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Rapid Communication

A note on the occurrence of non-native tiger prawn (*Penaeus monodon* Fabricius, 1798) in Biscayne Bay, FL, USA and review of South Florida sighting and species identification

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Abstract

The Asian tiger prawn (*Penaeus monodon*) is considered an established non-native species throughout the greater Caribbean, Gulf of Mexico, and southeastern United States. A previous investigation on the non-native distribution of *P. monodon* documented its presence in south Florida. Here we update information regarding its south Florida presence and report our capture of a specimen that may be the smallest tiger shrimp juvenile yet observed in the Western Atlantic Ocean. Continued reports of both adult and juvenile *P. monodon* from Nov. 2011 through Aug. 2017 suggest that the species is established in the south Florida region. One of several goals of the Comprehensive Everglades Restoration Plan is to reduce the salinity of nearshore waters to approximate conditions prior to construction of levees, canals, and control structures. An unforeseen consequence of this massive restoration program could be the facilitation of *P. monodon* population retention and further expansion in south Florida. *P. monodon* would likely be able to outcompete native species under lower salinity conditions; continued vigilance and laboratory experimentation could improve knowledge of *P. monodon*'s potential advantages.

Key words: invasive species, alien species, Asian tiger shrimp, salinity, CERP, juvenile

Introduction

The Asian tiger prawn (*Penaeus monodon* Fabricius, 1798) is native to the western Pacific and Indian oceans, where it inhabits coastal areas from South Africa to Yemen on the western edge of its range and Queensland, Australia to Honshu, Japan along the eastern extent of its range (Motoh 1981; Motoh 1985; FAO 2012). *Penaeus monodon* has become established in many areas outside of its native range, including West Africa and many areas throughout the western Atlantic such as eastern Brazil, Venezuela, the Caribbean Sea, the Gulf of Mexico, and the southeastern United States (Fuller et al. 2014 and references cited therein; Wakida-Kusunoki et al. 2013, 2016). Tiger prawns were introduced by escapement from aquaculture facilities and subsequent dispersal by ocean currents and/or release of larvae in ballast water. *Penaeus monodon* releases from aquaculture facilities have occurred many times from 1988 (South Carolina) through 2006 (Caribbean facilities; Fuller et al. 2014). Collection of juvenile specimens of *P. monodon* throughout the Gulf of Mexico and the southeastern USA suggests that established, reproducing populations are present in these regions (Fuller et al. 2014).

In this note we update information on previously reported south Florida *P. monodon* captures and note that, by their reported geographic coordinates, some of them came from Biscayne Bay Florida, USA, a subtropical lagoonal estuary located on Florida's southeastern coast. Although Fuller et al. (2014) noted presence of *P. monodon* in south Florida, their study does not report specific locations. We thought it especially important to point out that several captures reported by Fuller et al. (2014), as well as another

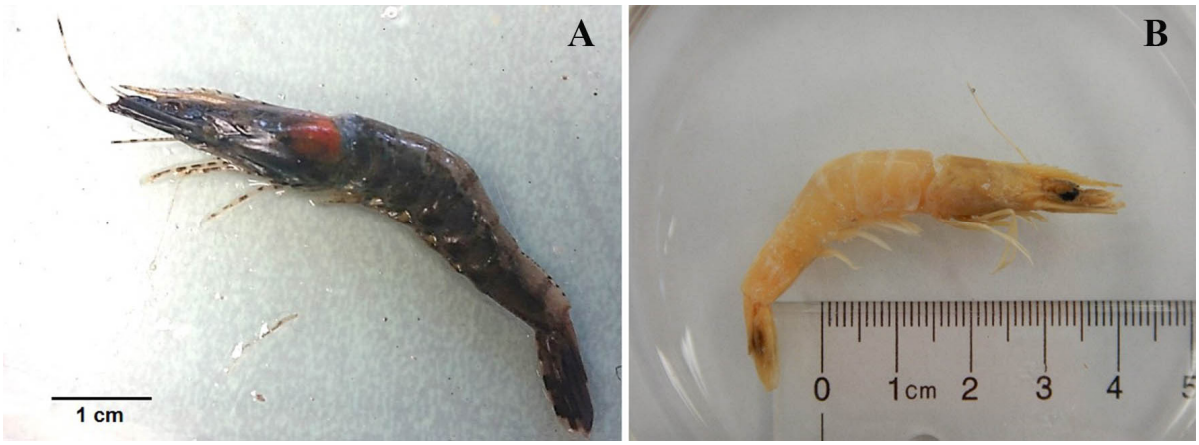

Figure 1. *Penaeus monodon* specimen collected by NOAA NMFS SEFSC personnel in the nearshore waters along the western, mainland shoreline of Biscayne Bay, FL, USA. A) Previously frozen specimen depicting dark coloration and banding and B) the specimen after ethanol preservation. Photo credit: Tom Jackson (Figure 1A) and Ian Zink (Figure 1B).

more recent capture in the data base, came from Biscayne Bay. The small size of a new *P. monodon* we have captured in Biscayne Bay suggests Biscayne Bay is a nursery ground for this introduced species. The characteristics we used to identify our specimen may be useful to others who think they have captured small individuals of this species.

Reported Information

We collected a suspected juvenile *P. monodon* in September 2016 (Supplementary material Table S1) during ecological monitoring of epifaunal communities along the western shore of southern Biscayne Bay (Lirman et al. 2017; Zink 2017). The size of this specimen (12.49 mm Carapace Length: CL) was much smaller than the size at sexual maturity (~ 47 mm CL: Motoh 1981, 1985). The CL specimen stood out from native penaeid specimens because of its dark coloration (Figure 1A). A closer look confirmed that the specimen lacked prominent adrostral sulci of the carapace (Figure 2A, B) and dorsolateral sulci of the 6th abdominal segment (Figure 2C, D) that characterize the farfantepenaeid species common to this area (*Farfantepenaeus duorarum* (Burkenroad, 1939) and *Farfantepenaeus brasiliensis* (Latreille, 1817): Browder et al. 2005; Zink et al. 2017). The adrostral crest and sulci (Figure 2A) terminated approximately in line with the epigastric tooth (Motoh 1985; FAO 2012). Lack of prominent sulci on the carapace and the 6th abdominal segment (Figure 2A, C) resembles *Litopenaeus* spp. which inhabit the southeastern United States but previously have not been reported from south Florida waters (Perez-Farfante and Kensley 1997). Unlike litopenaeids, however, the specimen, a female, exhibited a closed thelycum (Figure 2E), like *P. monodon* (Motoh 1981), but also similar to the farfantepenaeids (Figure 2F) we regularly encounter (Browder et al. 2005; Zink et al. 2017) in Biscayne Bay and other south Florida estuaries. Given the specimen's size (12.49 mm Carapace Length: CL), its lateral thelycum plates (Figure 2E) appeared underdeveloped relative to figures presented by Perez-Farfante (1970). This underdevelopment of the thelycum relative to the size of the specimen agreed with the larger size of sexual maturity for *P. monodon* (~ 47 mm CL: Motoh 1981, 1985) and did not agree with the more advanced state of development that would accompany the smaller size of sexual maturity for *F. duorarum* (24 mm CL: Cummings 1961). The state of thelycum lateral plate development of this specimen seemed more like that of a similarly sized specimen illustrated by Motoh (1981: Fig. 64A). The 5th pereopod (Figure 2G) of our specimen lacked an exopod (Motoh 1985; FAO 2012), unlike that of farfantepenaeids (Figure 2H). The rostral shape also matched that of *P. monodon* (Figure 2I), as did the pattern of the dorsal/ventral rostral teeth (7/3) (Motoh 1981, 1985; FAO 2012). Farfantepenaids generally lack a third ventral rostral tooth (Figure 2J: Perez-Farfante 1970). Although genetic analysis should be used to confirm this identification, we suggest that the preponderance of evidence from these morphological and developmental characteristics indicate a young *P. monodon* juvenile.

Information about other *P. monodon* specimens collected in south Florida (Lee, Collier, Monroe, Miami-Dade, Broward, and Palm Beach Counties: Figure 3) was extracted from the USGS Nonindigenous Aquatic Species (USGS NAS) database (USGS 2017),

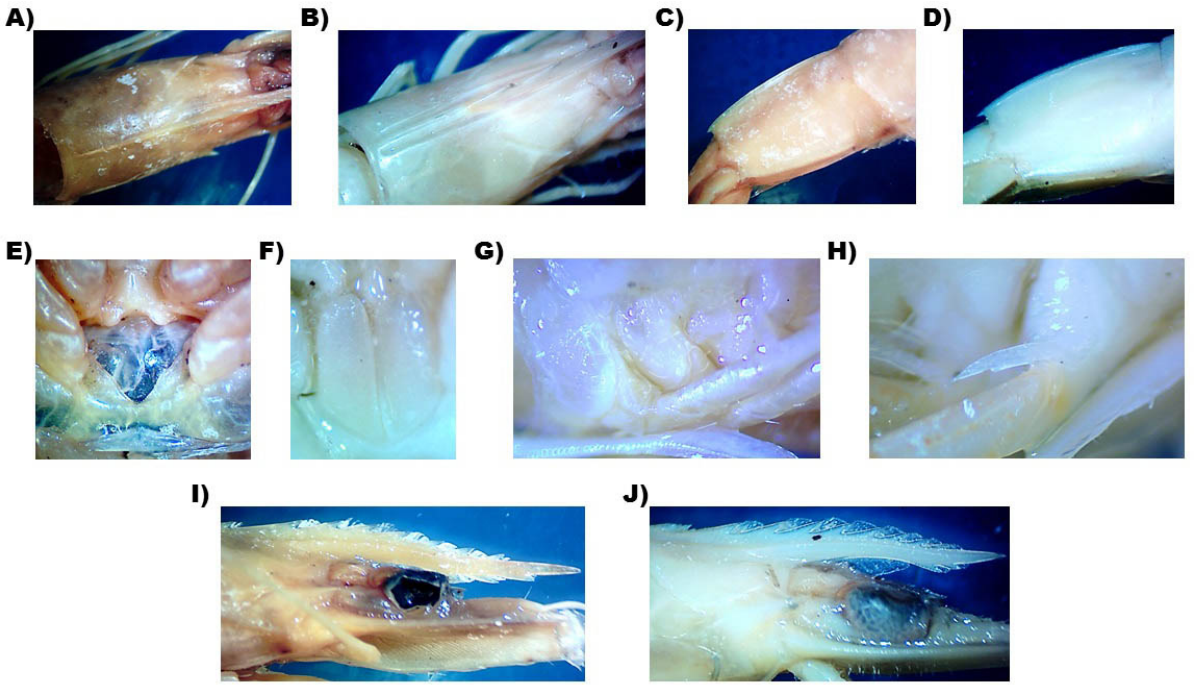

Figure 2. Photographs of dorsal view of carapace of A) *P. monodon* and B) *Farfantepenaeus duorarum*; lateral view of sixth abdominal segment of C) *P. monodon* and D) *F. duorarum*; ventral view of thelycum of E) *P. monodon* and F) *F. duorarum*; lateral view of 5th periopod coxa, basis, ischium, and exopod (or lack thereof) of G) P. *monodon* and H) *F. duorarum*; and lateral view of rostrum of I) P. *monodon* and J) *F. duorarum* . See text for descriptions of differences between species for these anatomical features. Photos A, C, E, G, and I from 12.49 mm CL *P. monodon* specimen; photos B, D, F, H, and J from a 14.61 mm CL *F. duorarum* specimen. Both specimens were photographed after preservation in ethanol. Photo credit: Ian Zink.

tabulated, and depicted on a timeline of observations (Table S1, Figure 4). Size data reported as Total Length (TL) were converted to CL from the plot of CL vs TL presented by Motoh (1981: Fig. 71). Motoh (1981) reported that male *P. monodon* become sexually mature at ~ 37 mm CL (~ 133 mm TL) and females at ~ 47 mm CL (~ 164 mm TL).

Discussion

The first report of a tiger prawn in south Florida was of a specimen collected by commercial trawlers on the Tortugas Grounds, a major commercial fishing ground for pink shrimp *Farfantepenaeus duorarum* (Hart et al. 2012). Unfortunately, no size information was reported for this individual (Table S1). Generally, penaeid shrimps migrate to offshore waters at sexual maturity, where they complete spawning activities and reside until death (Motoh 1981; Dall et al. 1990). Although no other south Florida offshore specimens have been reported, other reports of single adults (~ 65 and 80 mm CL: Table S1) captured from nearshore waters at different locations confirms the presence of

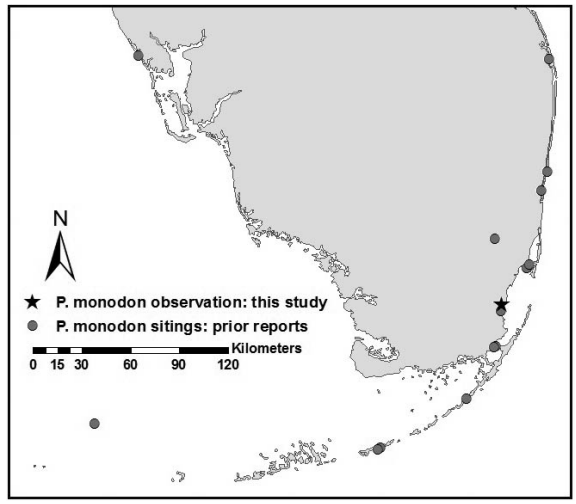

Figure 3. Map depicitng locations of prior (Nov. 2010–Aug. 2017) south Florida *Penaeus monodon* reports (circles) and the capture location of the specimen reported here (for details see Table S1).

sexually mature individuals in the south Florida region. Female tiger prawn may spawn in shallow waters (Motoh 1985), making migration to offshore locations unnecessary to complete their life cycle.

Where size information was available, most specimens reported from south Florida appear to be larger juvenile and subadult tiger prawns (Table S1). This is likely due to penaeid ontogeny, with juveniles inhabiting nearshore area;, gear selectivity of wing net and trawling gear; and selective shrimp fishing pressure targeting larger juvenile shrimps for live bait and food fisheries (Johnson et al. 2012). Our Biscayne Bay specimen appears to be the smallest individual caught from waters of southern United States, including the Gulf of Mexico (Fuller et al. 2014; Wakida-Kusunoki et al. 2013, 2016). In agreement with Fuller (2014), we note that the repeated presence of juveniles over multiple years suggests that breeding populations have become established in south Florida waters or, at least, in Biscayne Bay, where multiple specimens have been reported (Figure 4). We also acknowledge that the number of reported sightings presented here are likely an underestimate of actual sightings; we are aware of at least one instance of non-reporting of a tiger shrimp caught in the Florida Keys. Although not quantified, internet searches have revealed discussion of tiger shrimp on fishermen's web forums that suggests their catch frequency of *P. monodon* is higher than reported to the NAS database.

Continued vigilance regarding the occurrence and abundance of *P. monodon* will be crucial to understanding potential economic and ecological impacts of its western North Atlantic invasion (Fuller et al. 2014). These concerns are supported by consequences of another invasion of south Florida waters by nonnative marine species; the invasion of red lionfish *Pterois volitans* (Linnaeus, 1758) has had sweeping, negative impacts on recruitment and survival of many commercially important reef fish species (Albins and Hixon 2008; Green et al. 2012). Concern over invasion of nonnative penaeids in other locations has led to study of potential ecological consequences of their establishment. Should nonnative *Litopenaeus vannamei* (Boone, 1931) shrimps become established in the estuaries of Thailand, it is feared ecological harm to native species will occur due to overlapping diets and *L. vannamei*'s more aggressive feeding behavior (Panutrakul et al. 2010; Chavanich et al. 2016). However, a search of the USGS NAS database revealed no *L. vannamei* sightings for southeastern United States waters. Competitive advantage over, and direct predation on, native penaeid species, both within south Florida and elsewhere throughout its nonnative range, are two major concerns about

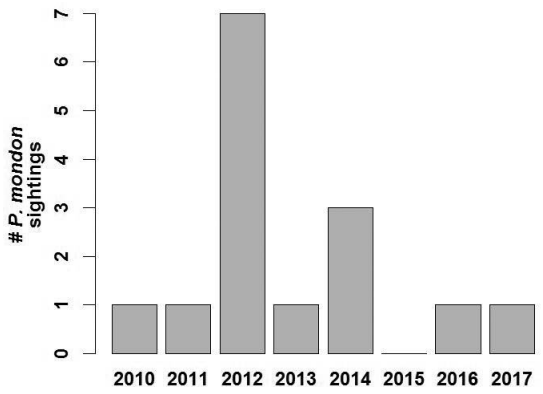

Figure 4. Number of *P. monodon* sightings reported in south Florida by year from 2010 to 2017.

P. monodon establishment (Fuller et al. 2014). Nonnative *P. monodon* has been demonstrated to selectively predate upon polychaetes and juvenile blue crabs, *Callinectes sapidus* Rathbun, 1896 over small flat fish, grass shrimps, and other juvenile penaeid shrimps (Hill et al. 2017). The carnivorous dietary preferences of *P. monodon* (Thomas 1972; Marte 1980; Luna-Marte 1982; Motoh 1985; Hill et al. 2017) and their large size (Motoh 1981, 1985) means that nonnative tiger shrimp may not act as a direct ecological replacement for native penaeid species. Invasive tiger shrimp seem capable of altering food webs and could impact productivity of commercially exploited species, such as blue crabs and other penaeid shrimps. Another concern is the potential of *P. monodon* to introduce and spread bacterial and viral diseases, some which could exhibit resistance to antibiotics, to native species (Fuller et al. 2014).

Implementation of the Comprehensive Everglades Restoration Plan may reestablish the persistence and spatial extent of mesohaline nearshore habitats in southwestern Biscayne Bay (Browder et al. 2005; Stabenau et al. 2015) and within the mangrove estuaries of the Whitewater Bay system of lower southwest Florida (RECOVER 2005). This habitat seems similar to the preferred native habitats of *P. monodon* (Motoh 1981) and is similar to other locations where higher abundance of non-native tiger shrimp were caught (Sandoval et al. 2014). Juvenile *P. monodon* can tolerate salinity down to 5 ppt with minimal mortality (Motoh 1981; Cawthorne et al. 1983; Ye et al. 2009). It is possible that *P. monodon* juveniles could outcompete the primary native penaeid species *F. duorarum*, which does not tolerate low salinities well (Browder et al. 1999, 2002; Zink 2017; Zink et al. 2017). Our *P. monodon* specimen was collected

just south of the mouth of Black Creek Canal, an area where salinity is highly influenced by moderate freshwater discharges from the adjacent canal (Caccia and Boyer 2005) and is marked by low and variable salinity conditions (Serafy et al. 1997; Lirman et al. 2008; Zink 2017). This same location exhibits spatiotemporally consistent low *F. duorarum* density (Zink 2017). Perhaps an unforeseen consequence of this restoration would be the facilitation of *P. monodon* establishment.

Alteration of south Florida's hydrology, and especially more recent changes in freshwater management, has already been implicated as favorably influencing translocation of native and non-native fish species previously not present in Everglades National Park (Trexler et al. 2000; Kline et al. 2014). Continued monitoring for persistence of a local *P. monodon* population is necessary to begin to understand potential future impacts of its establishment. However, potential impacts of *P. monodon* establishment can also be investigated in controlled laboratory comparative studies of predation competition, aggression, and physical resilience among *P. monodon* and native shrimps.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Information on south Florida *P. monodon* specimens reported to the USGS Nonindigenous Aquatic Species database as well as the specimen described in the present note.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2018/Supplements/BIR_2018_Zink_etal_Table_S1.xlsx