent.

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