

# A CHECKLIST OF THE MOLLUSKS FROM THE MIRAFLORES AND PEDRO MIGUEL LOCKS, PANAMA CANAL, PANAMA

TECNOCIENCIA

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**Resumen:** El sistema de esclusas del Canal de Panamá proporciona un ambiente adecuado para el asentamiento y el reclutamiento de organismos marinos, siendo los invertebrados los que aportan una diversidad local sustancial. En julio y septiembre de 2019, muestreamos el interior de dos de las cámaras de esclusas en el lado Pacífico de Panamá; una en las esclusas de Miraflores y otra en las esclusas de Pedro Miguel. Ilustramos las especies encontradas y proporcionamos una lista de especies de toda la fauna de moluscos de este y estudios anteriores. Se recolectaron e identificaron un total de 17 especies (4 bivalvos y 13 gasterópodos) de las cuales 6 son nuevos reportes para las esclusas. Dos especies, *Mytella strigata* y *Brachidontes playasensis*, son nuevos reportes para el país, ambas especies se conocían del Pacífico Oriental Tropical. PALABRAS CLAVES Mollusca, Gastropoda, Bivalvia, nuevos reportes. INTRODUCTION

**Abstract:** The Panama Canal Lock System provides an adequate environment for the settlement and recruitment of marine organisms, being invertebrates which contributes substantially to the local diversity. In July and September of 2019, we sampled inside two of the lock's chambers on the Pacific side of Panama; one at the Miraflores locks and one at Pedro Miguel locks. We illustrate the species found and we made a checklist of the entire molluscan fauna from this and previous studies. A total of 17 species were collected and identified (4 bivalves and 13 gastropods), of which 6 are new reports for the locks. Two bivalves species, *Mytella strigata* and *Brachidontes playasensis*, which are new records for the country, already known from the Tropical Eastern Pacific.

## INTRODUCTION

Since its opening in 1914, the Panama Canal has served as a freshwater transoceanic passageway connecting the Atlantic and the Pacific Oceans (Bennett & Hammond, 1915). The Panama Water Lock System helps the vessels entering to the canal are lifted to the higher level and later dropped down to the sea level at the other end of the canal- Today, the Canal has 5 sets of locks, two of which were recently inaugurated in 2016. On the Pacific side there are three locks. The original Miraflores and Pedro Miguel locks occurred in sequence while the new Cocoli Lock is in parallel with them (Fig. 1). Miraflores locks has 2 sequential chambers, and Pedro Miguel has one in each direction. On the Atlantic side the Gatun locks has 3 chambers in sequence. Each one of the old chambers is a box made of reinforced concrete measuring 304.8 m (1000 ft) long by 33.5 w (110 ft) with an average depth of 26 meters (40 ft) (ACP, 2020). This mechanism has operated for 100

years without appreciable increases in the salinity of Gatun Lake, and has largely prevented the migration of marine species from one ocean to the other. We focused on the diversity reported in the original locks since the new locks haven't yet been surveyed.

Salinity varies among the chambers thus influencing the diversity found in each one. The first, lower chamber of the Miraflores locks that connects directly to the Pacific Ocean, has a salinity of 26 ‰ (Menziés, 1968). To transit ships in this chamber, it has to be filled with fresh water from the upper chamber which has a salinity of 3 ‰ (Menziés, 1968). To lift ships in the upper chamber, it must be filled with fresh water from Miraflores Lake which has a salinity of 0 – 1 ‰ (Menziés, 1968; Jones & Dawson, 1973). Vessels in the single chamber of the Pedro Miguel Locks meet water salinity which equalizes with the Gatun Lake. The salinity of Pedro Miguel chambers and Gatun Lake is 0 ‰ (Jones & Rützler, 1975). On the Caribbean side, the Gatun Locks also differ in salinity, ranging 0 – 1 ‰, 10 – 16 ‰ and 18 – 20 ‰ in the upper, middle, and lower chambers, respectively (Hildenbrand, 1939).

Several authors have made observations about the marine invertebrates found in the Panama Canal Locks and surrounding areas (McCosker & Dawson, 1975; Jones & Rützler, 1975; Abele, & Kim, 1989). Some dated to the early years of the Canal (Hildebrand, 1939), while others focus on the biology of target species (Roche & Torchin, 2007). Several environmental technical reports have documented the benthic mollusks in soft sediments from the Miraflores and Gatun Lake (Toole, 1985; Garcés, & García, 2003a, 2003b, 2004). Hildenbrand (1939) was the first to report 12 species of mollusks occurring inside the lock's chambers. Rosewater (1975a) reported 10 species in Gatun Locks. In the same year, he reported 74 species of mollusks from the entire lock systems (Gatun, Miraflores and Pedro Miguel), collected from 1971 to 1975 (Rosewater, 1975b). Many authors have done additional observations of the mollusks from the lock chambers (McCosker & Dawson, 1975; Jones & Rützler, 1975; Abele, & Kim, 1989). However, in many cases, samples have been collected and vouchered in museums, but the resulting publications provided summary numbers, rather than giving species names.

In this paper, we present a checklist of the diversity of mollusks registered from the Pedro Miguel and Miraflores locks, 44 years after the major mollusk survey made by Rosewater (1975b). We also provide photographs of the mollusk species most recently collected inside these 2 locks.

## MATERIALS AND METHODS

Specimens were collected in the Miraflores Locks (8.995114, -79.589696) in July 2019 and in the Pedro Miguel Locks (9.016931, -79.612327) on September 2019 (Fig. 1). Each set of locks is drained every five years for maintenance. During the 2019 maintenance event we sampled the lower east chamber of Miraflores Lock three days after the chamber was totally drained. We collected on the left side of the chamber over the course of three hours. At the Pedro Miguel Locks we collected for 2 hours around the east chamber, a few hours after the chamber was drained.

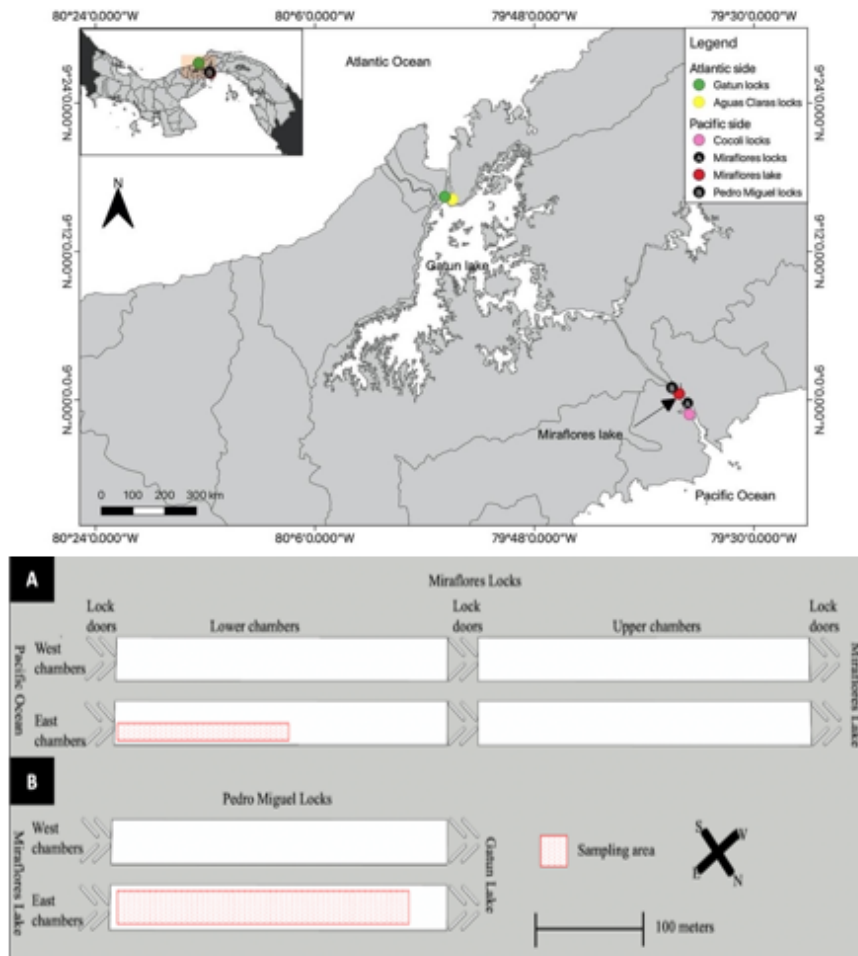


Fig. 1 Map of the sampling areas in the Miraflores Locks (A) and Pedro Miguel Locks (B).

Samples were handpicked and initially stored in vials with water from the lock chamber until they were processed later the same day. In the laboratory the soft tissue was removed, and shells were gently dried and stored in clear plastic shell cases. The shells were identified with references to the local fauna (Keen 1958; Coan & Valentich-Scott, 2012; Tejera et al., 2016). One representative shell of each species was photographed in standard view with a camera Olympus OM-D EM-5 Mark II with a 60mm f2.8 macro lens, the photos were stacked and arranged in Photoshop CC 2019 (Fig. 2,3). Vouchers were deposited in the Malacology Museum of the University of Panama (MUMAUP). Specimens were collected with the authorization of the Panama Canal Authority (ACP) and with the permission of the Ministry of Environment (Mi Ambiente) under the collection permits SE/AP-26-19.

We compiled literature on the species that have previously been reported in the locks, and records of observations in our curated database of the Marine Biodiversity of Panama (<http://www.invertebase.org/stri/index.php>). The species which contributes to the diversity reports by Rosewater, (1975b) were obtained from the database of the National Museum of Natural History (NMNH), since the original publication did not include the list of species collected, only the total of them. The total list of species was checked for distribution and synonyms by using the World Register of Marine Species (WORMS) database online, then registered as appropriate.

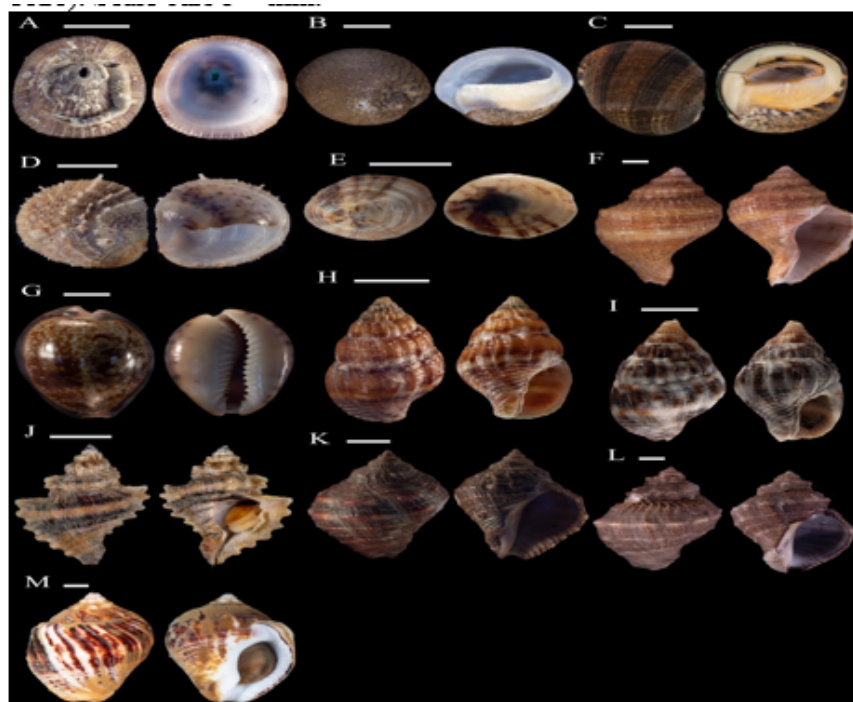
List of museum codes:

FMNH = The Field Museum of Natural History, Invertebrate Zoology Collections (USA)  
IZ-YPM = Yale Peabody Museum of Natural History  
MCZ = Museum of Comparative Zoology, Harvard University (USA)  
NL = Naturalis Biodiversity Center – Mollusca, (Netherlands)  
NMNH = National Museum of Natural History, Smithsonian Institution, Invertebrate Zoology Collections (USA)  
UF = Florida Museum of Natural History, Invertebrate Zoology (USA)  
UMMZ = University of Michigan Museum of Zoology (USA)

## RESULTS

A total of 41 gastropods belonging to 13 species from eight families were collected (Table 1, Fig. 2). The two locks had distinct gastropod faunas, with *Clypeolum latissimum* being the only species found at the Pedro Miguel lock, while the other 12 species were found at the Miraflores Lock. Gastropods were located inside crevices in the walls or below the sparse rocky rubble on the lock's floor. Twelve bivalves were collected belonging to two families and four species (Table 1, Fig. 3). *Mytilopsis sallei* was the only bivalve species found at Pedro Miguel and it was scarcely found inside crevices or holes in the lock walls. Meanwhile the floor from the Miraflores Chamber was carpeted with three species of bivalves: *Brachidontes playasensis*, *Mytella strigata* and *M. guyanensis*.

Fig. 2 Gastropod species from the Miraflores and Pedro Miguel locks in the Panama Canal. A) *Diodora saturnalis* (Carpenter, 1864), B) *Clypeolum latissimum* (Broderip, 1833), C) *Nerita scabricosta* Lamarck, 1822, D) *Bostrycapulus calyptraeiformis* (Deshayes, 1830), E) unidentified sample, F) *Monoplex wiegmanni* (Anton, 1838), G) *Pseudozonaria arabicula* (Lamarck, 1810), H) *Anachis lyrata* (G. B. Sowerby I, 1832), I) *Anachis varia* (G. B. Sowerby I, 1832), J) *Eupleura nitida* (Broderip, 1833), K) *Stramonita biserialis* (Blainville, 1832), L) *Thaisella kiosquiformis* (Duclos, 1832), M) *Triumphis distorta* (Wood, 1828). Scale bars 5 = mm.



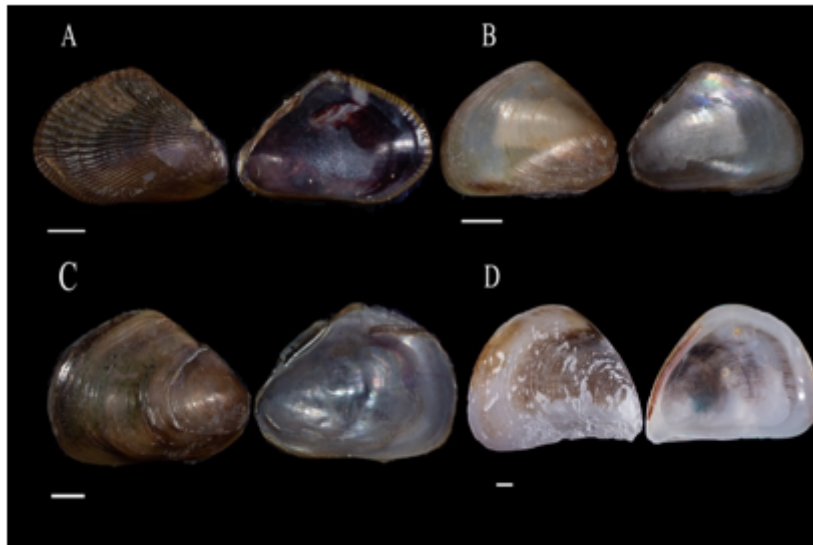


Fig. 4 Venn diagram summarizing the number of shared species between each one of the systems of lock chambers.



A total of 592 records of mollusks were found in the literature and online databases from museum collections. These records are exclusively from samples collected inside the original lock systems (Gatun, Pedro Miguel and Miraflores). These records represent 150 species, from which 55 are bivalves, 4 cephalopods, 88 gastropods and 3 polyplacophorans. Names of 36 species were updated based on the taxonomy in WORMS. Comparisons with geographic ranges showed that 7 species were away from their natural population distributions (Table 1), suggesting either misidentifications or possible introduction of these species. Miraflores has the greatest number of species (111) followed by Gatun (45) and finally Pedro Miguel (14). Only 13 species of mollusks have been reported to occur in both locks Miraflores and Gatun and two species (*Mytilopsis sallei* and *Melanoides tuberculata*) in all 3 locks (Figure 4). From the 111 species reported for Miraflores Lock 's chambers, only 15 were found, but our collecting effort was minimal, and spatially limited to one part of the locks and by the time available for sampling.

Table 1. Mollusca diversity inside the lock chambers of the Panama Canal. G = Gatun locks, M = Miraflores locks, PM = Pedro Miguel locks, + = new reports for the locks (NL), - = new reports for the country (NC), # = species out of their natural distribution range (OD), \* = species name updated, bold = samples collected in 2019 and illustrated in Fig. 2 and Fig. 3.

## DISCUSSION

The diversity of Mollusca in the Gulf of Panama was entirely reviewed recently by Keen (1958). Most recently efforts have been made to document additional biodiversity in localized sites (Córdoba et al, 2010; Tejera et al, 2016) and samples from Panama are often included in taxon-specific revisions (e.g., Collin, 2005; Reid et al, 2010; deMaintenon, 2014; Raines, 2020). With each biodiversity study, new species and/or new reports are added to the Mollusca fauna in Panama. In this review of the fauna of the Panama Canal locks, we recorded two new species for the country: *Mytella strigata* and *Brachidontes playasensis*. These two species are native to the Eastern Pacific Ocean (Keen, 1958; Coan & Valentich-Scott, 2012) and they have been reported for Colombia (Puyana et al, 2012), and Mexico (Lopez-Rojas et al, 2017), so its presence in Panama should be expected.

The salinity of each one of the locks' chambers shapes the diversity of species in that chamber (Figure 4). There is very little overlap of the fauna in each set of locks; and very few species occur in multiple locks. In the lower chambers of the Miraflores Locks, the high salinity and frequent water exchange promotes the arrival of larvae and survival of settlers from the diverse mollusk's fauna of the Bay of Panama (Keen, 1958; Menzies, 1968).

After 40 years, since the last two major mollusk censuses in the locks (Hildenbrand, 1939; Rosewater, 1975b), we observed lower diversity and some new records for the locks. According to Rosewater (1975b), *Mytilopsis sallei* was a bivalve commonly found in all the lock chambers. We only found this species at the Pedro Miguel Locks, but they were not entirely covering the lock walls as stated by Hildebrand (1939). Instead, were scarcely found inside of crevices in the lock's walls. Historically, *M. sallei* has been one of the two species of mollusk that was found in the three locks systems. Due to its high tolerance to changes in salinity, temperature and its fast growth and reproductive rate (Morton, 1981) *M. sallei* has invaded many sites in Australia (William et al, 2000), Malaysia and Singapore (Tan & Morton, 2006). Outside the lock's chambers, this species can be found covering hard substrates around the Gatun Lake (M.M. pers. Obs.). It is likely that *M. sallei* was found at the upper chambers in Miraflores Locks, where the salinity is 3 ‰ (Menzies, 1968), and where we did not collect samples. In the upper chambers *M. sallei* would not be released from competition for space with species of *Brachidontes* that were commonly found at the lower chamber and which are less tolerant to low salinities (Sará et al, 2008). Rosewater (1975b) found the freshwater snail *Melanoides tuberculata*, an invasive species capable of surviving at salinities up to 21.56‰ (Farani et al, 2015), in the three sets of locks, but we did not find this species.

Overall, each set of locks chambers has different communities of mollusks reflecting the differences in salinity generated by the constant exchange of ocean water from the lower chambers of the Miraflores and Gatun locks. If the salinity changes it is likely that the distribution of the more euryhaline species may expand to include more locks.

## CONCLUSION

We provide an annotated checklist of 150 species of mollusks found at the Miraflores, Pedro Miguel and Gatun Locks compiled over 80 years of observations in the Panama Canal. We added six new records (*Brachidontes playasensis*, *Mytella strigata*, *Anachis lyrata*, *Pseudozonaria arabicula*, *Diodora saturnalis*,

Nerita scabricosta, and an unidentified Patellogastropoda) from our observations of the Miraflores Locks. We hope that this compilation will facilitate the detection of new or introduced species in the future.

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