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First Record of the Invasive Mussel *Mytella strigata* (Mollusca: Bivalvia: Mytilidae) in Panguil Bay, Southern Philippines

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ABSTRACT

Here, we report the first record of the invasive mussel species *Mytella strigata* Hanley, 1843 in Panguil Bay, southern Philippines confirmed through its conchological features. Mussels appeared in dense mats attached to rocks, wood, and substrate in the intertidal region in the innermost portion of the bay. Locals first noticed the species in late 2018, which, according to them, adversely affected their catches of mangrove crabs *Scylla* spp. and the Asian hard clam *Meretrix meretrix* Linnaeus, 1758. There is a need to ascertain the distribution of the species within the bay, investigate socio-ecological and economic impacts, and formulate monitoring, surveillance, and impact mitigation measures.

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INTRODUCTION

Biological invasions are a grave problem faced by native species and marine ecosystems worldwide (Lim et al., 2018). The success of an invasive species lies in its ability to survive a wide range of environmental conditions outside its native range and its capability to reproduce rapidly to establish large populations (Jayachandran et al., 2018). In Asia, *Mytella strigata* Hanley, 1843 in Hanley (1842-1846) is considered an emerging invasive mussel species that has expanded from its native range in Central and South Americas to North America and Asia. Ballast waters of ship hull spread these mussel species (Spinuzzi et al., 2013; Rice et al., 2016; Mediodia et al., 2017; Vallejo et al., 2017; Lim et al., 2018; Biju Kumar et al., 2019; Jayachandran et al., 2019; Sanpanich and Wells, 2019).

In the Philippines, this species— formerly identified as *Mytella charruana* d'Orbigny, 1846 in d'Orbigny (1834-1847), now considered as a junior synonym of *M. strigata*— was first reported by Vallejo et al. (2017) in 2014 during a survey in Manila Bay. Since then, the species has spread to the adjacent provinces of Cavite, Bulacan, Bataan, Pangasinan, Cagayan, La Union, Ilocos Sur, Zambales, Pampanga and in the cities of Parañaque and Navotas in Metro Manila (Rice et al., 2016; Mediodia et al., 2017, Fuertes et al., 2021). The recent survey by Fuertes et al. (2021) in 2018–2019 did not record the occurrence of this species in the Visayas region while no survey has been conducted in the Mindanao region.

The present study aims to report the occurrence of *M. strigata* in the inner portion of Panguil Bay in the southern Philippines, whose identification has been confirmed morphologically. This paper brings initial attention to the occurrence of this invasive species in the bay to elicit rapid response to prevent their expansion and establishment and mitigate socio-economic and ecological impacts.

MATERIALS AND METHODS

The presence of dense mats of black mussels not previously recognized and morphologically different from the native species of brown mussel Modiolus *modulaides* Röding, 1798 were first noticed to occur in the ponds of the Brackishwater Fisheries Research and Development Center and the nearby coastal area in Lala, Lanao del Norte. The black mussels in the ponds were semi-infaunal; that is, half of its shell is buried in the substrate, while in the coastal area, it was observed that they attached using its byssal thread to stones and wood. Hence, in February, a survey of its

occurrence in nearby coastal areas in Barangays Pacita and Camalan in Lala and Barangay Taguitic in Kapatagan, Lanao del Norte (Fig. 1) was conducted. Informal interviews with fisherfolk were done to determine the first occurrence, utilization, and problems encountered with the presence of the species in the area. Samples (n= 28) were taken for morphological identification of the species with the shell length recorded using a ruler (precision: 0.01cm). Photo documentation was done in the areas where the species occurred.

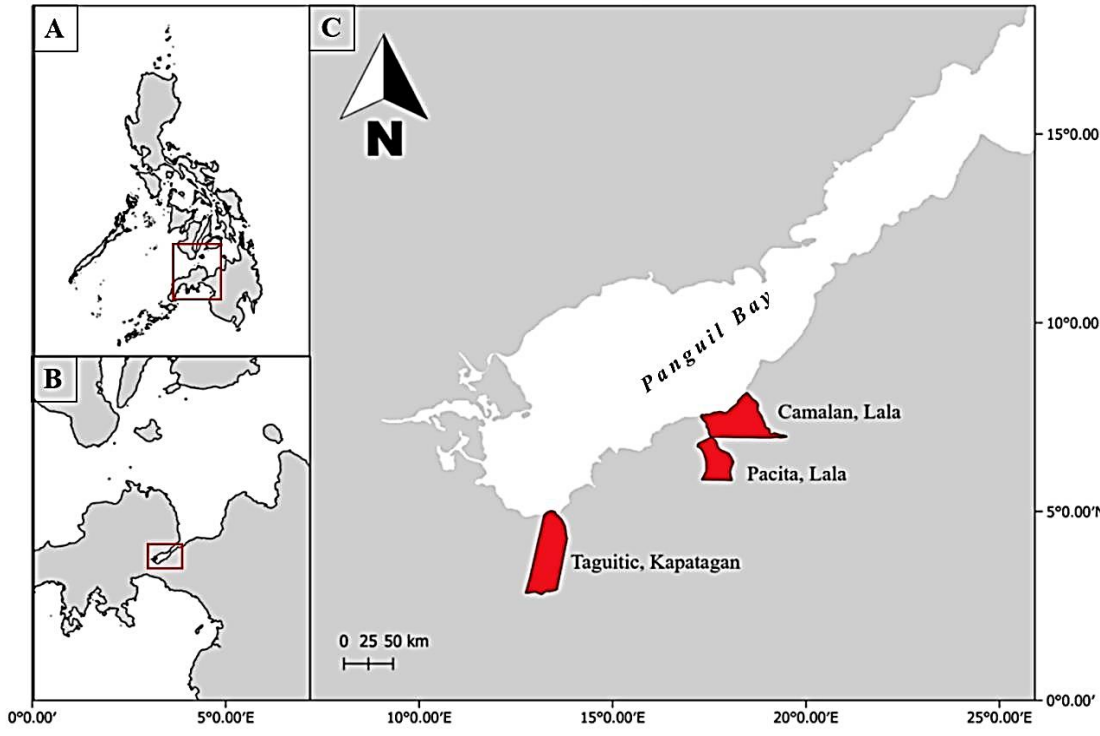

Figure 1. Map showing the sites visited with thriving *Mytella strigata* Hanley, 1843 populations in the innermost part of Panguil Bay in Lanao del Norte (A- Philippine Map, B- Northwestern Mindanao, C- Panguil Bay).

RESULTS AND DISCUSSION

The collected specimens from Panguil Bay were typically mytiliform in outline, with terminal umbones and rounded posterior margin. Individuals ranged from 3.60cm to 5.80cm with a mean of 4.72±1.00cm in shell length. The external shell coloration was greenish-brown to grey and entirely black, while a bluish to purplish nacreous interior was observed. Internally, the shell hinge has a pitted resilial ridge along the base of the ligament on each valve. In addition, small but distinct teeth on the inner

anterior margin are observed. A curved pallial line is present with the posterior adductor muscle scar confluent with the byssus retractor muscle scar (Fig. 2).

These conchological features agree well with the American charru *mussel M. strigata* found in Singapore (Lim et al. 2018) and India (Jayachandran et al. 2019). Moreover, the curved pallial line described by Mediodia et al. (2017) unique to *M. charruana* (=*M. strigata*) was present in the collected samples from Panguil Bay. Table 1 shows the comparison of the shell morphological characteristics and unique identifying features of common mussel species. Among all the common mussel species, *M. strigata* can be uniquely identified based on the presence of a curved pallial line towards the adductor muscle scar (Mediodia et al., 2017). In addition, its anterior scar has only one retractor scar and the shape of the valve is more angular with radial ribs.

Moreover, various experts (Dr. Michael Rice, 2021, The University of Rhode Island, U.S.A.; Dr. Yu-San Han, 2021, National Taiwan University, Taiwan; Dr. Tan Koh Siang, 2021, National University of Singapore, Singapore; Dr. Paravanparambil Rajakumar Jayachandran, 2021, Cochin University of Science and Technology, India) confirmed the morphological identification of the mussel samples from Panguil Bay as *M. strigata*. However, they all expressed that a final verification through molecular techniques is necessary.

Dense populations of an unknown mussel species grew in the ponds of the Brackishwater Fisheries Research and Development Center in Pacita, Lala, Lanao del Norte (Fig. 3D-E). Upon examination, the species is morphologically different from *M. modulaides*, the native species of brown mussel abundant in the area. The field survey conducted in nearby areas revealed that the same species is abundantly growing attached to rocks, wood, and seabed in the intertidal area (Fig. 3A). Informal interviews with local fisherfolk revealed that these fisherfolks first observed these mussel species in late 2018. Moreover, they perceive the prevalence of the mussel as a problem, which adversely affected both the mangrove crab fishery and culture in the area. Accordingly, with the occurrence of the mussel, their catches of mangrove crabs have lowered. Locals have observed mangrove crabs attached by mussels on their carapace and eye sockets (Fig. 3C). Moreover, they noted that populations of local bivalve species such as the Asian hard clam *Meretrix meretrix* Linnaeus, 1758 have lowered, which may be caused by the mussels attaching to the clam (Fig. 3B). While locals tried to consume the mussel as food, they still preferred the native brown mussel species.

Table 1. Comparison of the shell morphological characteristics and unique identifying features of common mussel species.

Species	Shell color and description	Unique identifying feature	Author
Mytella strigata (=M. charruanna)	Shell is predominantly dark brown to a black color and a bluish to the purplish nacreous interior. Size ranges from 2870 mm in length.	The pallial line showed a curved line towards the adductor scar. In addition, the anterior scar has only one retractor scar and the shape of the valve is more angular with radial ribs.	Rice et al. (2016); Vallejo et al. (2017); Lim et al. (2018); Biju Kumar et al. (2019); Jayachandran et al. (2019); Fuertes et al. (2020); Huang et al. (2021)
Perna viridis	The shell is brilliant emerald-green for juveniles while dark green with a more significant proportion of brown color observed for adults. Size ranges from 4994 mm in length.	There is a presence of enlarged sensory papillae along the edges of the mantle.	Siddall (1980); Rajagopal et al. (2006); Gobin et al. (2013); Gracia and Rangel-Buitrago (2020)
Perna perna	Shell is generally brown to maroon with irregular areas of light brown and green. Size ranges from 34-60 mm in length.	There is an absence of an anterior adductor muscle and the gaping behavior.	Hicks and Tunnel (1995); Rajagopal et al. (2003); Lourenco et al. (2012); Oliveira et al. (2016); Biju Kumar et al. (2019); Alves et al. (2020)
Perna canaliculus	The shell is smooth or slightly ribbed in some species and the shiny, smooth periostracum is black or brown. Its size ranges from 80-120 mm in length.	There may be one or two teeth but no laterals. Further, light-colored zigzag markings are most common in this species.	Siddall (1980); Quayle and Newkirk (1989); Zeldis et al. (2004); Skelton and Jeffs (2020)
Mytilus edulis	Shell is triangular and elongated with round edges of purple or blue color. It is smooth with a sculpturing of fine concentric growth lines but no radiating ribs. Size ranges from 25-60 mm in length.	Anterior adductor is always present with one retractor scar. It has no primary lateral teeth and has one to two dysodont teeth and with pitted resilial ridge.	Siddall (1980); Akumfi and Hughes (1987); Quayle and Newkirk (1989); Mediodia et al. (2017)

Earlier comprehensive mollusks resource assessment conducted by De Guzman et al. (1991) in 1990-1991 only identified *M. modulaides* (formerly *M. metcalfei*) as the only mussel species in Panguil Bay. However, in the rivers of Losno and Migpangi, the local divers collected freshwater mussel species locally called *tahong-tahong*, which was not scientifically identified and characterized as "tiny mussels."

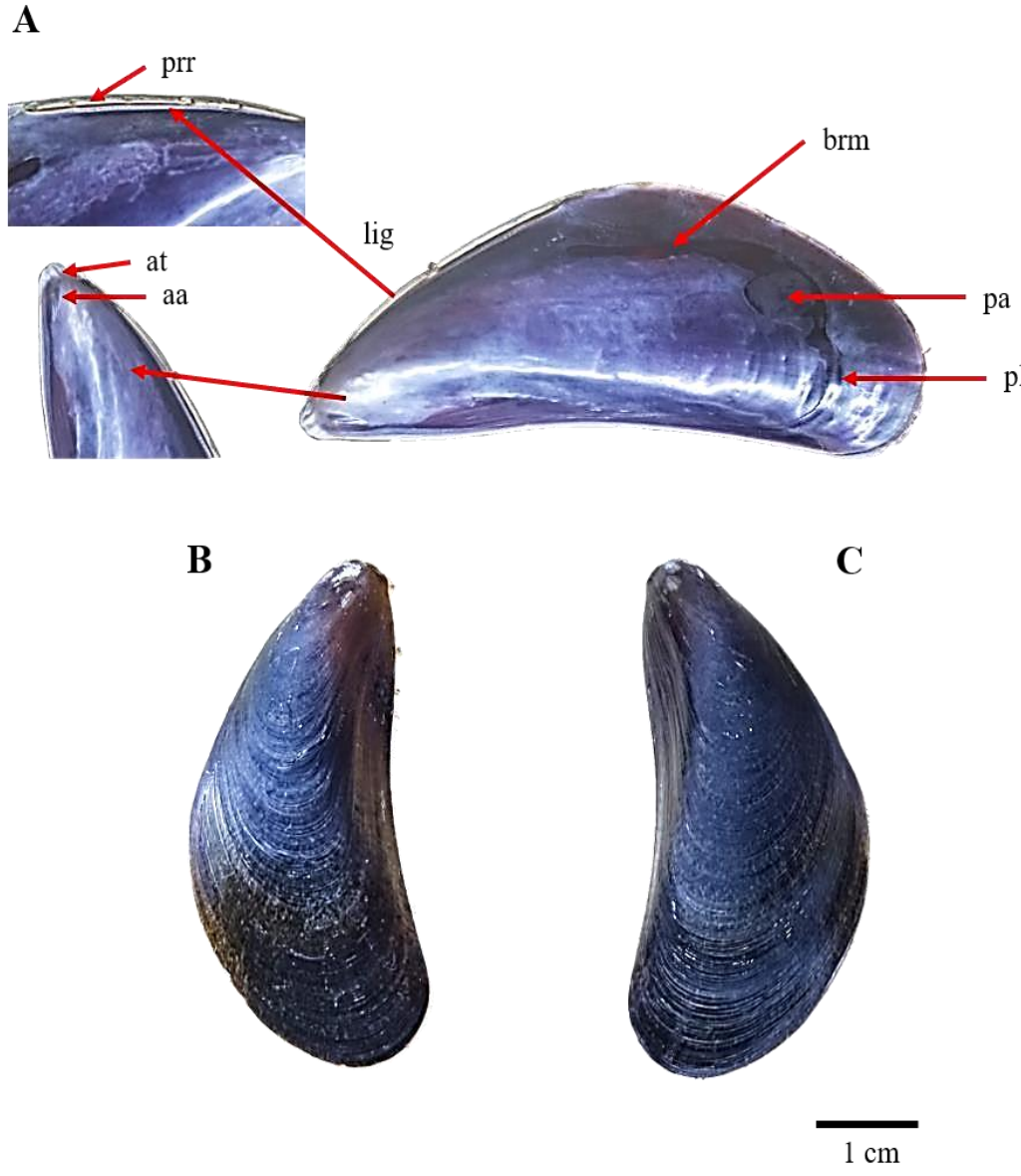

Figure 2. The shell of *Mytella strigata* Hanley, 1843 collected from Panguil Bay, southern Philippines, showing the inner valve with different conchological features (A) and outer right (B) and left (C) valves of the shell. Abbreviations: aa, anterior adductor muscle scar; at, anterior teeth; brm, byssus retractor muscle scar; lig, ligament; pa, posterior adductor muscle scar; pl, pallial line; prr, pitted resilial ridge.

Figure 3. The invasive mussel *Mytella strigata* Hanley, 1843 observed in Panguil Bay: A) newly collected specimens growing on rocks in the mangrove area, B) small invasive mussel observed attaching to the Asian hard clam (*Meretrix meretrix*) as indicated by the red arrow, C) small invasive mussel observed attaching below the eyestalk of a mangrove crab (*Scylla* sp.) as indicated by the red arrow, and D–E) drained fishpond showing the abundance of M. strigata (red arrow: close-up photograph).

The same findings were reported in the succeeding resource assessments in 1995-1996 by MSUNFSTDI (1996) and in 2005 by Jimenez et al. (2009). Moreover, Rosell (1991) reported another mussel species in the bay, the green mussel *Perna viridis*. However, there was no mention of any mussel species with the same characteristics as described in this present study.

Vallejo et al. (2017) suggested that the invasion of *M. strigata* in the Philippines was mediated by ballast water discharge from ships or biofouling on the hulls of shipping boats. A similar model is suggested here, as Panguil Bay hosts the Port of Ozamiz, one of the Philippines' major gateway ports. While our survey sites were located in the innermost portion of the bay, it is still unknown whether populations of *M. strigata* have been established in the outer region. However, the inner portion of the bay is an ideal habitat for this species due to the lower salinities (< 16.0 ppt, Jumawan et al., 2020). Mussel *M. strigata* can survive both in marine environments—e.g. salinities higher than 25 ppt and in estuarine environments—e.g. salinities as low as 5 ppt (Rice et al., 2016). Furthermore, this species can acclimate to gradual changes in salinity, further increasing its potential to invade a wide variety of habitats (Yuan et al., 2010; Rice et al., 2016). Thus, the establishment of this invasive species in the bay may not only have adverse impacts on the local species that may be displaced but will also have socioeconomic implications.

CONCLUSION AND RECOMMENDATIONS

In this present report, we confirmed through morphological identification the presence of the invasive mussel *M. strigata* in Panguil Bay, southern Philippines. While this species has been recorded in the northern parts of the country, this is the first report of its presence in the south. Informal interviews revealed that fishermen were adversely affected by the presence of this species in the bay. In this sense, it is important to develop a conservation and management framework for the early detection and impact mitigation on the presence of marine alien invasive species.

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