Record of the non-indigenous species *Sternaspis* aff. *nana* Zhadan, Tzetlin & Salazar-Vallejo, 2017 (Annelida: Sternaspidae) in the Southwest Atlantic Ocean

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Abstract. The introduction of non-indigenous marine species in new habitats is generally associated with ships arriving at ports, driven by species transported in ballast water and sediment and biofouling communities on ship hulls, drifting object and underwater surfaces in dock areas. The present paper reports the record of the species *Sternaspis* aff. *nana* in the Atlantic Ocean, discussing its possible conservation status and method of arrival to Brazil. Sediments samples were collected in the external area (11 m depth) of the Suape Harbor (Brazil) in February 2018. Two individuals of *Sternaspis* aff. *nana* were recorded, representing the first record of this species in the Southwest Atlantic Ocean. The way *S. aff. nana* arrived in Brazilian waters cannot be easily determined, the short-lived lecithotrophic larvae of sternaspids suggest that the specimens found in Suape have arrived in ballast sediment. An increase in trade between Brazil and Asian countries since the 2000s has led to that more ships coming from China having arrived in Brazilian harbors. The arrival of *S. aff. nana*, originally described in the South China Sea, in the Suape harbor area may have resulted from this intense movement of ships between China and Brazil.

Keywords. Polychaeta; Exotic species; Northeastern Brazil; Shipping activities; Ballast sediment.

INTRODUCTION

The introduction of non-indigenous species (NIS) may cause significant ecological impacts (Carlton, 1999; Çinar, 2013), being these introductions generally associated with ships arriving at ports (Bumbeer & Rocha, 2016), driven by species associated with ballast water/sediment and biofouling communities on ship hulls, drifting object and underwater surfaces in dock areas (Keppel et al., 2015). Benthic invertebrates have a wide variety of life histories (Godwin, 2003) and many have long larval stages, favoring transport of these species between areas separated by thousands of kilometers (Townsend et al., 2006; Çinar, 2013). Even benthic species without planktonic stage or with short-lived larvae can efficiently disperse using different ways of transportation (Jablonsky & Lutz, 1983; Winston, 2012), such as drifting, rafting, hitchhiking, creeping, and hopping (Thiel & Haye, 2006; Winston, 2012).

The number of NIS has increased concomitantly with the increase of transoceanic transport (Keppel et al., 2015), since the shipping transport is considered the main vector of marine species invasions worldwide (Gollasch et al., 2002; Çinar, 2013; Gollasch & David, 2019) and it can lead to a profound alteration of the diversity and structure of coastal communities (Carlton, 1999; Hamer, 2002; Çinar, 2013). Carlton (1999) estimated that a 17th century wooden vessel could easily have transported 150 species of marine protists, invertebrates and plants per voyage, a number that may be rivalled or exceeded by a 21st century ship due to faster transit times and larger hull sizes. Ahyong et al. (2020) recorded more than 1.737 marine alien species globally. Most were probably introduced by ship movements (ballast tanks and/or biofouling) (Ruiz, 1997; Godwin, 2003; Seebens et al., 2013). More than 292 species of marine polychaetes, belonging to 164 genera, have been reported as NIS globally, most of them Syllidae Grube, 1850, Spionidae Grube, 1850, Sabellidae Latreille, 1825, Serpulidae Rafinesque, 1815 and Nereididae Blainville, 1818 (Çinar, 2013). Among the approximately 46 polychaeta species classified as NIS in Brazil (Rodrigues et al., 2020), eight are invasive exotic species (I3N, 2018). To date,
RESULTS

Systematics
Order Terebellida Rouse & Fauchald, 1997
Family Sternaspidae Carus, 1863
Genus Sternaspis Otto, 1820

*Sternaspis aff. nana* Zhadan et al., 2017
(Figs. 1-3)

*Sternaspis nana* Zhadan et al., 2017: 79-82, fig. 3-5; Salazar-Vallejo, 2017: 4.

Examined material

Two specimens collected at the external area of the Suape Harbor, Pernambuco, Brazil (08°23′37.6″S, 34°57′19.3″W), mud substrate, 15 m depth, 16-II-2018, MOUPFE 003.

Description

The morphology of the two specimens agree with the descriptions of *Sternaspis nana* by Zhadan et al. (2017), but due to the impossibility of observing the gametes due to the small size of the specimens, the morphological differences of the shield and the amount of papillae in the species found here in Brazil, we classify the specimens as *Sternaspis aff. nana*. Our specimens seem to be more rugose than the type specimens and the posterior shield margin has a round projection, as opposed to having a sharp one, or none as in the type species (Zhadan et al., 2017).

Complete specimens with 26 segments without clear borders (Body: 2.20 mm long, 0.82 mm wide). Body hourglass-shaped, introvert narrower than abdomen, constriction between segments 5 and 6. Body wall semi-transparent; introvert colorless, abdomen creamish-white with abundant minute papillae evenly distributed, both dorsally and ventrally, and papillae cirriform (Fig. 1C). Intestine and ventral nerve are visible through body wall (Figs. 1A-B, 2B).

First three chaetigers with 13 falcate hooks per bundle, not subdistally expanded, hooks transparent (Fig. 3). Genital papilla small, digitate, protruding ventrally from sixth chaetiger (Fig. 1A, C). Pre-shield region with 7 segments, with 1-2 fine capillary chaetae laterally in some segments (Fig. 2A).

Table 1. Main morphological features of *Sternaspis aff. nana*, *S. africana*, *S. papillosa*. Legend: BP (Body papillae), IH (Introvert Hooks), CBW (Chaetae of body wall), S (Shield), LSC (Lateral shield chaetae), PSC (Posterior shield chaetae), PC (Peg Chaetae).

<table>
<thead>
<tr>
<th>Species</th>
<th>BP</th>
<th>IH</th>
<th>CBW</th>
<th>S</th>
<th>LSC</th>
<th>PSC</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sternaspis aff. nana</em></td>
<td>Very small not arranged in series and long cirriform</td>
<td>13</td>
<td>Fine capillary chaetae Ribs and concentric lines not visible. Without papillae and no sediment particles attached.</td>
<td>8 in oval pattern</td>
<td>5-6 slightly curved pattern</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td><em>Sternaspis africana</em></td>
<td>Minute, rows of cluster</td>
<td>15-20</td>
<td>Fine capillary chaetae Ribs and concentric lines barely visible. Without papillae and no sediment particles attached.</td>
<td>9 in oval pattern</td>
<td>5 slightly curved pattern</td>
<td>Present</td>
<td></td>
</tr>
<tr>
<td><em>Sternaspis papillosa</em></td>
<td>Simple cirriform papillae forming irregular transverse rows</td>
<td>16</td>
<td>Absent</td>
<td>Ribs and concentric lines barely visible. Sediment particles adhered; covered by fine papillae.</td>
<td>9 in oval pattern</td>
<td>5 in linear pattern</td>
<td>Present</td>
</tr>
</tbody>
</table>

MATERIAL AND METHODS

Sediments samples were collected in the external area of the Suape Harbor (Pernambuco, Brazil – 08°23′37.6″S 34°57′19.3″W) in February 2018. Samples were collected using a Van Veen Grab at a depth of 15 m. After collection, samples were fixed in saline formalin 4% and thereafter the polychaetes were identified following Zhadan et al. (2017). After identification, all specimens were deposited in the 'Museu de Oceanografia Prof. Petrónio Alves Coelho (MOUPFE) at Universidade Federal de Pernambuco, Recife, Brazil.
Figure 1. *Sternaspis* aff. *nana* collected in Suape Harbor (Pernambuco, Brazil). (A) Ventral view. White arrows showing genital papillae; (B) Dorsal view; (C) Detailed ventral view of abdomen (pre-shield). Black arrows showing long filiform papillae and white arrows showing genital papillae.
Figure 2. *Sternaspis* aff. *nana* collected in Suape Harbor (Pernambuco, Brazil). (A) Detailed view of the margin of abdomen wall. White arrows showing pre-shield capillary chaetae; (B) Ventracaudal shields. Black dotted showing shield plates nearly square. White arrows showing fascicles containing only one thick chaeta each, black arrow showing fan corners extended.
Ventrocaudal shield soft, smooth, papillae not observed and no sediment particles attached. Left shield plate 0.21 mm long, 0.25 mm wide. Shield plates nearly square. Ribs and concentric lines not visible. (Fig. 2B). No visible borders between lateral plates and fan (Fig. 2B). Anterior keels visible, suture well-defined, visible throughout shield (Fig. 2B).

Branches of shield chaetae with eight lateral shield chaetae, ovaly arranged and five posterior fascicles each containing only one thick chaeta, slightly curved (Fig. 2B). Peg-chaetae not observed. Branchial filaments arranged in discrete branchial plates.

Distribution

Type locality: Pacific Ocean – Nha Trang Bay, South China Sea (15-40 m depth). New occurrence: Atlantic Ocean – Suape Harbor Area, Pernambuco, Brazil (15 m depth).

Remarks

On the Brazilian coast, only one species of Sternaspidae has been recorded to date, Petersenaspis capillata (Nonato, 1966) [= Sternaspis capillata Nonato, 1966], which is native and found in Brazilian waters (Nonato, 1966). The morphology of our specimens is similar to the original description of Sternaspis nana by Zhadan et al. (2017) and resembles S. papillosa Zhadan et al., 2017 and S. africana Augener, 1918. Sternaspis aff. nana markedly differs from these species by combined features related to hooks of introvert, papillae pattern and ventral shield characteristics.

In S. aff. nana there are 13 falcate hooks per bundle in the introvert chaetigers, while the number of falcate hooks per bundle is 16 in S. papillosa and 15-20 in S. africana. Sternaspis aff. nana has abundant micropapillae and regular rows of long cirriform papillae along the body. In S. papillosa digitiform papillae are organized in more or less regular transverse rows, and in S. africana minute papillae are densely present on segments 7 and 8, but evenly spaced in other segments. Ventral shield in S. aff. nana is without ribs and papillae, usually without concentric lines, with eight lateral shield chaetae in oval pattern, and six posterior shield chaetae consisting of a single thick chaeta in slightly curved pattern. In S. papillosa, ventral shield is with underdeveloped ribs and concentric lines, covered by fine papillae, with nine lateral shield chaetae in oval pattern, and five posterior shield chaetae in oval pattern; in S. Africana, ventral shield is with ribs and concentric lines barely visible, without papillae, with nine lateral shield chaetae in oval pattern, and five posterior shield chaetae in slightly curved pattern. The morphological features remarks are resumed in Table 1.
DISCUSSION

The polychaete *Sternaspis nana* was originally described in the South China Sea at depths ranging from 15-40 m in muddy substrates (Zhadan *et al.*, 2017). This is the first record of this species on the Brazil coast, expanding the known geographic distribution of *S. aff. nana* to the Southwest Atlantic Ocean and indicating the occurrence of a new non-indigenous species (NIS) for the Brazilian waters.

Studies have shown that the occurrence of some organisms could not be explained by the natural distribution of larvae and/or adults (Farrapeira *et al.*, 2011). The shipping industry, via ballast water and sediments, anchoring, and biofouling, may be the main vector of marine species introduction, including polychaetes (Neves & Rocha, 2008; Çinar, 2013; Gollasch & David, 2019). Introduction of NIS by commercial shipping typically results in harbors becoming hotspots of biotic invasion (Wasson *et al.*, 2001; Hewitt *et al.*, 2004). Globally, about 1.697 species are classified as alien species, 78 species with uncertain origin and 121 species with unknown origin (Ahyong *et al.*, 2020). In Brazil, around 46% of recorded marine NIS were introduced by ballast water/sediments and/or biofouling (Lopes *et al.*, 2009). Farrapeira *et al.* (2011) cite that introduction by hull biofouling has been proven for 228 species of marine invertebrates. Polychaetes such as *Branchionma luctuosum* (Grube, 1870) (original distribution: Red Sea; Nogueira *et al.*, 2006; Oricchio *et al.*, 2019), *Polydora cornuta* Bosc, 1802 (original distribution: Western Atlantic and Caribbean; Neves & Rocha, 2008), *Pseudopolydora diopatra* Hsieh, 1992 (original distribution: Western Pacific – Taiwan; Silva & Barros, 2011), *Hydrodes elegans* (Haswell, 1883) (original distribution: Australasia and the Indian Ocean; Schwan *et al.*, 2016; Oricchio *et al.*, 2019) and *Trochochaeta japonica* Imajima, 1989 (original distribution: Pacific North – Japão; Radashkevych *et al.*, 2018) are already known to have been introduced to the Brazilian coast in ship ballast tanks and/or biofouling.

The way *S. aff. nana* arrived in Brazilian waters cannot be easily determined. In general, species with larvae that actively seek food (planktotrophic larvae) disperse easily and may invade new areas, although species with lecithotrophic development (that do not need external food) have also been registered as invaders (Jablonsky & Lutz, 1983). Given that sternaspids larvae are short-lived and lecithotrophic (Strathmann, 1987), generally settling in less than two days (Rouse & Pleijel, 2001), and the great distance from China to Brazil (four to seven weeks travel), the species probably did not arrive in Suape Harbor as larvae, but as juveniles or adults, however it was not possible to observe the gametes in the specimens due to their small size, and thus estimate their ages.

As discussed by Winston (2012) invertebrates with direct development (without planktonic stage) or with short-lived larvae (yolkly nonfeeding larvae) can disperse using different ways such as drifting, rafting, hitchhiking, creeping, and hopping. *Sternaspis aff. nana* (larvae or adults) may have arrived in Suape in ballast tanks of ships. When a vessel takes on ballast water, sediment and the associated benthic organisms, resting stages can be taken onboard (Hamer, 2002; Gollasch *et al.*, 2002; Gollasch & David, 2019). Suspended sediment settles to the tank bottom, providing suitable habitat for benthic organisms (Gollasch & Leppakoski 1999; Briski *et al.*, 2010, 2011). Lucas *et al.* (1999) found volume of sediments (mostly mud) varying from a few cm to more than 30 cm depth in ballast tanks. Williams *et al.* (1988) recorded 21 taxa (crustaceans and polychaetes) in ballast sediments in ships sailing between Japan and Australia. Macroinvertebrates were found by Briski *et al.* (2012) in ballast sediments of 10.4% of transoceanic ships in Canada harbors, with an average density of 2.8 individuals per tank when present. Considering that *S. aff. nana* occurs in muddy bottoms, it is probable that the dispersion to the Suape Harbor occurred in ballast sediments.

The Suape Harbor Complex is one of Brazil’s largest and most important harbors for cargo and container operation, receiving more than 1,000 ships annually from 160 countries (SUAPE, 2019). Between 2013 and 2017, cargo volume in the Suape Harbor Complex increased by 73.3% for long-haul vessels, with origins and destinations to the United States, Argentina, Germany, Holland, Mexico, China and Kuwait (MTPA, 2018). In recent years, the trade between Brazil and Asia has increased; China has become Brazil’s primary trading partner (Moore, 2009; The World Bank, 2014) and China’s relative share in Brazilian foreign trade increased from only 2% in 2000 to close to 20% in 2015 (Dantas & Jabbour, 2016). This increase in trade has led to more ships from China arriving in Brazilian harbors, favoring the introduction of Chinese marine species. The arrival of *Sternaspis aff. nana*, originally described in the South China Sea, into the Suape harbor area is likely to be a result of this intense movement of ships between China and Brazil.

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AUTHORS’ CONTRIBUTION

N.C.: research conceptualization, data collection, data analysis and interpretation, roles/writing – original draft;
writing – review & editing. J.S.R.F.: research conceptualization, data analysis and interpretation, roles/writing – original draft; writing – review & editing.

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**CONFLICT/DECLARATION OF INTEREST**

None.

**ETHICS AND PERMITS**

All research pertaining to this article did not require any research permits.

**REFERENCES**


