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RESEARCH

Survey of Fouling Organisms at Songkhla Port in Thailand

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ABSTRACT The fouling organisms at Songkhla Port were investigated from November 2011 to December 2012. Samples were collected using PVC panels (10 cm x 20 cm) submerged for one-month and three-month periods. Analysis of fouling panels was carried out using PhotoGrid software. In addition to slime and silt, three types of fouling organisms, namely encrusting bryozoa, barnacles and calcareous polychaetes, were observed on the submerged PVC panels. Calcareous polychaetes and molluscs were the most diverse groups (ten species) on panels that were submerged for one-month and three-month periods. Barnacles (*Balanus* spp.) were most abundant on panels submerged for three-month periods, while calcareous polychaetes dominated one-month panels. The dominant species of mollusc was the mussel *Brachidontes* sp. The major polychaetes identified were *Ficopomatus macrodon*, *F. enigmaticus* and *Hydroides norvegicus*. A highlight of this study was the first record of the Caribbean tubeworm *Hydroides sanctaecrucis* in Thailand, which has previously invaded and established in Australian waters through hull fouling.

1. INTRODUCTION

Fouling is the undesirable accumulation of organisms (e.g., barnacles, tubeworms, mussels, crustaceans, hydroids, and bryozoans) on surfaces of non-living objects such as piers, navigation buoys, pilings and hulls. The accumulation of fouling organisms can often extend over a large area and this can have significant impacts including corrosion, clogging, contamination, or efficiency loss on ship transportation (Wikipedia contributors 2013). Fouling organisms can grow rapidly, adhere strongly, and reach sexual maturity before their eventual dislodgement due to size induced drag, hull cleaning or natural senescence. Not only economically, but fouling organisms have also been implicated in trans-boundary introductions via ship's hull and causing invasion (Global Invasive Species Programme 2008). Alien invasive species (also called "non-indigenous" species) are not native to the ecosystem under consideration and likely to cause adverse economic or environmental problems (National Invasive Species Council 2006).

This study treats the hitherto poorly known fouling organisms in Thai waters, which cause many impacts on biodiversity of native species, economy and human health. The Songkhla Port in Thailand is frequented by marine vessels from various bio-regions across the world facilitating introduction of aquatic invasive species. Previously, an invasive bivalve species, *Mytilopsis sallei* was reported in Songkhla Lake Basin and may have been introduced through shipping during 1990-2000 (Wangkulangkul and Lheknim 2008). Hence there is a need to monitor invasive species in this area.

In view of this, the present study on composition and species diversity of fouling organisms at Songkhla Port in Thailand would help in understanding the status of invasive fouling organisms. Moreover, an effort was made to analyze temporal variations of these organisms to infer about their eco-biological aspects.

2. MATERIALS AND METHODS

2.1 Study area

Songkhla Port or Songkhla Deep Sea Port is located in the southern Gulf of Thailand (7°13.7'N, 100°34.5'E), adjacent to the mouth of Songkhla lake, in Songkhla Province (Figure 1). The major items exported from this port are rubber, frozen seafood, canned foods and furniture, whereas the major import is frozen tuna.

2.2 Data collection and analysis

Fouling organisms were collected during the period from November 2011 to December 2012 by using PVC panels (10 cm x 20 cm) submerged in the port waters for one-month and three-month periods, respectively. The first batch of panels was deployed in October 2011 and left during November 2011-January 2012; the second batch was deployed in April 2012 and left during May 2012-July 2012; the third batch was deployed in September 2012 and left during October 2012-December 2012. Each batch comprised two sets of experimental PVC panels. The first set consisted of three panels, which were changed every month (for three months), and the second set consisted of three panels, which were submerged for three months. In the case of the first set, the panels were removed after one month and photographed on both sides. These were in turn replaced by another set of new panels for the next one-month duration. In the case of the second set, the panels were removed, photographed on both sides of each panel, put back to the sea and left for three months.

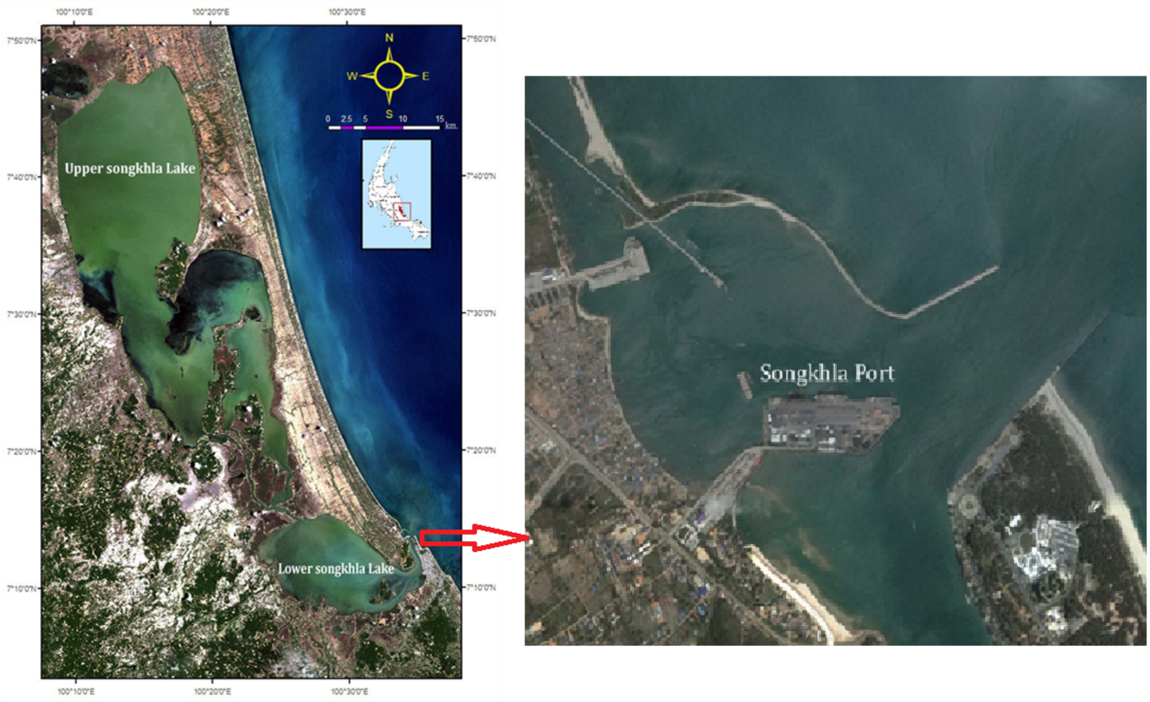

Figure 1. Map of sampling area. The PVC panels were located in Songkhla Port that connects the Lower Songkhla Lake to the Gulf of Thailand.

Subsequently, all panels were preserved in 70% alcohol, and the fouling organisms were scraped and identified.

The percentage of surface coverage by biofoulers was determined by subjecting the panel photographs to PhotoGrid 1.0 beta program software. In the laboratory, the fouling organisms were sorted and enumerated under a stereomicroscope. Taxonomic identification of fouling organisms followed published literature on respective faunal groups (Day 1967a, b; Fauchald 1977; Swennen et al. 2001).

3. RESULTS

The fouling organisms that settled on PVC panels were categorized into five groups, namely encrusting bryozoa, barnacles, calcareous polychaetes, slime and silt (Figure 2). The constituents of encrusting bryozoa, slime and silt could not be identified.

3.1 Percentage of fouling surface coverage

3.1.1 First experimental period (November 2011 to January 2012)

The major fouling groups observed on panels submerged for one-month period during November 2011 were calcareous polychaetes (53.0%) and silt (27.0%). The December 2011 panels largely contained slime (41.3%) and calcareous polychaetes (37.3%), while the January panels had less fouling, mostly slime (70.0%).

In the case of three-month panels during the same period, the major groups observed were slime (43.0%) and calcareous polychaetes (42.7%; Figure 3). Monthly observations of these panels revealed that calcareous polychaetes were the initial settlers during the first month (November 2011) and covered 89% of the panel area. Subsequent monthly observations (December 2011 and January 2012) revealed a progressive reduction in the percentage coverage of this group (Figure 4). Concurrently, percentage cover of encrusting bryozoans increased 10-fold toward the end of this period (Figure 4).

3.1.2 Second experimental period (May 2012 to July 2012)

The major fouling groups observed on panels submerged for one-month period during May 2012 were silt (48.0%) and barnacles (26.0%). The June 2012 and July 2012 panels largely contained encrusting bryozoans (51.0% each).

In the case of three-month panels during the same period, the major groups observed were barnacles (49.0%) and encrusting bryozoans (41.0%) (Figure 5). Monthly observations of these panels revealed that silt (51.0%) covered largest area during May 2012 followed by barnacles (31.0%), calcareous polychaetes (>10.0%) and encrusting bryozoans (<10.0%). Subsequent monthly observations (June 2012 and July 2012) revealed a progressive reduction in the percentage coverage of bryozoans. Simultaneously, the encrusting bryozoans (~80.0% coverage) were observed to cover barnacles resulting in the elimination of other biofoulers (Figure 4).

3.1.3 Third experimental period (October 2012 to December 2012)

The major fouling groups observed on panels submerged for one-month period during October 2012 were encrusting bryozoans (40.0%) and silt (~35.0%). During November 2012, the percentage cover of silt (61.0%) doubled along with that of calcareous polychaetes (>30.0%), whereas that of encrusting bryozoans reduced. During December 2012, the percentage cover of encrusting bryozoans dominated the panel surface (53.0%), whereas that of calcareous polychaetes reduced marginally (Figure 6).

In the case of three-month panels during the same period, the encrusting bryozoans (70.0%) dominated the panel surfaces (Figure 6). Monthly observations of these panels revealed that encrusting bryozoans and silt dominated the panel surfaces during October 2012 (40.0% each). During November 2012, the percentage cover of silt and calcareous polychaetes increased, whereas that of encrusting bryozoans decreased. However, their trends reversed during December 2012 (Figure 4).

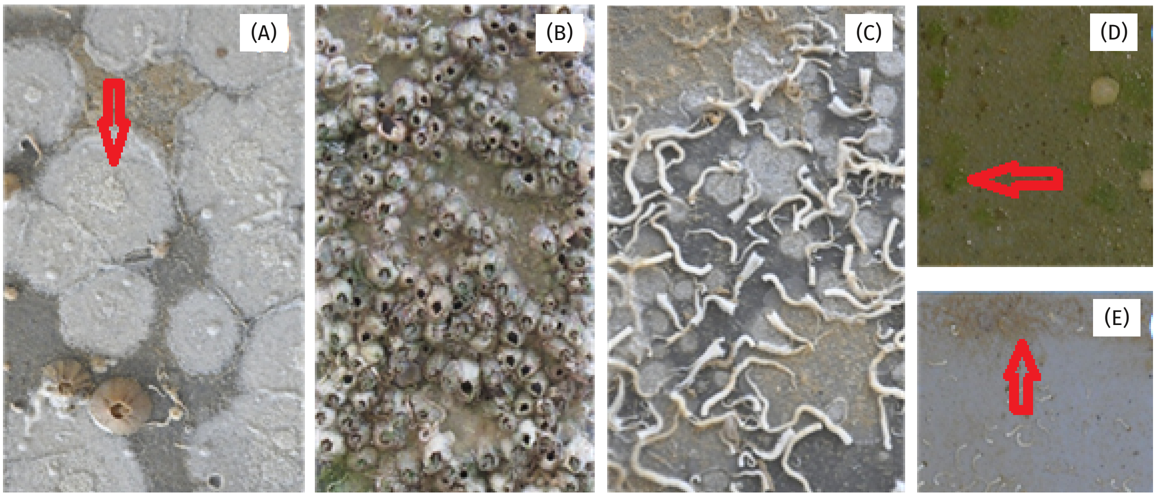

Figure 2. Types of fouling organisms observed at Songkhla Port during the present study. (A) encrusting bryozoan; (B) barnacles; (C) calcareous polychaetes; (D) slime; (E) silt.

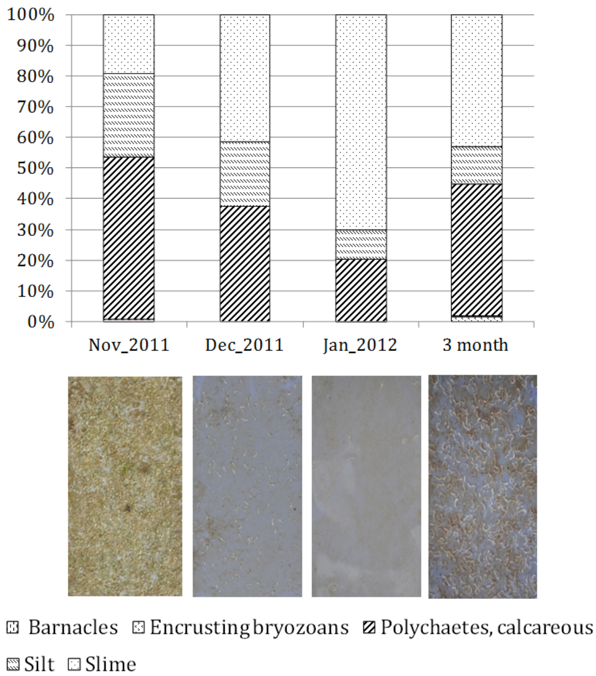

Figure 3. Percentage surface cover of fouling organisms on PVC panels submerged for one-month and three-month periods in Songkhla Port during the first observation period (November 2011-January 2012).

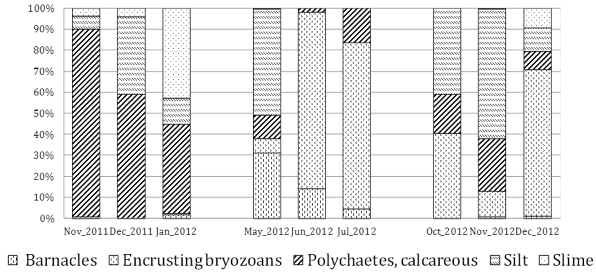

Figure 4. Month-wise trends of percentage surface cover of fouling organisms on PVC panels submerged for three-month periods in Songkhla Port from November 2011 to December 2012.

3.2 Fouling species composition

A total of 27 taxa of fouling organisms belonging to three animal phyla were recorded from PVC panels submerged in Songkhla Port (Table 1). Calcareous polychaetes (14 taxa) were the most diverse group followed by molluscs (12 taxa), whereas arthropods were represented by a single genus. Examination of panels submerged for one-month and three-month periods revealed that polychaetes were the most diverse (13 and 12 taxa, respectively), followed by molluscs (8 species during both experimental periods) and arthropods (*Balanus* spp.).

3.3 Abundance and frequency of occurrence

Quantitative analysis of fouling organisms revealed that *Balanus* spp. was the most abundant and frequently occurring taxon on both sets of experimental PVC panels deployed for this study (6 and 3 months, respectively) (Table 1). Among the polychaetes, *Ficopomatus macrodon* was the most abundant taxon on both the experimental sets. On the other hand, *F. enigmaticus* was observed to occur more frequently (6 and 3 months, respectively) (Table 1). Among the molluscs, *Brachidontes* sp. was the most abundant taxon on one-month PVC panels, followed by an undetermined plicatulid bivalve. On the other hand, this plicatulid bivalve (*Plicatula* sp.) was the most abundant on three-month PVC panels. In terms of frequency of occurrence, *Plicatula* sp. occurred most frequently (4 months) on one-month PVC panels, whereas *Musculus* sp. was the most frequent (3 months) on three-month PVC panels.

3.4 Temporal trends

Analysis of monthly data revealed that *Balanus* spp. occurred during most months on one-month and three-month panels, and its abundances peaked during summer (May 2012) and monsoon (July 2012), respectively. A majority of the polychaete taxa observed on one-month panels occurred during the monsoon season (June-October) with abundance peaks in July 2012 and October 2012. The remaining polychaetes occurred during the post-monsoon season (November-February) with abundance peaks in November and December months of 2011 and 2012. On three-month panels, their peak abundances were observed during January, June and December 2012. In the case of molluscs, most taxa observed on one-month panels occurred in monsoon and post-monsoon seasons with abundance peaks in October and November 2012. On three-month panels, these taxa occurred only in January, July and December 2012.

Table 1. Species composition of fouling organisms at Songkhla Port for one-month and three-month periods. N: November 2011; D: December 2011; Ja: January 2012; M: May 2012; J: June 2012; Ju: July 2012; O: October 2012; No: November 2012; De: December 2012.

Taxon	Set 1 (one-month period)		Set 2 (three-month period)	
	Occurrence	Max. abundance (ind.m^{-2})	Occurrence	Max. abundance (ind.m^{-2})
Phylum Annelida				
Class Polychaeta				
Family Sabellidae				
Undetermined sabellid	No	200	De	50
Family Serpulidae				
Ficopomatus enigmaticus	N,D,Ju,O,No,De	8,450	Ja,Ju,De	500
Ficopomatus uschakovi	M,Ju,O	800	Ja,Ju	150
Ficopomatus macrodon	N,D,Ja,O,De	31,300	Ja	10,700
Undetermined *Ficopomatus*	O	100	Ju	200
Hydroides norvegicus	Ju,O,No,De	2,150	Ju	150
Hydroides elegans	Ju,O,No	1,200		
Hydroides sanctaecrucis	O	50		
Hydroides sp. 1	No	50	Ju	50
Hydroides sp. 2			Ju	50
Undetermined *Hydroides*	Ju,O,No	400	Ju	50
Pomatoceros sp.	Ju,O	600	De	50
Pomatoleios sp.	Ju,No,De	250	Ju,De	850
Undetermined serpulid	N,D,J,Ju,De	2,950	Ja,Ju	600
Phylum Mollusca				
Class Bivalvia				
Family Arcidae				
Scaphula sp.			Ja	50
Family Dreissenidae				
Mytilopsis sp.	De	50		
Family Mytilidae				
Brachidontes sp.	O,No	7,500	Ju,De	100
Musculus sp.			Ja,Ju,De	200
Modiolus auriculatus			Ju	50
Arcuatula senhousia	No	400	De	50
Perna cf. *viridis*	No	50		
Undetermined mytilid			Ju,De	250
Family Plicatulidae				
Plicatula cf. *australis*	No	800	Ja,De	350
Undetermined plicatulid	M,O,No	3,700	Ju	650
Plicatula sp.	J,Ju,O,De	350		
Family Isognomonidae				
Isognomon sp.	De	50		
Phylum Arthropoda				
Class Maxillopoda				
Order Sessilia				
Family Balanidae				
Balanus spp.	N,M,J,O,No,De	22,050	Ja,Ju,De	16,500

Underlined letter refers to the month of maximum abundance of fouling organisms.

4. DISCUSSION

The present study attempts to provide baseline information pertaining to the biofouling organisms at Songkhla Port, Thailand with an aim of documenting alien aquatic species introduced through maritime activities. Further, an attempt has also been made to provide information on temporal distribution patterns of these organisms.

The biofouling community in the Port is dominated by tropical species of barnacles, polychaetes and molluscs, mostly of Indo-West Pacific origin. However one polychaete species of Caribbean origin, *Hydroides sanctaecrucis* was also observed in small numbers during the study. Lewis et al. (2006) have documented this species in Queensland, Australia and suggested its unintentional introduction through hull-fouling. Latest shipping data for the Port of Songkhla suggested voluminous maritime trade with the Atlantic region (Marine Traffic 2013), which could be a probable mode of introduction of this species to the study area.

Analysis of quantitative data revealed higher abundances and diversity of fouling organisms during the monsoon and post-season. This could be attributed to warmer temperatures in the equatorial region, which could favour prolonged spawning in most of these species (Dixon 1981).

Most of the fouling species observed in this study are gregarious in habit and quick to colonize on newly submerged surfaces (Holm et al. 2000) adhering very tightly to surfaces and are more resistant to dislodgement than many barnacles (Nedved and Hadfield 2008). Moreover, tubes can accumulate rapidly and create serious problems for ships (Ghobashy and Ghobashy 2005). Chavanich et al. (2010) showed that fouling species compete for space and suspended food resources with native species and their rapid growth may lead to the death of local species of commercial importance. Moreover, these organisms are known to

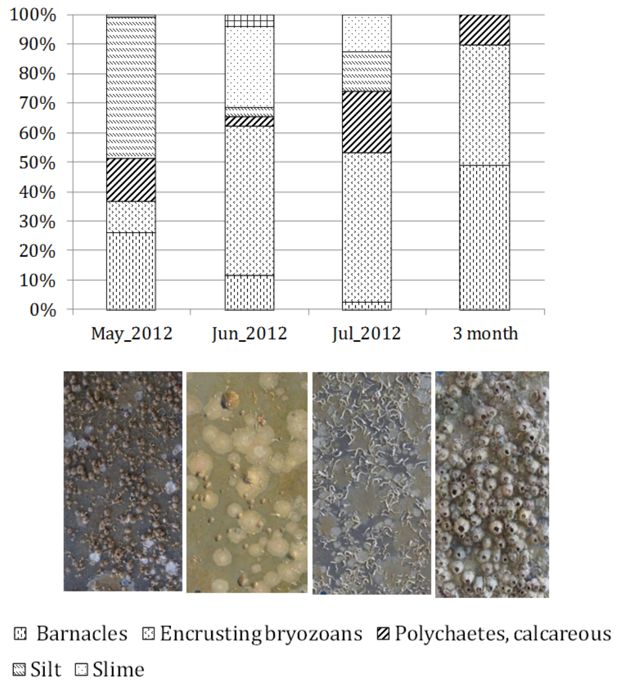

Figure 5. Percentage surface cover of fouling organisms on PVC panels submerged for one-month and three-month periods in Songkhla Port during the second observation period (May 2012-July 2012).

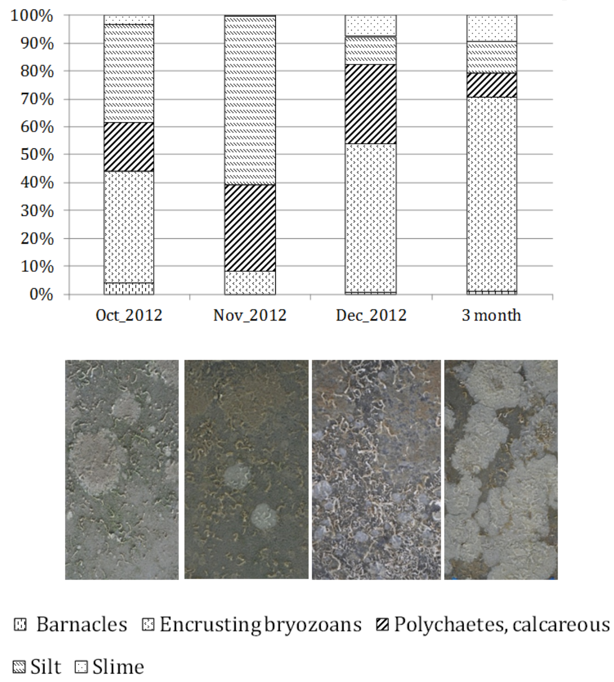

Figure 6. Percentage surface cover of fouling organisms on PVC panels submerged for one-month and three-months in Songkhla Port during the third observation period (October 2012-December 2012).

attach to mangrove root systems, fish cages leading to ecological and economic losses (Angsupanich and Himyi 2012).

In conclusion, this study provides baseline information pertaining to the occurrence and distribution of fouling organisms in the Songkhla Port. However, this is a preliminary study and further surveys are necessary to determine the economic impacts of fouling in the Port region as well as ecological impacts of invasive species in the adjacent coastal waters. Moreover, there is a need to study the pathways of biological invasions, to prevent their establishment in Thai coastal waters.

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