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A century of introductions by coastal sessile marine invertebrates in Angola, South East Atlantic Ocean

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ABSTRACT

South Atlantic studies referring to non-native taxa are mostly restricted to Argentinean, Brazilian, and South African coasts. In this study we examined the literature to provide a list of sessile marine invertebrates along the Angolan coast, to infer its introduction status according to their biogeographical distribution and natural history. We reported 29 non-native and 7 cryptogenic species, a small number when compared to other South Atlantic regions of similar extension. Half of the non-native species were reported for Luanda. The majority of the introduced species had a northern hemisphere origin, a consequence of the main introduction route being from the North Atlantic/Mediterranean Sea during the Portuguese colonization. This is the first comprehensive assessment of this kind for the Angolan coast and the diversity of introduced species is certainly underestimated. Regular and rigorous assessments and monitoring of introduced marine species will help to understand the vectors, routes and time of introductions.

1. Introduction

The diversity in local communities is the result of historical, regional and local processes that affect extinction, speciation and species dispersal, which, in turn, will determine the regional biotas and biogeographical domains (Mittelbach et al., 2007). However, since the start of the great interoceanic and transoceanic navigations, humankind is significantly changing species distribution and biogeographical patterns, introducing organisms beyond their native range. Therefore classical maps of human historical demography are good predictors of the introduction routes of many species of animals and plants (Carlton, 2003).

The transport of coastal species beyond their original distribution occurs by a variety of vectors such as aquaculture, aquarium trade, construction of canals linking disconnected seas, research activities, but mainly by shipping, an activity responsible for almost 80% of the world trade and also for most of the documented introductions of estuarine and marine species (e.g. Carlton, 1985, 1996; Carlton et al., 2011; Cohen and Carlton, 1998; Cranfield et al., 1998; Hewitt et al., 2004; Ruiz et al., 2000; Gollasch, 2002; Fofonoff et al., 2003). Vessels can transport sessile organisms attached to their hulls, propeller, rudder, exposed surfaces of water piping, and thruster tunnels, as well as in wet

or dry ballast (Carlton, 1985, 1996; Ruiz et al., 2000), either in the form of reproductive propagules or potential reproductive stages that can establish new introduced populations.

Once in the new habitat, introduced species can spread to natural and artificial substrata, changing the structure of native communities and ecosystem functioning and sometimes causing economical issues, such as the increase of the costs associated to industrial and commercial activities (Ruiz et al., 2000; Çinar et al., 2014). The harmful effects caused by invasive species may be of special concern in regions of the world where the state of knowledge of the marine biota is relatively poor, because they can promote the loss of native biota even before it was known to science (Nuñez and Pauchard, 2010).

Studies on non-native species and their impacts on ecosystems from the southern hemisphere are scarce when comparing to Europe and North America (Ruiz et al., 2000), and mostly concentrated to a few areas, such as New Zealand and Australia. South Atlantic studies referring to introduced and/or cryptogenic taxa are mostly restricted to Argentinean, Brazilian, and South African coasts (Orensanz et al., 2002; Rocha et al., 2013; Robinson et al., 2016). For instance, more than 75 non-native species have been reported for the region off Uruguay and Argentina (Orensanz et al., 2002), 42 introduced and 187 cryptogenic benthic invertebrate species were associated with hull fouling on the

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Table 1
Marine cryptogenic and introduced species along the Angolan coast. Status: C - cryptogenic; I - introduced. Date: DOC - date of collection; DOP - date of publication; NDD - no date determined. Likely vectors: SB - shipping boring; SF - shipping fouling; BW - ballast water; SB - solid ballast.

Taxon	Status	Source	Date	Locality	Presumed native range	Information about native distribution and/or introduction	Probable vectors
PORIFERA							
<i>Halticlonia (halticlonia) fuba</i>	I	1	1938 (DOC)	Luanda	NW Atlantic, Mediterranean Sea	Evceen et al., 2016	SF
<i>Lissodendoryx (lissodendoryx) isodictyalis</i>	I	1, 2	1938 (DOC)	Luanda	Caribbean Sea	Rützler et al., 2007	SF
Cnidaria							
<i>Serularella mediterranea</i>	C	3	1969 (DOC)	Namibe	Mediterranean	Ramil and Vervoort, 1992	SF/BW
<i>Ectopleura crocea</i>	I	4	2006 (DOP)	Namibe	NW Atlantic	Fofonoff et al., 2003	SF/BW
<i>Obelia dichotoma</i>	C	3	1973 (DOP)	Namibe	Cosmopolitan	Galea et al., 2007	SF/BW
<i>Caryophyllia (Caryophyllia) smithii</i>	I	5	1984 (DOC)	Luanda	N and SW Atlantic and Mediterranean Sea	Cornelius et al., 2005	SF/BW
POLYCHAETA							
<i>Branchiomma nigromaculatum</i>	C	2, 7	1915 (DOC)	Luanda	Probably SW Atlantic and Caribbean Sea	Jones, 1962; Keppel et al., 2015	SF/BW
<i>Hydroides elegans</i>	I	6	1955 (DOC)	Ambriz	Probably Australasia and Indian Ocean	Çinar, 2013	SF/BW
MOLLUSCA							
<i>Gibbula divaricata</i>	I	3	1969 (DOC)	Namibe	Mediterranean	Coll et al., 2010	SF/SB
<i>Leiosolenus aristatus</i>	I	3, 9, 10	1969 (DOC)	Namibe	Caribbean	Ignacio et al., 2010	SF/SB
<i>Saccostrea cucullata</i>	I	2, 3	1969 (DOC)	Luanda; Namibe	Western Indo Pacific	Coles et al., 1999	SF/SB
<i>Semimytilus algosus</i>	I	3, 11, 12	1969 (DOC)	Namibe; Luanda	S Pacific	Tokeshi and Romero, 1995	SF/SB
<i>Trinusculius afer</i>	I	3	1969 (DOC)	Namibe	S Pacific	Gofas et al., 2001	SF/SB
ARTHROPODA							
<i>Amphibalanus amphitrite</i>	I	3, 4, 13, 14, 18, 19	NDD	Ambrizete, Moita Seca, Off Kwanza river	Western Indo Pacific	Carlton et al., 2011	SF
<i>Balanus trigonus</i>	I	13, 14, 15, 18, 19	1909 (DOP)	Luanda, Lobito, Namibe	Pacific	Zullo, 1992	SF/SB
BRYOZOA							
<i>Bugula neritina</i>	C	16	1950 (DOC)	Luanda	Unknown, maybe Mediterranean	Gordon and Mawatari, 1992	SF
<i>Bugulina fulva</i>	I	16	1950 (DOC)	Luanda	Probably NW Atlantic	Ryland et al., 2011	SF
<i>Cleidothasma affinis</i>	I	5	2014 (DOP)	Malembe	W Atlantic, Caribbean	Trott, 2004	SF
<i>Crista denticulata</i>	I	16	1967 (DOP)	Quisembo	NE Atlantic, Mediterranean	Ryland, 2005	SF
<i>Electra pilosa</i>	I	5	1934 (DOC)	Cabinda	NE Atlantic (including the North Sea and the western Baltic Sea)	Nikulina et al., 2007	SF
<i>Electra verticillata</i>	I	12, 16	1967 (DOP)	Luanda, Namibe, Malembe	NE Atlantic, Mediterranean	Nikulina et al., 2012	SF
<i>Hagiosynodus latus</i>	I	16	1967 (DOP)	Ambrizete	NW Europe, Mediterranean	Hayward, 2001	SF
<i>Microporella ciliata</i>	I	16	1946 (DOC)	N'zeto	Probably Mediterranean	Kulinski and Taylor, 2008	SF
<i>Rhynchozoon bispinosum</i>	I	16	1946 (DOC)	N'zeto	Europe	Gordon and Hayward, 2005	SF
<i>Schizomavella (Schizomavella) auriculata</i>	I	16	1946 (DOC)	N'zeto	Europe	Cook, 1985	SF
<i>Schizoporella errata</i>	I	16	1946 (DOC)	Luanda	Mediterranean	Hayward and McKinney, 2002	SF
<i>Watersipora cucullata</i>	I	16	1946 (DOC)	Luanda	Mediterranean	Vieira et al., 2014	SF
TUNICATA							
<i>Ascidia curvata</i>	I	17	2010 (DOC)	Luanda	Probably Tropical W Atlantic	Rocha and Kremer, 2005	SF
<i>Ascidia dispersa</i>	I	8	2012 (DOC)	Luanda	NE Atlantic and Mediterranean	Kott, 1998	SF
<i>Botrylloides giganteum</i>	C	17	2010 (DOC)	Luanda	Uncertain	Rocha et al., 2009	IC
<i>Botrylloides nigrum</i>	C	17	2010 (DOC)	Luanda	Probably W Atlantic	Rocha et al., 2009	IC
<i>Clona intestinalis</i>	I	8, 17	2010 (DOC)	Luanda	N Atlantic	Dybern, 1965	IC
<i>Diplosoma listerianum</i>	I	17	2010 (DOC)	Luanda	NE Atlantic	Mead et al., 2011	IC
<i>Polyandrocarpa zorritensis</i>	I	17	2010 (DOC)	Luanda	S Pacific	Turon and Perera, 1988	IC
<i>Polychinum constellatum</i>	C	17	2010 (DOC)	Luanda	Uncertain	Rocha et al., 2009	IC
<i>Spyela plicata</i>	I	8, 17	2010 (DOC)	Luanda	WN Pacific	Mead et al., 2011	IC

Sources: NHM (2014) – 1 (<http://data.nhm.ac.uk/object/b63ca3f9-dbeb-4d38-8082-40e390656a41>); Santos (2007) – 2; Kensley and Penrith, 1973 – 3; Nsiangango et al., 2006 – 4; NHM (2014) – 5 (<http://data.nhm.ac.uk/object/b63ca3f9-dbeb-4d38-8082-40e390656a41>); Jeldes and Lefevère, 1959 – 6; Augener (1918) – 7; Cassoma (2014) – 8; Gofas et al., 1985–9; Ardovini and Cossignani, 2004 – 10; Inácio (2015) – 11; Kensley and Penrith, 1980–12; Stubbings (1961) – 13; Stubbings (1963) – 14; Gruvel (1912) – 15; Cook (1968) – 16; Andrade (2011) – 17; Stubbings (1964) – 18; Nilsson-Cantelli, (1938) – 19.

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