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Rapid assessment of target species: Byssate bivalves in a large tropical port

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Introduction

A B S T R A C T

Rapid assessment sampling for target species is a fast cost-effective method aimed at determining the presence, abundance and distribution of alien and native harmful aquatic organisms and pathogens that may have been introduced by shipping. In this study, the method was applied within a large tropical port expected to have a high species diversity. The port of Kaohsiung was sampled for bivalve molluscan species that attach using a byssus. Such species, due to their biological traits, are spread by ships to ports worldwide. We estimated the abundance and distribution range of one dreissenid (*Mytilopsis sallei*) and four mytilids (*Brachidontes variabilis*, *Arcuatula senhousa*, *Mytilus galloprovincialis*, *Perna viridis*) known to be successful invaders and identified as potential pests, or high-risk harmful native or non-native species. We conclude that a rapid assessment of their abundance and distribution within a port, and its vicinity, is efficient and can provide sufficient information for decision making by port managers where IMO port exemptions may be sought.

1. Introduction

Bivalve molluscan species, that attach using a byssus, have been recognized as successful global invaders; they have been distributed to ports and are continuing to spread worldwide (Morton and Tan, 2006; Robinson et al., 2007; Darrigran and Damborenea, 2011). The invasion success of these species is determined by their biological traits. Most of them have a free-living pelagic larvae lasting from a few days to weeks as veligers that have been found in samples of ballast water (Gollasch et al., 2015). The well-developed byssus allows the bivalve to tenaciously attach to ships' hulls and ensure transmission from port to port, especially by slow moving vessels. A study of hull fouling of vessels in dry-dock found ca. 10% of the species collected were attached by a byssus (Gollasch, 1996). In addition, such species may form extensive settlements within a few days (Minchin and Gollasch, 2003). Shipping has spread byssate molluscs, although it is often uncertain whether their transmission has resulted from either ships' ballast water or hull fouling. Another trait that contributes to the global invasion success of the byssate molluscs is their ability to feed on seston, which is enhanced within the often eutrophic environment of ports and their vicinities (Olenin and Daunys, 2005).

Several byssate mollusc species are listed among the worst invaders (ISSG, 2016), not only because of their ability to spread and proliferate within eutrophic waters, but also due to their multiple impacts on the environment and economies. Many of these species act as strong environmental engineers through the formation of dense aggregations or clusters that can modify benthic and pelagic communities, transforming habitats, and shifting ecosystem function (Sousa et al., 2009). Some byssate molluscan invaders have caused severe economic impact (i.e. Morton, 1977; Ricciardi, 1998; Mistri, 2002; Rajagopal et al., 2006) and thus, can be categorized as harmful aquatic organisms and pathogens (HAOPs) (IMO, 2004) or as target species, i.e. "Species identified by a Party that meet specific criteria indicating that they may impair or damage the environment, human health, property or resources and are defined for a specific port, State or biogeographic region" (IMO, 2007).

One approach to identifying target species is a rapid assessment sampling that is a fast cost-effective method aimed to determine the presence, abundance and distribution of alien and native HAOPs which may have been introduced by shipping (Awad et al., 2014). There are other approaches including extensive surveys of all biota in Port Biological Baseline Surveys (PBBS), based on a wide range of sampling methods (Hewitt and Martin, 2001). While PBBS involving comprehensive full-scale taxonomic investigations provide the most complete data (Hewitt and Martin, 2001; Awad et al., 2014), such studies are costly, time consuming and often not an option because of the lack of taxonomic expertise for many taxa. Whereas, rapid assessment

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surveys in many areas may be the only practical approach to obtain reliable information on target species in ports and thus the main basis for risk assessment and administrative decisions (Olenin et al., 2016).

Here we examine a single tropical port expected to have a high diversity of species (e.g. Liu, 2013) we show that, by sampling for a specific target group, in this case byssate bivalves, a rapid assessment of their abundance and distribution within a port, and its vicinity, is possible and can provide sufficient information for decision making.

2. Study site and methods

The rapid assessment was performed in the port of Kaohsiung, Taiwan, one of the world's largest ports for transporting international cargo and containers (Liu and Tsai, 2011). Due to its share of significant large volume of global ship traffic, it is likely that it may act as a receptor area for non-indigenous species (Liu et al., 2014). Kaohsiung Port extends for ca.11 km and has two entrances making the outer linear modified sand bar into an island (Fig. 1). This port has a wide range of services from dry-docking, ship-breaking to berthing many vessel classes, including recreational, fishing and merchant ships. The survey also included the canalized rivers, i.e. the Love, Canon and Cianjhen rivers, within vicinity of the port. The annual range of near surface salinity within the port area can vary from was 9.1 to 35.0, based on monitoring from 2006 to 2014, and temperatures 22.9° to 32.6 °C, with lowest salinity within the port region being at the entrance to the Love River during August 2012 during the southwest monsoon period (Fig. 1) (TIPC, 2014). Surface salinity during the 2015 study was measured using a refractometer at sampling stations. Hand–held temperatures were also taken. The combination of artificial and natural substrate together with an extended salinity gradient provides a wide range of habitats available for the settlement of various biota.

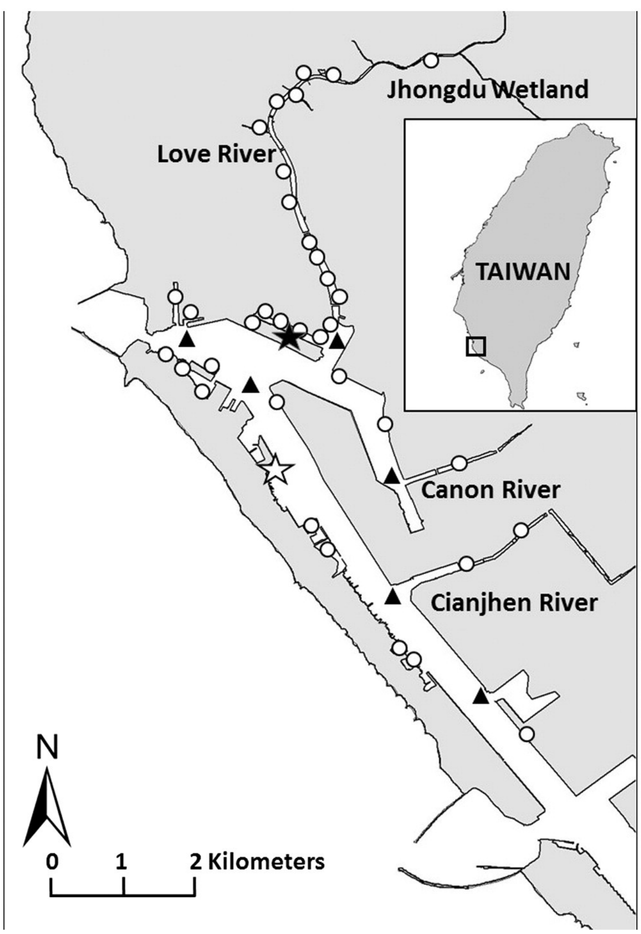

Fig. 1. Rapid assessment sampling sites (open circles) in the port of Kaohsiung, Taiwan. The solid star indicates the site where the '*Ocean Palace*' barge was berthed during 2000–2013 and the open star has been its present location since 2014. Triangles show position of environmental monitoring stations (TIPC, 2014).

The sampling was based on the abundance and distribution range (ADR) of the Biopollution method (Olenin et al., 2007). The abundance was considered '*low*' where mussels were less than ~5% cover, '*moderate*' where the species cover was less than half of the substrate and '*high*' where more than half of the substrate was covered. The distribution scales for each assessment unit ranged from '*local*', if present on one quay site, '*several localities*' if present in fewer than half the quay sites examined, '*many localities*' if present on more than half of the quay sites, and '*all localities*' if present on all quay sites. Combinations of abundance and distribution provide five levels that range from 'A', low numbers present at one or few stations, to 'E', high abundance at all stations within the port area (Table 1). This method has previously been used to assess the ADR of selected species in marinas (Minchin, 2012; Minchin and Nunn, 2013; Marchini et al., 2015), a lagoon (Wittfoth and Zettler, 2013) and employed here for the first time for a port region.

The study took place over three days (7, 8 and 13 November 2015). Prior to the study, a list of fourteen potential target species was compiled using literature of impacting byssate bivalves likely to be found in tropical western Pacific. Samples were collected by lifting submerged fouled ropes, scraping hard surfaces using a pole with attached blade of 15 cm beneath which a pocket-net collected loosened material and observation of anthropogenic substrates at low tidal levels. Areas sampled were restricted to quaysides with public access. The assessment was made at 34 stations (Fig. 1).

The results of an earlier survey on the false mussel *Mytilopsis sallei* performed in the Kaohsiung port and vicinity in 2009 (Huang et al., 2010) were used to evaluate its increase in range.

3. Results

During the survey in the port and its vicinity during November 2015 water temperature was 28°–30 °C while salinity ranged from 11 in the Love River to 35 in the port. The lowest salinity measured upstream in the Love River. Five species of byssate molluscs were found during the survey: four mytilids, *Brachidontes variabilis*, *Arcuatula senhousa*, *Mytilus galloprovincialis*, *Perna viridis*, and one dreissenid, *M. sallei* (Table 2).

3.1. The false mussel *Mytilopsis sallei*

The false mussel occurred in high abundance and was dominant in brackish conditions at all but two stations along 4.5 km the Love River, in lower sections of the rivers Canon and the Cianjhen and in the nearby port area. It was also present at the most northern mainland berthing area within the port (Fig. 2); however, it was not found in the high salinity areas in the port except at two stations where single individuals were recorded. In the upper part of the Love River there was a muddy shallow region with high turbidity and *Tilapia* spawning pools. Here only shells of *M. sallei* were found, indicating a presence at a former time. Further upriver, where there was an algal bloom and the boulders otherwise suitable for *M. sallei* attachment, were covered by a papery

Table 1
Classes of abundance and distribution (ADR) according to Olenin et al. (2007), with A, representing low abundance at one or few localities, and ranging to E, high abundance at all localities distributed within the port area sampled.

Abundance	Distribution scale			
	One locality	Several localities	Many localities	All localities
Low	A	A	B	C
Medium	B	B	C	D
High	B	C	D	E

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