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Short Note

A First Inventory of Echinodermata at Juan de Nova (Iles Eparses, France) in the Mozambique Channel

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Abstract — Juan de Nova is one of the scattered islands known as Iles Eparses in the Mozambique Channel (Western Indian Ocean). Historically, they have been isolated from many anthropogenic influences which makes them ideal areas to study biodiversity for comparison with areas that are heavily impacted by urbanization and fishing. The programme BioReCie (Biodiversity, Resources and Conservation of Eparses Islands) undertook inventories of several marine groups, including echinoderms, which had hitherto not been assessed in Juan de Nova. A multidisciplinary team surveyed the reef slopes of the island using SCUBA to a depth of 25 m as well as the reef flats at low tide, collecting specimens and taking photos for identification. Sixty echinoderm species were found, with 51 occurring on the reef flats and in the lagoon and 22 on the reef slopes, comprising 21 species of Holothuroidea, 16 Ophiuroidea, 10 Echinoidea, 7 Asteroidea, and 6 Crinoidea. Commercial species of Holothuroidea, some of which are classified as endangered in the IUCN red list, i.e. *Thelenota ananas* and *Holothuria nobilis*, were present on the reef flats, reef slopes and in the lagoon of the island, indicating the value that protection has on biodiversity.

INTRODUCTION

Juan de Nova is one of the Iles Eparses (French Scattered Islands) which include Tromelin, Glorieuses, Bassas da India and Europa around Madagascar in the south-west Indian Ocean. Collectively, these islands, which have an EEZ (Exclusive Economic Zone) of approximately 650 000 km^2, have been governed as a strict Nature Reserve under statutes promulgated in 1975 (Gabrié, 1998) and 2007, and constitute the fifth district of Terres Australes et Antarctiques Françaises (Territory of the French Southern and Antarctic Lands). Juan de Nova is located in the Mozambique Channel (17°03'16"S; 42°43'30"E), 150 km from the west coast of Madagascar and 285 km from the East African coast (Fig. 1). The island is 5.48 km^2 in area and its coral reefs are 206.69 km^2 in extent, comprising 163.22 km^2 of reef flats and lagoon and 43.47 km^2 of barrier reef (Andréfouët *et*

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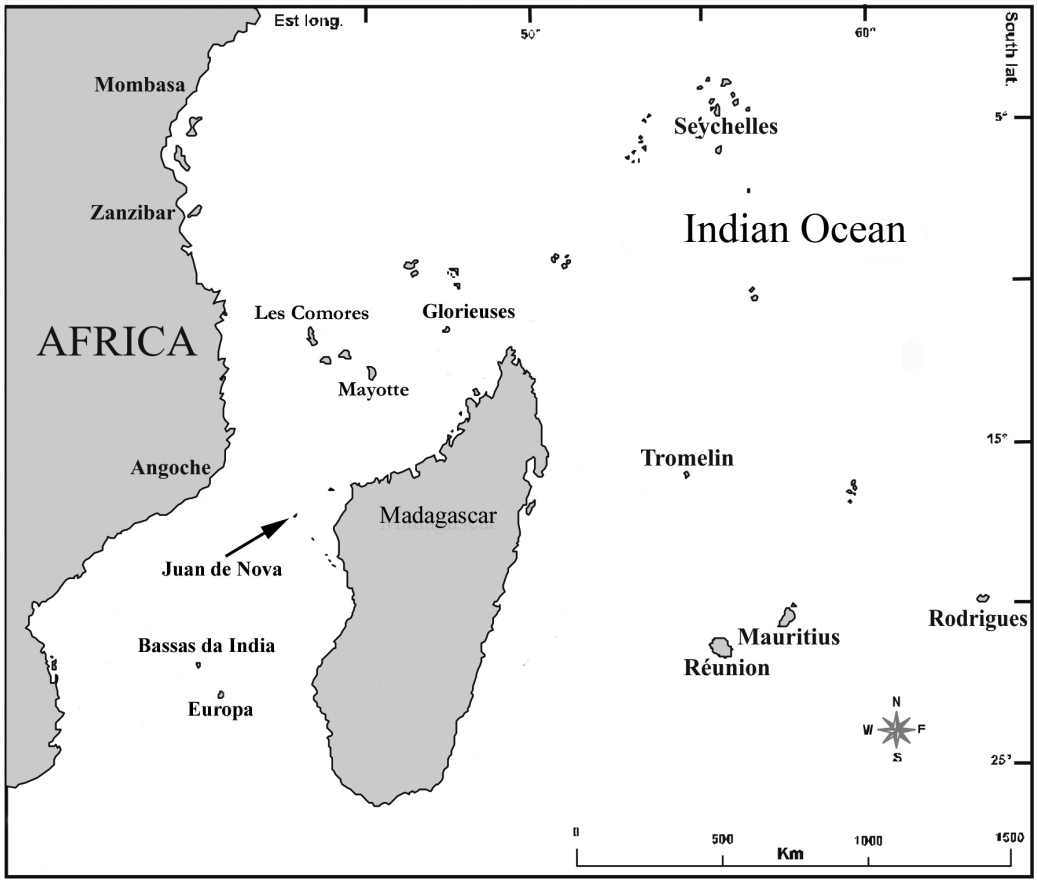

Figure 1. Map of the south-west Indian Ocean with the location of Juan de Nova.

al., 2009). The EEZ around Juan de Nova is 61 050 km^2 in area. A detailed presentation on the island covering its geomorphology and geopolitical and natural history is presented by Caceres (2003).

A survey of the island was undertaken during the BioReCie (Biodiversity, Resources and Conservation of Eparses islands) programme to map its reef areas and prepare inventories of several marine taxa for management purposes (Chabanet *et al*., 2012, 2013, 2014). Information on echinoderm diversity in the Iles Eparses has hitherto been very scarce (Vergonzanne, 1977; Mulochau & Conand, 2008) and inventories on the echinoderms were thus undertaken and presented for Europa (Conand *et al*., 2013a) and on the holothurians for the Glorieuses (Conand *et al*., 2013b) through the BioReCie programme.

Scientific studies within protected areas in the Indo-Pacific region that are not influenced by serious anthropogenic perturbation increase our knowledge on marine biodiversity, including echinoderms, and more particularly on commercially harvested holothurians (Conand *et al*., 2008; FAO, 2013; Purcell *et al*., 2013; Eriksson *et al*., 2015). The aim of this study was thus to compile the first inventory of echinoderms of Juan de Nova.

METHODS

Fieldwork was conducted during 7-17 December 2013 at Juan de Nova. An echinoderm species inventory was undertaken using an underwater visual census method (UVC) during SCUBA dives around the island at depths of 3-25 m, except on the reef flats

where snorkeling was more efficient at depths of 0-3 m. The UVC method entailed a diver randomly swimming for a period of 50 minutes in the designated area. Most echinoderms were photographed but were collected when identification in situ was not possible, which was found to be the case particularly for the Ophiuroidea and Crinoidea. A total of 25 sites were sampled around the island, 19 on the reef flat and on reef patches in the lagoon, and six on the outer slopes (Fig. 2; Table 1). A total of 300 hours were spent searching for echinoderms on the reef surface, in cavities, under rubble blocks that could be overturned, and in the sand.

Indices of occurrence of each species were calculated as the number of sites where they were present in total and within the two main habitat types, viz. the reef flat and lagoons (rf), and outer reef slope (rs), divided by the total number of sites sampled in each habitat type. Taxonomic classification followed the World Register of Marine Species (Boxshall *et al*., 2014).

Table 1. Site codes, geomorphology, date sampled, coordinates and depth of sites sampled at Juan de Nova in 2013.

Site code	Reef geomorphology	Date	Lattitude	Longitude	Depth (m)
2	Reef flat	08/12/2013	-17.06136	42.71416	0.2
3	Reef flat	09/12/2013	-17.07019	42.71046	0.5
8	Reef flat	12/12/2013	-17.05806	42.69461	0.5
15	Reef flat	15/12/2013	-17.04192	42.71683	1
17	Reef flat	16/12/2013	-17.04783	42.68040	1
20	Lagoonal reef patch	07/12/2013	-17.03259	42.73574	10
25	Lagoonal reef patch	10/12/2013	-16.95350	42.75982	15-18
27	Outer reef slope	11/12/2013	-17.08177	42.72536	13-16
28	Lagoonal reef patch	12/12/2013	-17.01960	42.68127	14
29	Outer reef slope	12/12/2013	-17.05418	42.67435	16-18
30	Lagoonal reef patch	13/12/2013	-16.96562	42.69472	16
31	Lagoonal reef patch	13/12/2013	-16.94298	42.70940	18-19
33	Outer reef slope	14/12/2013	-17.01507	42.65688	20-22
34	Subtidal reef flat	15/12/2013	-17.01076	42.80413	17
35	Outer reef slope	15/12/2013	-17.07472	42.76651	14-20
36	Reef flat	16/12/2013	-17.03337	42.72390	1
37	Reef flat	16/12/2013	-17.03573	42.68453	2
38	Lagoonal reef patch	17/12/2013	-17.03507	42.77117	10
52	Reef flat	07/12/2013	-17.03712	42.72429	3
86	Lagoonal reef patch	09/12/2013	-17.01781	42.71705	15
117	Lagoonal reef patch	11/12/2013	-17.02772	42.72481	16
140	Outer reef slope	14/12/2013	-17.01493	42.65645	28
144	Reef flat	14/12/2013	-17.02939	42.68913	3
165	Reef flat	15/12/2013	-17.05728	42.77669	2
196	Lagoonal reef patch	17/12/2013	-17.03056	42.75651	10

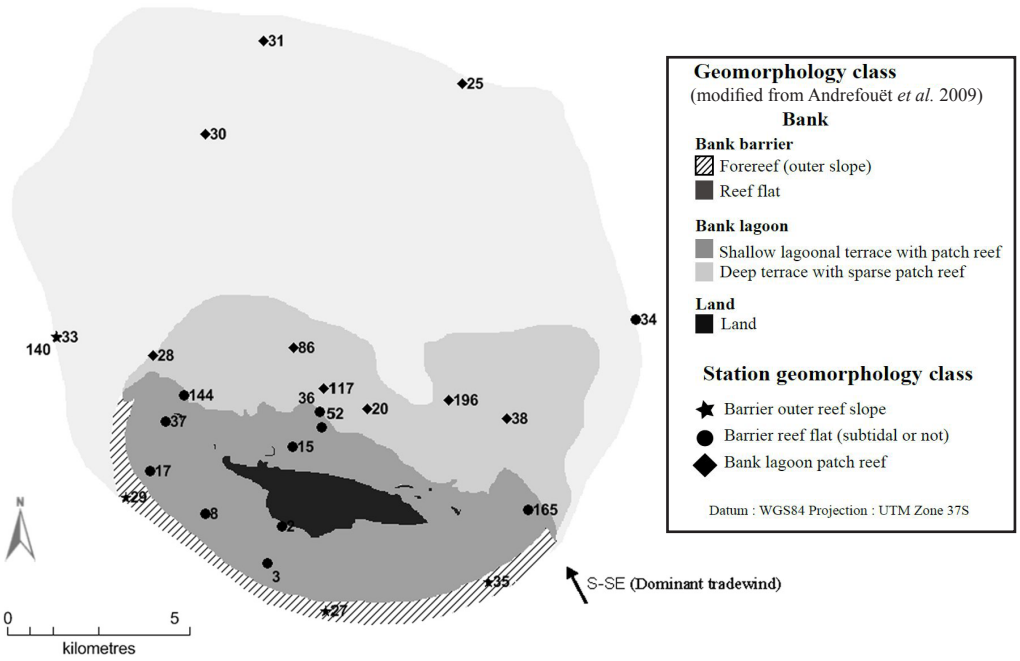

Figure 2. Sampling sites surveyed at Juan de Nova in 2013.

RESULTS

Sixty echinoderm species were found, with 51 occurring on the reef flats and in the lagoon and 22 on the reef slopes (Table 2). Only a single echinoderm species was found at some stations (8, 15 and 36) which were all on the reef flats. Stations 86 and 30 located on lagoonal patch reef yielded the highest species richness with 17 and 16 echinoderm species. A mean of 8.5 echinoderm species was sampled per site on the reef slopes and 7.3 on the reef flats and lagoonal reef patches.

Table 2. Echinoderm classes sampled at Juan de Nova in 2013.

Class	Reef flat and lagoon	Outer reef slope	Total
Holothuroidea	20	10	21
Ophiuroidea	14	4	16
Echinoidea	8	5	10
Asteroidea	7	2	7
Crinoidea	2	4	6
Total	51	22	60

CLASS HOLOTHUROIDEA

A total of 21 species of *Holothuroidea* were found at Juan de Nova (Table 3). The species with the highest occurrence was *Holothuria atra* (0.48), which was found at ten sites on reef flats and lagoonal reef patch and two sites on the outer slopes. *Bohadschia subrubra* (0.42) were also frequently sampled on reef flats and lagoonal reef patch, as were *Bohadschia atra*, *Holothuria nobilis* and *Stichopus chloronotus* each at an occurrence of 0.37. *Thelenota ananas* was the most abundant (0.83) species on the outer slopes but *Actinopyga* cf. *obesa* was also frequently sampled in this habitat (0.50).

We found at least one species of Holothuroidea at each station. Site 52, in the lagoon, had seven species, registering the greatest diversity for this class. Six species of Holothuroidea were recorded sites 17 and 86 in the lagoon, and site 140 on the outer slope.

Table 3. Occurrence of the Holothuroidea observed at Juan de Nova with the total number of sites at which species occurred, total occurrences (25 sites), occurrence on the reef flats and lagoonal reef patches (rf; 19 sites) and occurrence on the outer reef slopes (os; 6 sites).

Species	N of sites	Occurrence Total	rf	os
Holothuria nobilis	7	0.28	0.37	0
Thelenota ananas	10	0.4	0.26	0.83
Stichopus chloronotus	10	0.4	0.37	0.33
Holothuria atra	12	0.48	0.53	0.33
Bohadschia subrubra	10	0.4	0.42	0.33
Bohadschia atra	9	0.36	0.37	0.33
Pearsonothuria graeffei	5	0.2	0.16	0.33
Stichopus herrmanni	1	0.04	0.05	0
Holothuria impatiens	2	0.08	0.1	0
Actinopyga cf.*miliaris*	3	0.12	0.1	0.17
Actinopyga cf.*obesa*	5	0.2	0.05	0.5
Actinopyga mauritiana	4	0.16	0.21	0
Holothuria hilla	2	0.08	0.1	0
Holothuria pardalis	1	0.04	0.05	0
Actinopyga echinites	1	0.04	0.05	0
Thelenota anax	1	0.04	0.05	0
Holothuria fuscogilva	2	0.08	0.05	0.17
Holothuria difficilis	1	0.04	0.05	0
Holothuria sp. 1	1	0.04	0.05	0
Holothuria sp. 2	1	0.04	0	0.17
Holothuria cf.*fuscocinerea*	1	0.04	0.05	0

CLASS OPHIUROIDEA

A total of 16 species of Ophiuroidea were sampled (Table 4) but not all were identified due to difficulties in their collection. Two species were recorded with the highest occurrence on the reef flats and lagoonal reef patches: *Ophiocoma* (*Breviturma*) *brevipes* (0.24) and *Macrophiothrix longipeda* (0.20). *Ophiocoma erinaceus* and *O. cynthiae* were also regularly observed. Only three species were sampled on the reef slopes, the most common being *Ophionereis porrecta* which was also found on the reef flats and in the lagoon. Site 30 in the north of the lagoon near the outer slope had the highest species richness of Ophiuroidea with six species.

Table 4. Occurrence of the Ophiuroidea observed at Juan de Nova with the total number of sites at which species occurred, total occurrences (25 sites), occurrence on the reef flats and lagoonal reef patches (rf; 19 sites) and occurrence on the outer reef slopes (os; 6 sites).

	No. of sites/sp	total occ.	occ. rf	occ. os
Macrophiothrix longipeda	5	0.2	0.26	0
Ophiocoma erinaceus	3	0.12	0.16	0
Ophiocoma (breviturma) brevipes	6	0.24	0.26	0.17
Ophiomastix venosa	1	0.04	0.05	0
Ophiocoma cynthiae	3	0.12	0.16	0
Ophionereis dubia	1	0.04	0	0.17
Ophiarachnella gorgonia	1	0.04	0.05	0
Ophionereis sp.	1	0.04	0.05	0
Ophionereis porrecta	3	0.12	0.1	0.17
Ophiopeza fallax	1	0.04	0	0.17
Ophiactis savignyi	1	0.04	0.05	0
cf. *Ophiactis*	1	0.04	0.05	0
cf. *Ophiolepis* (juv)	1	0.04	0.05	0
Ophiura cf. *kinbergi*	1	0.04	0.05	0
Ophiocoma pusilla	1	0.04	0.05	0
cf. *Ophiothela*	1	0.04	0.05	0

CLASS ASTEROIDEA

Seven species of Asteroidea were sampled (Table 5), two of which were recorded with the highest occurrence on the reef flats and in the lagoon: *Culcita schmideliana* (0.20) and *Linckia laevigata* (0.20). Two species (*Neoferdina offreti* and *Acanthaster planci*) found in the lagoon were also sampled on the outer slopes. Site 86 has the highest species richness of Asteroidea with three species being recorded.

Table 5. Occurrence of the Asreroidea observed at Juan de Nova with the total number of sites at which species occurred, total occurrences (25 sites), occurrence on the reef flats and lagoonal reef patches (rf; 19 sites) and occurrence on the outer reef slopes (os; 6 sites).

	No. of sites/sp	total occ.	occ. rf	occ. os
Acanthaster planci	4	0.16	0.16	0.17
Culcita schmideliana	5	0.2	0.26	0
Linckia laevigata	5	0.2	0.26	0
Asteropsis carinifera	1	0.04	0.05	0
Neoferdina offreti	3	0.12	0.05	0.33
Dactylosaster cf.*cylindricus*	1	0.04	0.05	0
Linckia multifora	1	0.04	0.05	0

CLASS ECHINOIDEA

Ten species of Echinoidea were sampled (Table 6), two of which (*Echinostrephus molaris* and *Echinothrix diadema*) had the highest abundance on the reef flats and lagoonal reef patches. *Echinostrephus molaris* was frequently sampled at 14 of the 25 sites and, on the outer slopes, was always found associated with four other species: *Echinothrix calamaris*, *Eucidaria metularia*, *Prionocidaris* cf. *pistillaris* and *Heterocentrotus mammilatus*. Site 86 had the highest species richness of Echinoidea with three species being recorded.

Table 6. Occurrence of the Echinoidea observed at Juan de Nova with the total number of sites at which species occurred, total occurrences (25 sites), occurrence on the reef flats and lagoonal reef patches (rf; 19 sites) and occurrence on the outer reef slopes (os; 6 sites).

	No. of sites/sp	total occ.	occ. rf	occ. os
Echinothrix calamaris	9	0.36	0.42	0.17
Echinothrix diadema	2	0.08	0.1	0
Echinostrephus molaris	14	0.56	0.37	1
Echinometra mathaei	1	0.04	0.05	0
Stomopneustes variolaris	2	0.08	0.1	0
Plococidaris verticillata	1	0.04	0.05	0
Eucidaris metularia	3	0.12	0.1	0.17
Prionocidaris cf. *pistillaris*	1	0.04	0	0.17
Heterocentrotus mammillatus	1	0.04	0	0.17
Metalia spatagus	1	0.04	0.05	0

CLASS CRINOIDEA

Six species of Crinoidea were sampled (Table 7) with site 34 having six species, the highest number of crinoid species.

Table 7. Occurrence of the Crinoidea observed at Juan de Nova with the total number of sites at which species occurred, total occurrences (25 sites), occurrence on the reef flats and lagoonal reef patches (rf; 19 sites) and occurrence on the outer reef slopes (os; 6 sites).

	No. of sites/sp	total occ.	occ. rf	occ. os
Stephanometra indica	1	0.04	0	0.17
Antedonidae	1	0.04	0	0.17
Tropiometra carinata	1	0.04	0.05	0
Cenometra bella	1	0.04	0	0.17
Crinoidea sp. 1	1	0.04	0.05	0
Crinoidea sp. 2	1	0.04	0	0.17

DISCUSSION

A total of 60 species of echinoderms were recorded at Juan de Nova, a lower number than that recorded at Glorieuses (67 species; Mulochau & Conand, 2008, 2013; Vergonzanne, 1977) but higher than Europa where only 39 species were found (Conand *et al*., 2013a). Indices of their abundance are provided but the data were qualitative and not amenable to further analysis; the objective of the study was a first inventory of echinoderms related to reef geomorphology within the broader context of the reef slopes and the reef flats with associated lagoonal patch reefs.

The occurrence of the Holothuroidea revealed that commercially valuable species such as *Thelenota ananas*, *Bohadschia atra*, *B. subrubra*, and *Holothuria nobilis* were present right around the island. Several species of Holothuroidea are listed on the IUCN list as endangered or vulnerable (Conand *et al*., 2014) and the strict Nature Reserve within which Juan de Nova lies represents an important area for the protection of this marine resource. A further survey will be necessary to quantify the Holothuroidea in the protected areas of the Les Eparses to compare their abundance with other areas that are highly fished (Conand, 2008; Purcell *et al*., 2012, 2013; FAO, 2013; Muthiga *et al*., 2014; Eriksson *et al*., 2015). The taxonomy of several species still needs more investigation and samples of tegument will be needed for their identification based on the spicules. DNA barcoding employing the COI gene may help to separate morphologically related species as *Actinopyga miliaris*, *A. obesa* and, perhaps a third morphotype.

Ophiuroidea are common on the reef flats and in the lagoon, whereas only two species were found on the reef slopes. Nevertheless, some Ophiuroidea are known to be negatively phototactic (Fell, 1966) and hide in the crevices of coral reefs during the day, making them difficult to find.

Amongst the Asteroidea, outbreaks of the crown-of-thorns sea star *Acanthaster planci* remain one of the most significant biological disturbances on tropical coral reefs (Baird, 2013). We did not encounter a high abundance of *A. planci*, although this species was present at Juan de Nova. *Linckia laevigata* and *C. schmideliana* are two large-sized species of Asteroidea that have frequently been found at Juan de Nova, Europa and the Glorieuses Islands (Conand *et al*., 2013a & 2013b).

Among the Echinoidea, *Echinostrephus molaris* was abundant at all the sites on the outer reef slopes and was the echinoderm with the highest occurrence. This concurs with our previous findings at the other Iles Eparses (Mulochau & Conand, 2008; Conand *et al*., 2013a).

Crinoidea, like the Ophiuroidea, have the ability to hide in crevices of a coral reef during the day to protect themselves from predators. DNA barcoding of two species encountered, *Stephanometra indica* and *Tropiometra carinata*, has revealed that their genetic diversity is higher than expected (Hemery, pers com). The specimens from Reunion Island and those collected elsewhere in the Mozambique Channel, e.g. the Glorieuses Islands and Madagascar have revealed significant genetic differences (Torrence *et al*., 2012; Hemery *et al*., 2013). *Stephanometra indica* and *T. carinata* could, therefore, constitute complexes of several species.

More field-work is needed to improve this first inventory for further comparison with other surveys in the south-western Indian Ocean. Sampling at night might produce a more complete inventory, especially for the Ophiuroidea, small species of Asteroidea and the Crinoidea. Further studies will also improve our understanding of their ecological role on the reefs of Juan de Nova in terms of their distribution, community structure and habitat utilization.

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