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Rapid Communication

A ferry line facilitates dispersal: Asian green mussels *Perna viridis* (Linnaeus, 1758) detected in eastern Indonesia

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Abstract

While part of a single country, the Indonesian archipelago covers several biogeographic regions, and the high levels of national shipping likely facilitate transfer of non-native organisms between the different regions. Two vessels of a domestic shipping line appear to have served as a transport vector for the Asian green mussel *Perna viridis* (Linnaeus, 1758) between regions. This species is indigenous in the western but not in the eastern part of the archipelago, separated historically by the Sunda Shelf. The green mussels collected from the hulls of the ferries when in eastern Indonesia showed a significantly lower body condition index than similar-sized individuals from three different western-Indonesian mussel populations. This was presumably due to reduced food supply during the ships' voyages. Although this transport-induced food shortage may initially limit the invasive potential (through reduced reproductive rates) of the translocated individuals, the risk that the species will extend its distributional range further into eastern Indonesia is high. If the species becomes widely established in eastern Indonesia, there will then be an increased risk of incursions to Australia, where the mussel is listed as a high-priority pest species.

Key words: invasion vector, hull-fouling, bivalve, body condition index, Indonesian archipelago

Introduction

The Indonesian archipelago (4°N to 10°S and 95° to 141°E) lies at the confluence of the Eurasian, Indo-Australian, and Pacific tectonic plates and is framed by the Indian Ocean in the west and south and the Pacific Ocean in the north and east. Indonesia's large longitudinal extension (5200 km), its position between the two ocean basins, the current systems of the Indonesian Through Flow, and the isolation of sea basins during the last few glacial cycles, when parts of the Java and the Sunda Shelf were dry land, have caused a genetic break between marine species from the western (Sunda Shelf, Makassar Strait and Lombok Strait) and the eastern parts of the archipelago (Flores Sea, Banda Sea and Suhul Shelf) (Nuryanto and Kochzius 2009). The separation of the sea basins has also resulted in a high degree of endemism in the Indonesian archipelago, with a large number of species restricted to certain biogeographic regions (Briggs 2005; Allen 2008; Nuryanto and Kochzius 2009; Lord et al. 2012).

The natural borders between the various biogeographic regions of the archipelago occur within the borders of a single country, Indonesia. The many domestic shipping lines, essential for passenger and cargo transport within Indonesia, constantly cross these biogeographic borders (Abdullah et al. 2005) and thereby represent a potential vector (as fouling on their hulls or as larvae in their ballast water tanks) for transfer of species between biogeographic regions. For example, the national ferry company (PT. Pelni) operates 24 steel passenger ships that connect all parts of Indonesia from Sumatra in the west to Papua in the east. As well, many large fishing vessels transport their catches from the major fishing grounds in the east to the markets in the

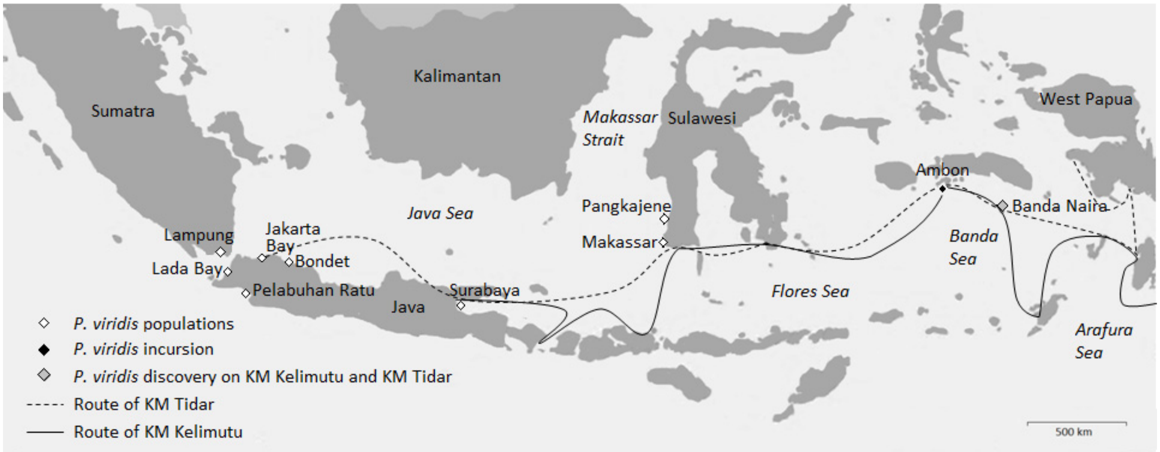

Figure 1. Routes of the KM Tidar and the KM Kelimutu in Indonesia and locations along the route where *Perna virdis* occurs and where it was found in this study. Ambon Bay and Banda Naira are outside the natural distribution of the species.

west (Williams 2009). However, there have been almost no studies to evaluate whether domestic ships serve as a significant vector for transfer of marine species between the different biogeographic regions of the Indonesian archipelago.

The Asian green mussel *Perna viridis* (Linnaeus, 1758) is a well-known hull-fouling organism with a wide indigenous and non-indigenous distribution. Moreover, in Southeast Asia, it is an important aquaculture organism that constitutes a fast-growing and cheap protein source (Rajagopal et al. 2006). Because of its moderately long planktonic-larval stage (3 weeks) and its ability to attach to surfaces by means of strong byssal threads, *P. viridis* can reach areas outside its natural distributional range when transported in ballast water or as fouling on ship hulls (Baker et al. 2007; Rajagopal et al. 2006). The mussel's native range extends from the Persian Gulf to the Malaysian peninsula and includes the Indonesian islands Sumatra, Java, and Sulawesi, as well as the Philippines (Siddall 1980). In the 1970s, the species was introduced to a number of South Pacific islands for aquaculture purposes and subsequently established populations on New Caledonia, Fiji, Tahiti, Tonga, and Samoa (Baker et al. 2007). In the West Atlantic, established populations of green mussels were detected in Trinidad, Venezuela, and Jamaica in the 1990s, and it subsequently was discovered along the southeastern coast of the United States (Buddo et al. 2003; Baker et al. 2007).

In Indonesia, *P. viridis'* native range is limited to the western part of the archipelago (Siddall 1980). Several well-studied populations of *P. viridis* occur in the Java Sea, while fewer are known from the Indian Ocean and the Strait of Malacca (Table 1). In eutrophic and anthropogenically-influenced habitats in the western archipelago, such as in Jakarta Bay, Asian green mussels often occur at high densities. Here they are harvested from bamboo structures, on which they settle naturally, by mussel farmers and sold locally (Yaqin 2010). Green mussel farming in Indonesia began in the late 1970s with first attempts at yield optimization conducted in Jakarta and Banten Bay (Davy and Graham 1982). To date, there is not any evidence of green mussel populations east of the Makassar Strait (Figure 1). Here, we report the detection of *P. viridis* in the eastern part of the Indonesian archipelago (in Ambon Bay), which is outside the mussels' native distributional range, and the finding of live specimens on the hulls of two passenger ferries that regularly cross the country from west to east. The latter hints at the particular role of national Indonesian ferries as transport vectors for marine species within the archipelago. We discuss the influence of transport conditions on the mussels' invasiveness and highlight the particular risk that the Asian green mussel poses to the ecosystems of the Banda and Arafura Sea.

Materials and methods

We obtained information about the possible presence of *Perna viridis* in the eastern region of Indonesia from interviews with bivalve specialists of the Indonesian Institute of Science (LIPI) and the Ministry of Marine Affairs and

Table 1. Known populations of *Perna viridis* in Indonesia. References referring to a mussel population are marked by * and those referring to habitat quality by †. All but Ambon Bay are within the native distribution range of the species.

Location	Habitat quality	Reference
Belawan, North Sumatra, Malacca Strait	medium anthropogenic influence	Sudharyanto et al. (2005)*†, Hayati (2009)*†
Lampung, Sumatra, Sunda Strait	medium-high anthropogenic influence, evidence of heavy metals	Damar (2003)†, Sudharyanto et al. (2005)*†, Tugiyono (2007)*†
Lada Bay, Java, Sunda Strait	medium anthropogenic influence	Sudharyanto et al. (2005)*†, Jalius et al. (2008)*†, present study*†
Jakarta Bay, Java, Java Sea	high anthropogenic influence, heavy metals, evidence of organochlorines	Sudharyanto et al. (2005)*†, Jalius et al. (2008)*†, present study*†
Bondet, Java, Java Sea	high anthropogenic influence, evidence of organochlorines	Sudharyanto et al. (2005)*†
Pelabuhan Ratu, Java, Indian Ocean	medium anthropogenic influence	present study*†, Arfin et al. (2012)†
Surabaya, East Java, Java Sea	high anthropogenic influence, evidence of organochlorines	Sudharyanto et al. (2005)*†
Pangkajene, South Sulawesi, Makassar Strait	low anthropogenic influence	Sudharyanto et al. (2005)*†, Yaqin et al. (2011)*†
Makassar, South Sulawesi, Makassar Strait	high anthropogenic influence, evidence of heavy metals	Fachruddin and Musbir (2011)*†, Lestari (2002)*†
Ambon Bay, Banda Sea	medium anthropogenic influence, evidence of TBT	present study (possibly not established)*†, Evans et al. (1995)†

Fisheries (KKP) in Ambon, Moluccas. These workers have occasionally sighted *P. viridis* in Ambon Bay since 1994. We confirmed this information by collecting live specimens from two locations within Ambon Bay in July and November 2012 and in March 2013. The species was identified according to morphological characteristics based on Siddall (1980). Within Ambon Bay, the mussels had settled on Mangrove roots and on mariculture platforms. Additional work will be needed to determine whether the populations are reproducing and, if so, the extent of the populations. The focus of this study, however, was on identifying potential vectors for the transfer of the green mussel to the eastern part of Indonesia.

Discovery of mussels on the hull of two ferries

On 26 August 2013, live specimens of *P. viridis* were found in the front propeller slot of the ferry *KM Kelimutu*. The mussels were discovered in Banda Naira, Banda Islands, Moluccas, (Figure 1) by local divers who had been asked to free the propeller from an entangled rope. Ten specimens of the approximately 100 individuals on the ship were collected, the soft tissue separated from the shell, and the shells sent to us at the Marine Centre, Agricultural Institute Bogor (IPB), Indonesia, for identification. Here the shell length (longest anterior-posterior dimension) was measured with calipers to the nearest 0.1 mm. Two months later, on 28 October 2013, divers in Banda Naira discovered another group of live *P. viridis* on the ferry *KM Tidar*. As on the *KM Kelimutu*, the mussels had settled inside the front propeller slot, where they covered an area of about 4 m² (Figure 2). Twenty-six specimens of different sizes were collected and the shell length determined as described above.

On *KM Tidar's* next return trip to Banda on 15 November 2013, another 58 live mussels with a mean (± SD) shell length of 30.7 ± 2.1 mm were collected in order to compare their body condition indices (BCI) to those of green mussels gathered in Ambon (mean 43.0 ± 8.1 mm, n = 22) and at three locations along the coast of West Java (Figure 1) between April 2012 and May 2013: Jakarta Bay (mean 40.1 ± 5.0 mm, n = 60), Lada Bay (mean 36.9 ± 6.9 mm, n = 60), Pelabuhan Ratu (mean 49.6 ± 7.0 mm, n = 25). The BCI is a measure of the physical condition of mussels and was calculated as the dry weight of the soft tissue (dried at 60°C until the weight remained constant, which was the case for all samples within 24 hours) divided by the dry weight of the shell. The higher the BCI, the better the mussel's nutritional status and its resistance to environmental stress (Wang et al. 2011). We used ANOVA followed by a Tukey's all-pairwise-comparison

Figure 2. Asian green mussel fouling on the KM Tidar, Banda Naira, 28.10.2013. Photograph by Guido Weissenfeld.

test using the free software R (R Core Team 2013) to test whether the BCIs of mussels differed significantly between the various origins. A reciprocal data transformation was conducted prior to the analysis to achieve normality.

Route and layover times of KM Tidar and KM Kelimutu

Both ferries that had *P. viridis* on their hulls are important connections between the island of Java in the western part and the Moluccas and West Papua in the eastern part of the Indonesian archipelago. The *KM Tidar* travels between Jakarta and West Papua biweekly. On its way, it passes by Surabaya, Makassar, Bau Bau, Ambon, Banda, Tual and Dobo (Figure 1). The longest stopover is in Jakarta with a layover time of 18 hours. Layover times at the other harbours are shorter, ranging between two and four hours. The *KM Kelimutu* follows a similar route, but starts its monthly journey in Surabaya (Java), passes by Benoa (Bali), Bima (Sumbawa), Makassar, Bau Bau and Wanci (Sulawesi), Ambon, Banda, Saumlaki, Tual and Dobo (Moluccas), and ends its trip after a few additional stopovers in the Arafura Sea in Merauke (West Papua). Layover times in Surabaya usually are 18 hours but can be extended to several days. The longest layover known to us was 18 days in April/May 2013. The *KM Kelimutu* visits all other harbours for two to four hours on its regular trips. In January 2013, the *KM Kelimutu* spent one month in Tanjung Priok, Jakarta Bay, which is where all Pelni ferries go for a dry dock inspection annually.

Results

The mean (± SD) shell lengths of *Perna viridis* specimens collected from the *KM Kelimutu* on 26 August 2013 was 28.04 ± 8.02 mm (range 18.7 to 41.7 mm, n = 10). The mean shell length of specimens collected from the *KM Tidar* on 28 October 2013 was 28.07 ± 12.55 mm (range 7.7 to 49.7 mm, n = 26).

The mean BCIs of the mussels collected from the *KM Tidar* on 15 November 2013 and the BCIs of the mussels collected from Ambon and from places along the coast of West Java in 2012 and 2013 differed significantly (ANOVA, $F_{4, 220} = 121.3$; $P < 0.0001$). The BCIs of the *KM Tidar* mussels were the lowest, being, on average, 62% lower than those of mussels from Jakarta Bay, 34% lower than those of Lada Bay mussels, 13% lower than in mussels from Pelabuhan Ratu and 10% lower than in mussels from Ambon (Figure 3). With two exceptions (Ambon Bay vs. *KM Tidar* and Ambon Bay vs. Pelabuhan Ratu), all pairwise comparisons revealed significant differences (Tukey's test, $P < 0.01$, Figure 3).

Discussion

The discovery of *Perna viridis* on two ferries demonstrates the potential role of domestic ship traffic as a vector for species transfer within the Indonesian archipelago. Moreover, the current case of *P. viridis* illustrates how this anthropogenic influence can break open the faunal discontinuity between the western and eastern Indonesian

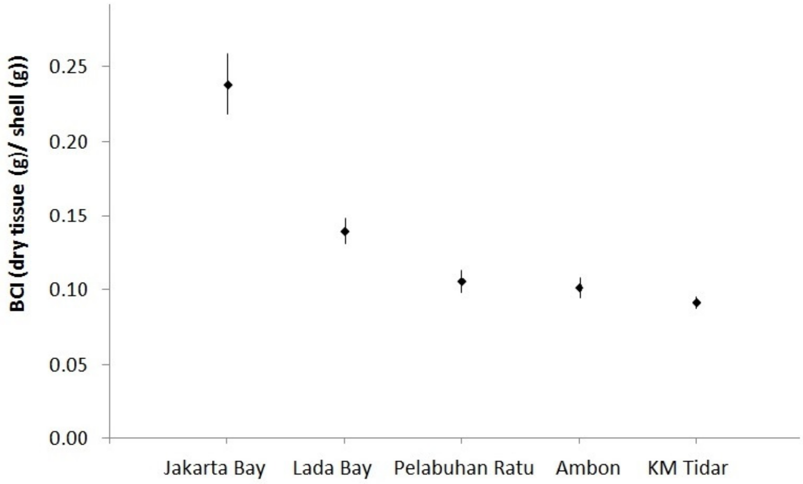

Figure 3. Body Condition Indices (means and 95% confidence intervals) of *Perna viridis* (shell length = 24.2 – 60.0 mm) from different locations in Indonesia. Means sharing the same letter were not significantly different (Tukey's test, $P > 0.05$)

archipelago, since *P. viridis* is considered to be non-indigenous in the eastern archipelago. Passenger and military naval ship traffic in the archipelago have been frequent since the mid 9th century (Rutz and Coull 1996), and, therefore, incursions of *P. viridis* to Ambon Bay or to other parts of the eastern archipelago are probably not new, but have never been reported. If a history of mussel incursions exists, the question arises, why the species did not establish in the eastern areas at an earlier date, and whether growing anthropogenic pressure would increase the potential for the mussels to establish permanent populations. If earlier incursions of *P. viridis* to the eastern Indonesian archipelago have indeed been overlooked in the past, the cryptic number of other species transported between the different biogeographic regions is presumably high as well.

The mussels collected from the *KM Kelimutu* ranged from 18.7 to 41.7 mm in shell length and those from *KM Tidar* from 7.7 to 49.7 mm. Therefore, mussels from both ferries likely stem from multiple recruitment events. Growth rates in *P. viridis* can be very variable and dependent on the habitat quality. Therefore, it is difficult to infer the ages of the mussels found on the ferries. The lowest growth rate reported for *P. viridis* in a size range of 30–50 mm is 2.29 mm per month (Cheung 1993). Using this as a reference, and taking into account that the *KM Kelimutu* had left Tanjung Priok, Jakarta Bay, 7 months before our sampling, and did not return there until the mussels were discovered in Banda Naira, it is possible that some of the larger individuals had colonized the ship in Jakarta Bay. Because of the large variation in the sizes of mussels found on *KM Kelimutu*, additional recruitment must have occurred in other locations along the route. The most likely donor harbour for the mussels on *KM Kelimutu* is Surabaya because of the long layover times known from there. In all other harbours, the 1–3 hours stops would only be sufficient for a substantial colonization of surfaces by *P. viridis* if propagule pressure was high and if the pediveligers were competent to settle.

The mussels found on the *KM Tidar* covered a nearly continuous size range. This means that all harbours on its route with known *P. viridis* populations are possible sources of colonists but, due to the above mentioned reasons, unlikely origins of mussels. If the number of recruits is a positive function of layover-time, the most likely source population is Jakarta Bay where the ferry spends 18 hours between two trips every 14 days. There, according to local mussel fishermen, reproduction in *P. viridis* occurs throughout the year. Therefore, mussels may have settled on the *KM Tidar* during several stopovers in Jakarta in 2013. Stopovers in Surabaya are much shorter (3–6 hours), which makes this place a less likely origin. However, we cannot exclude that some mussels recruited in Jakarta Bay, while others stem from Surabaya or Makassar.

Regardless of where along the ferry routes the mussels originate from, the facts that mussels A) had settled on two different ferries and B) very likely stem from several recruitment events demonstrate that the domestic ferries serve as a vector that may facilitate the west-to-east dispersal of *P. viridis* (and likely other species) in Indonesia. So far, the possible ecological consequences of the establishment of Asian green mussels in eastern Indonesia have not been investigated. Since 2012, we regularly found *P. viridis* in Ambon. However, it is unclear whether the mussels have already established a permanent population or whether the findings from there result from repeated introductions by ferries or other domestic vessels. These are not mutually exclusive mechanisms.

Not only is ferry traffic from Java and Sulawesi to Ambon frequent occurrence but the Banda and Arafura Sea are very important fishing grounds (Abdullah et al. 2005; Stacey et al. 2011). Thus, there is a lot of fishing-vessel traffic that brings with it another set of problems, in particular for adjacent jurisdictions. The control of fishing activities in the remote areas of the Arafura Sea is difficult (Stacey et al. 2011) as there is a problem with illegal crossings of fishing vessels between this region and northern Australia (Fox and Sen 2002). These fishing boats, in addition to the large cargo vessels that connect Australia to the western part of the Indonesian archipelago, may represent a pathway for the introduction of *P. viridis* to Australia. The green mussel is listed as a high priority pest species in Australia (Australian Government National System for the Prevention and Management of Marine Pest Incursions 2011) and comprehensive management efforts have been taken to prevent it from becoming established (McDonald 2012; Dias et al. 2013). The establishment of permanent populations of *P. viridis* in the Banda and Arafura Seas increases the risk of further introductions of the bivalve to Australia.

The establishment of *P. viridis* in the Banda and Arafura Seas seems likely because most of the individuals we found on the *KM Kelimutu* and the *KM Tidar* had reached reproductive size. Under favourable conditions, gonad development in *P. viridis* usually starts at a shell length of 12 mm and, when mussels are growing slowly, they mature even at shorter lengths (Rajagopal et al. 2006). In addition, spawning events can be triggered by fluctuating environmental conditions such as sudden changes in temperature or salinity (Vakily 1989; Rajagopal et al. 2006). This may increase the likelihood of spawning during one of the layovers because many harbours are located near estuaries and therefore show pulses of low salinity. However, the mussels from *KM Tidar,* which we dissected to measure BCIs, had pale yellow to orange gonads, which indicates that they were not in a mature but in a resting or post-spawning phase within the reproductive cycle. The fact that the mussels we collected from the *KM Tidar* had significantly lower BCIs than those from coastal populations is plausible since the animals presumably experienced food shortage during transport. While the one sample of mussels examined in this study was not in spawning condition, should any of these mussels become detached from the hull, they may become reproductively active. In general, the environmental conditions in the eastern regions of the Indonesian archipelago are suitable for *P. viridis,* which is able to tolerate a wide range of environmental conditions (Rajagopal et al. 2006). On a local scale, environmental stressors such as sedimentation, fresh water runoff, or hypoxia may even favour *P. viridis* over other native hardbottom species, because of its broad environmental tolerance (Seed 1999; Wang et al. 2011).

To minimize the risk of establishment of *P. viridis* in eastern Indonesia, regular inspections of ship hulls and their cleaning from fouling organisms should be mandatory. This, in particular, applies to ferries that connect biogeographic regions within the Indonesian archipelago and to vessels on trans-border routes between Indonesia and its neighboring countries. The establishment of the Asian green mussel in the Banda and Arafura Sea, which are part of one of the world's biodiversity hotspots and support a large number of marine endemic species (Allen 2008), represents a major risk to the integrity of these unique marine ecosystems. For their future protection, comprehensive monitoring activities are needed to be able to detect and then stop invasions by species like the Asian green mussel at an early stage.

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References

Abdullah A, Agustina H, Astuty W, Bachtiar I, Bizot D, Budimawan, DeVantier L, Dutton I, Djohani R, Erdmann M (2005) Global International Waters Assessment Indonesian Seas, GIWA Regional Assessment 57: 1–160

Allen GR (2008) Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18(5): 541–556, http://dx.doi.org/10.1002/aqc.880

Arfin Z, Puspitasari R, Miyazaki N (2012) Heavy metal contamination in Indonesian coastal marine ecosystems: A historical perspective. *Coastal Marine Science* 35(1): 227–233

Baker P, Fajans JS, Arnold WS, Ingrao DA, Marelli DC, Baker SM (2007) Range and Dispersal of a Tropical Marine Invader, the Asian Green Mussel, *Perna viridis*, in Subtropical Waters of the Southeastern United States. *Journal of Shellfish Research* 26(2): 345–355, http://dx.doi.org/10.2983/0730-8000(2007)26[345:RADOAT]2.0.CO;2

Briggs JC (2005) The marine East Indies: diversity and speciation. *Journal of Biogeography* 32(9): 1517–1522, http://dx.doi.org/10.1111/j.1365-2699.2005.01266.x

Buddo DS, Steele RD, D'Oyen RE (2003) Distribution of the invasive Indo-Pacific Green mussel, *Perna viridis*, in Kingston harbour, Jamaica. *Bulletin of Marine Science* 73(2): 433–441

Cheung S (1993) Population dynamics and energy budgets of green-lipped mussel *Perna viridis* (Linnaeus) in a polluted harbour. *Journal of Experimental Marine Biology and Ecology* 168: 1–24, http://dx.doi.org/10.1016/0022-0981(93)90113-3

Damar A (2003) Effects of enrichment on nutrient dynamics, phytoplankton dynamics and productivity in Indonesian tropical waters : a comparison between Jakarta Bay, Lampung Bay and Semangka Bay. PhD Thesis, Kiel University, Kiel, Germany, 196 pp

Davy FB, Graham M (1982) Bivalve Culture in Asia and the Pacific. Proceedings of a workshop held in Singapore, 16-19 February 1982. International Development Research Center, Ottawa, Ontario Canada, 90 pp

Dias JP, Fotedar S, Gardner JPA, Snow M (2013) Development of sensitive and specific molecular tools for the efficient detection and discrimination of potentially invasive mussel species of the genus *Perna*. *Management of Biological Invasions* 4: 155–165, http://dx.doi.org/10.3391/mbi.2013.4.2.09

Evans SM, Dawson M, Day J, Fried CLJ, Pattisina LA, Porter J (1995) Domestic Waste and TBT Pollution in Coastal Areas of Ambon Island (Eastern Indonesia). *Marine Pollution Bulletin* 30(2): 109–115, http://dx.doi.org/10.1016/0025-326X(94)00182-9

Fachruddin dan Musbir L (2011) Konsentrasi Logam Berat Cd Dalam Air Laut, Sedimen dan Daging Kerang Hijau (*Perna viridis*) di Perairan Pantai Makassar. Research Report, Hasanuddin University Makassar, Sulawesi, Indonesia, 7 pp

Fox JJ, Sen S (2002) A Study of Socio-Economic Issues Facing Traditional Indonesian Fishers who Access the MOU Box: A Report for Environment Australia, Research School of Pacific and Asian Studies, The Australian National University, Canberra, Australia, 64 pp

Hayati N (2009) Analisis kadar Arsen (As) pada kerang (Bivalvia) yang berasal dari laut Belawan. Universitas Sumatera Utara, Medan, Sumatra, Indonesia, 66 pp

Jalius, Setiyanto DD, Sumantadinata K, Riani E, Ernawati J (2008) Akumulasi Logam Berat dan Pengaruhnya Terhadap Spermatogenesis Kerang Hijau (*Perna viridis*). *Jurnal Ilmu-ilmu Perairan dan Perikanan Indonesia* 15(1): 77–83

Lestari A (2002) Kandungan logam berat Hg dan Pb pada kerang hijau (*Mytilus viridis*) berbagai ukuran hasil tangkapan di pantai Losari Makassar Propinsi Sulawesi Selatan. S1 Thesis Agricultural University Bogor IPB, Bogor, West Java, Indonesia, 41 pp

Lord C, Lorion J, Dettai A, Watanabe S, Tsukamoto K, Cruaud C, Keith P (2012) From endemism to widespread distribution: phylogeography of three amphidromous *Sicyopterus* species (Teleostei: Gobioidei: Sicydiinae). *Marine Ecology Progress Series* 455: 269–285, http://dx.doi.org/10.3354/meps09617

McDonald JI (2012) Detection of the tropical mussel species *Perna viridis* in temperate Western Australia: possible association between spawning and a marine heat pulse. *Aquatic Invasions* 7(4): 483–490, http://dx.doi.org/10.3391/ai.2012.7.4.005

Nuryanto A, Kochzius M (2009) Highly restricted gene flow and deep evolutionary lineages in the giant clam *Tridacna maxima*. *Coral Reefs* 28(3): 607–619, http://dx.doi.org/10.1007/s00338-009-0483-y

R Core Team (2013) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/

Rajagopal S, Venugopalan VP, van der Velde G, Jenner HA (2006) Greening of the coasts: a review of the *Perna viridis* success story. *Aquatic Ecology* 40(3): 273–297, http://dx.doi.org/10.1007/s10452-006-9032-8

Rutz WOA, Coull JR (1996) Inter-island passenger shipping in Indonesia: development of the system. Present characteristics and future requirements. *Journal of Transport Geography* 4(4): 275–286, http://dx.doi.org/10.1016/S0966-6923(96)00028-2

Seed R (1999) Evolutionary traits in *Perna viridis* (Linnaeus) and *Septifer virgatus* (Wiegmann) (Bivalvia: Mytilidae). *Journal of Experimental Marine Biology and Ecology* 239(2): 273–287, http://dx.doi.org/10.1016/S0022-0981(99)00043-X

Siddall SE (1980) A clarification of the genus *Perna* (Mytilidae). *Bulletin of Marine Science* 30(4): 858–870

Stacey N, Nurhakim S, Nugroho D, Soselisa H, Resosudarmo B, Kalis O, Monteiro J, Prescott J, Martin J, Karam J (2011) Socio-economic Profile of the Arafura Timor Seas. Report Prepared for the Transboundary Diagnostic Analysis component of the Arafura Timor Seas Ecosystem Action Program, ATSEA Program, Jakarta, Indonesia, 135 pp

Sudharyanto A, Muchtar M, Razak H, Tanabe DS (2005) Kontaminasi organoklorin persisten dalam kerang hijau. *Oseanologi dan Limnologi di Indonesia* 37: 1–14

Tugiyono (2007) Bioakumulasi Logam Hg dan Pb di Perairan Teluk Lampung, Propinsi Lampung. *Journal Sains MIPA* 13(1): 44–48

Vakily JM (1989) The Biology and Culture of Mussels of the Genus *Perna* 17th ed., Manila, Philippines: ICLARM Studies and Reviews, 63 pp

Wang Y, Hu M, Wong WH, Cheung SG, Shin PKS (2011) Combined Effects of Dissolved Oxygen and Salinity on Growth and Body Composition of Juvenile Green-Lipped Mussel *Perna viridis*. *Journal of Shellfish Research* 30(3): 851–857, http://dx.doi.org/10.2983/035.030.0326

Williams P (2009) Indonesian tuna fisheries: getting to know our neighbours. *SPC Fisheries Newsletter* 129: 29–33

Yaqin K, Lay BW, Riani E, Masud ZA, Hansen PD (2011) Hot spot biomonitoring of marine pollution effects using cholinergic and immunity biomarkers of tropical green mussel (*Perna viridis*) of the Indonesian waters. *Journal of Toxicology and Environmental Health Sciences* 3(14): 356–366

Yaqin K (2010) Potential use of cholinesterase activity from tropical green mussel, *Perna viridis* as a biomarker in effect-based marine monitoring in Indonesia. *Coastal Marine Science* 34(1): 156–164