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The Echinoderm fauna of Europa, Eparses Island, (Scattered Islands) in the Mozambique channel (South Western Indian Ocean)

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Abstract: Europa is one of the Eparses Islands, French islands scattered in the Mozambique Channel. They are isolated islands of coral origin, without permanent human population. This situation makes them good candidates to evaluate the evolution of biodiversity without direct anthropogenic influences. Knowledge is still scarce because their accessibility is limited. With the idea of classifying them as Marine Protected Areas, a management plan is required based on the coral reef communities. Among several aims, the program BioReCIE (Biodiversity, Resources and Conservation of Eparses Islands) was to complete the inventories of several marine groups, including the echinoderms, which had never been assessed before. In November 2011, a multidisciplinary team explored the reef slopes of the island by scuba diving down to 20 meters (10 sites), and the reef flats at low tide (14 sites, including the lagoon surrounded by mangrove), collecting and taking photos of the organisms which have been preserved in 95% ethanol and identified. The total species richness for echinoderms was 39 including 4 Crinoidea, 8 Echinoidea, 5 Asteroidea, with *Aquilonastra chantalae* a new species, 13 Ophiuroidea and 9 Holothuroidea. Twenty three species were collected on the slopes and 21 on the reef flats. Given the limited number of sites studied, the occurrence of the different species in each class is presented as frequent, infrequent or rare. The semi quantitative measure of abundance identified populations with high densities, as *Stichopus chloronotus*, *Ophiocoma scolopendrina* and *Echinometra mathaei* on the reef flats. Several species were only collected as juveniles. On the slopes *Echinostrephus molaris*, *Ophiothela danae* and diadematids were frequent, but with lower densities. On the whole the echinoderm fauna is not very diverse, nor abundant, except on the reef flats; the presence of holothurians near the lagoon entrance, in a mangrove habitat is notable.

Résumé : *Les Echinodermes de l'île Europa (îles Eparses, France) dans le canal de Mozambique (sud-ouest océan Indien).* Europa est l'une des îles Eparses, îles françaises du canal de Mozambique. Ce sont des îles coralliennes isolées, non peuplées. Cette situation en fait de bons candidats pour évaluer l'évolution de la biodiversité sans influences humaines directes. Les connaissances sont encore faibles, en raison de leur accessibilité limitée. Avec le but de les classer comme Aires Marines Protégées, un plan de gestion basé sur les communautés coralliennes est nécessaire. Parmi plusieurs buts, le programme BioReCIE complètera l'inventaire de plusieurs groupes marins dont les Echinodermes qui n'avaient encore jamais été étudiés. En novembre 2011, une équipe pluridisciplinaire a exploré les pentes récifales jusqu'à 20 m (10 sites) et les platiers à marée basse (14 sites, incluant le lagon bordé d'une mangrove), en récoltant et prenant des photos des organismes qui ont été fixés à l'alcool à 95% puis identifiés. La richesse spécifique en Echinodermes est de 39 espèces. Elle correspond à 4 crinoïdes, 8 échinides, 5 astérides dont *Aquilonastra chantalae* une nouvelle espèce, 13 ophiurides et

9 holothurides. Au total 23 espèces ont été récoltées sur les pentes et 21 sur les platiers. Compte tenu du nombre restreint de sites, l'occurrence des espèces est présentée comme fréquente, peu fréquente ou rare. L'abondance semi-quantitative estimée des populations permet de pointer celles à fortes densités comme *Stichopus chloronotus*, *Ophiocoma scolopendrina* et *Echinometra mathaei* sur les platiers, où certaines espèces ont été trouvées à l'état juvénile, sans observer d'adultes. Sur les pentes, *Echinostrephus molaris*, *Ophiothela danae* et les diadematidés sont fréquents mais avec des densités moindres. Globalement cette faune n'est pas très diverse, ni abondante, à l'exception du platier ; la présence d'holothuries près de l'entrée du lagon sous influence de la mangrove est intéressante.

Introduction

Europa is one of the Eparses Islands, French islands scattered in the Mozambique Channel. These isolated islands of coral origin have no permanent human population. This situation makes them adequate sites to evaluate the evolution of biodiversity without direct anthropogenic influences. Europa is situated in the South of the channel, (22°22'S-40°22'E) approximately 355 km N-NW of Toliara (Madagascar) and 529 km N-NE of Inhambane (Mozambique). It is an elevated atoll with an important eroded karstic structure and a lagoon opening into the ocean, bordered by a mangrove (Battistini, 1966; Chabanet et al., 2011a); its land surface is around 30 km^2 and 47 km^2 when the reef flats and slopes are included.

Knowledge is still limited because the inaccessibility of the islands. With the idea of classifying them as Marine Protected Areas, a management plan was required based on the topography and the coral reef communities. Among several aims, the multidisciplinary program BioReCIE (Biodiversity, Resources and Conservation of coral reefs at Eparses Is.) set out to complete the inventories of several marine groups (Chabanet et al., 2011b & 2012), including the echinoderms, that had never been studied before. There has been only one report of *Acanthaster planci* (Linnaeus, 1758), which had an apparent population *outbreak* in 2002, probably following the intense 1998-bleaching event (Quod et al., 2007).

Material and Methods

The sampling was achieved from 7th to 13th November 2011. The scientific team was composed of one group of scuba divers staying on the boat 'Antsiva', and one group staying on the island, working on the reef flats and the 'lagoon'.

The study included 10 sites on reef slopes and 14 sites on reef flats (including three sites at the lagoon entrance) (Table 1).

Echinoderms were collected on the scuba dives and exploration of the reef flats, and their relative abundance noted on a semi-quantitative three level scale, from abundant (xxx) to rare when only one specimen was found (x). Photos were taken whenever possible.

The samples were preserved in ethanol 95% in the field laboratory on Europa, after a first preliminary sort by class and morpho-species. The identifications were completed later to species level when possible by taxonomic experts. For the crinoids, molecular barcoding was used to confirm the identifications. Occurrence was calculated separately for the main habitats, as the number of sites where the species is present, divided by the total number of sites for each habitat.

The taxonomy follows the World Register of Marine Species (Appeltans et al., 2012)

Results

Table 2 presents the diversity of the echinoderms from Europa by class and by habitat, with a total of 39 species. The ophiuroids are the most diverse with 13 species. On the whole, 23 species are recorded for the reef slopes and 21 for the reef flats, including four holothuroids, the only echinoderms present at the entrance of the lagoon.

Since the reef slopes and flats habitats have very different substrates and general conditions, the species lists are presented separately, by class, with their occurrence and abundance.

Table 3 shows the main results for the reef slopes. The first is the absence of asteroids. Three frequent and relatively abundant species of ophiuroid are *Ophiothrix (Acanthophiothrix) purpurea* v. Martens, 1867 and *Ophiothela danae* Verrill, 1869 living on Nephtheidae alcyonarians which are abundant, and a black species cryptic in live *Pocillopora* coral (therefore not collected). For the echinoids, *Echinostrephus* sp., probably *E. molaris* (Blainville, 1825), is frequent, the diadematids are frequent and abundant but difficult to identify from photos (S. Coppard, pers. comm.). Only three large holothuroid species have been found with low occurrence and abundance. Because the crinoid species delimitation and classification is being revised (Hemery et al., 2012 & 2013), the four species of crinoids were compared using the

Table 1. Sampling sites: code, habitat, localization and date.

Site code	Depth	Habitat	Situation	Lattitude	Longitude	Date
dive 1 (EU7)	9 -12 m	outer slope	North	-22.32943	40.36508	07/11/11 09:00
dive 2 (EU6)	8 - 10 m	outer slope	North	-22.34063	40.33716	08/11/11 13:30
dive 3 (EU3)	11-13 m	outer slope	West	-22.373	40.32483	09/11/11 09:40
dive 4 (EU4)	12 m	outer slope	South	-22.40401	40.3702	09/11/11 13:40
dive 5 (BIO8)	11 m	outer slope	South-East	-22.38528	40.3885	10/11/11 09:18
dive 6 (EU2)	13 m	outer slope	East	-22.35291	40.3967	10/11/11 12:30
dive 7 (BIO14)	12 m	outer slope	West (Baie des Congres)	-22.35901	40.3296	11/11/11 09:15
dive 8 (BIO5)	10 m	outer slope	South West	-22.38401	40.3375	11/11/11 14:15
dive 9 (BIO12)	10 m	outer slope	North East	-22.33531	40.3889	12/11/11 09:00
dive 10 (EU5)	3 m	reef front	North	-22.34121	40.3376	13/11/11 08:30
Station 1 (Pl1)	0.5	reef flat	North	-22.33995	40.3461	07/11/11 09:40
Station 3	0-0.5	reef flat	North (meteo)	-22.3395	40.3641	07/11/11
Station 4 (BIO28)	0-0.5	reef flat	West (Baie des Congres)	-22.35959	40.331	08/11/11 09:30
Station 5	0-0.5	reef flat	North West	-22.3484	40.3314	08/11/11
Station 6	2	reef flat	North	-22.34308	40.38189	08/11/11 00:00
Station 6A	0.5	mangrove entrance	North	-22.3395	40.36411	08/11/11 21:00
Station 8 (B34)	0.5	reef flat	North	-22.34478	40.3676	09/11/11 08:30
Station 8A (CC)	0-0.5	reef flat	West			09/11/11 08:30
Station 9	0-0.5	mangrove entrance	North	-22.34891	40.37078	09/11/11 12:00
Station 10	0-0.5	mangrove entrance	North East	-22.34308	40.38189	10/11/11 10:30
Station 11 (BIO116)	0-0.5	lagon-mangrove	North East	-22.33644	40.3837	10/11/11 12:30
Station 11A (CC)	0-0.5	Reef flat	North West			10/11/11 10:00
Station14	0-0.5	lagon-mangrove	East	-22.35648	40.39122	11/11/11
Station15 (BIO25)	0-0.5	reef flat	South	-22.39529	40.37667	12/11/11 11:00

Table 2. Diversity of the Echinoderms from Europa island.

Class	Reef slope	Reef flat	Mangrove (entrance)	Total
Asteroidea	1	4	0	**5**
Ophiuroidea	8	5	0	**13**
Echinoidea	7	7	0	**8**
Holothuroidea	3	5	4	**9**
Crinoidea	4	0	0	**4**
Total	*23*	*21*	*4*	**39**

extensive dataset of reference sequences at MNHN to confirm the morphological species attribution.

Table 4 shows echinoderms of the reef flats and lagoon entrance; no species were found inside the lagoon. The asteroids were rare and only found at one site on a reef flat. Nevertheless, numerous specimens of a new, very small, fissiparous species of *Aquilonastra* O'Loughlin, 2004 (Asterinidae) was described by M. O'Loughlin (Museum Victoria) as *Aquilonastra chantalae* (O'Loughlin & Mackenzie, 2013) and the types are housed in Paris at the MNHN under the catalogue number IE- 2013-617 for the holotype and IE-2013-618 for the 11 paratypes.

In contrast, the ophiuroids are dominant with very dense populations of *Ophiocoma scolopendrina* (Lamarck, 1816). The frequently occurring and more or less abundant echinoids are *Echinometra mathaei* (Blainville, 1825) (but in low densities compared with other locations in the Indian Ocean), see Conand et al. (1998), *Echinostrephus* (probably *molaris*) and diadematids. A few juveniles of different species were collected and it is striking that no adult *Tripneustes gratilla* (Linnaeus, 1758) were observed. The holothuroids were rare, except *Stichopus chloronotus* Brandt, 1835 which occurred in high densities, up to several individuals.m^{-2}. Noteworthy is the presence of four holothuroid species on the reef flat at the entrance of the lagoon surrounded by the mangroves, but this mangrove habitat is unusual as there is no nearby freshwater. No crinoid was observed from this habitat.

Discussion

Overall the echinoderm fauna of Europa was not very diverse, with 39 species, nor abundant. These data however provide a first inventory for this phylum. The absence of *Acanthaster planci* and the general status of the coral colonies, only ten years after an outbreak, is the sign of good resilience and regeneration after a major disturbance. A new species of fissiparous *Aquilonastra,* described as *Aquilonastra chantalae* (O'Loughlin & Mackenzie, 2013) added to the numerous species recently described (O'Loughlin & Rowe, 2006). The presence of echinoid

Table 3. Echinoderms of the reef slopes of Europa island. Occurrence on 10 dives; abundance: x rare, xx a few individuals, xxx numerous; NA: non available.

Class	species	occurrence	abundance	observ
Ophiuroidea	*Ophiothrix (Acanthophiothrix) purpureus* von Martens, 1867	0.5	xxx	
	Ophiothrix (Ophiothrix) trilineata Lütken, 1869	0.1	x	
	Ophiura kinbergi Ljungman, 1866	0.1	x	
	Ophiocoma erinaceus Müller & Troschel, 1842	0.2	x	
	Ophiothela danae Verrill, 1869	0.6	xxx	
	Ophiactis macrolepidota Marktanner-Turneretscher, 1887	0.2	x	
	Ophiactis sp	0.1	x	
	black sp not collected	0.5	xx	*in Pocillopora*
Echinoidea	*Diadema savignyi* (Audouin, 1829)	0.1	x	
	Echinostrephus cf molaris (Blainville, 1825)	0.5	xx	
	Eucidaris metularia (Lamarck, 1816)	0.1	x	
	Echinothrix calamaris (Pallas, 1774)	0.1	x	
	Echinothrix sp	0.3	xx	
	Echinometra mathaei (Blainville, 1825)	0.2	xx	
	Diadema sp	0.1	x	
Holothuroidea	*Bohadschia atra* Massin, Rasolofonirina, Conand & Samyn, 1999	0.1	x	
	Stichopus chloronotus Brandt, 1835	0.1	x	
	Thelenota ananas (Jaeger, 1833)	0.1	xx	
Crinoidea	*Stephanometra indica* (Smith, 1876)	0.2	NA	
	Tropiometra cf carinata (Lamarck, 1816)	0.2	NA	
	*Cenometra cf bella (*Hartlaub, 1890)	0.1	NA	
	Dorometra cf aegyptica (AH Clark, 1911)	0.1	NA	

juveniles, *Tripneustes gratilla,* without any observation of adults is striking: did the adults die off, or are the juveniles new recruits? The dominance of the ophiuroids is common on eroded reef flats which offer them suitable shelter. The presence of holothuroids at the entrance of the mangrove is associated with the absence of brackish water and the presence of a favourable sandy bottom.

Results from the other taxa, obtained during the same fieldtrip at Europa, include fishes which occurred in high diversity (389 species and 302 new records during this fieldwork), most being widespread in the tropical Indo-Pacific (Fricke et al., 2013) and crustacean decapods (175 species including 61 new records and 2 new species of Hermit crabs) (Komai & Poupin, 2013; Poupin et al., 2012).

Other observations on the Eparses Islands have shown gradients in species diversity along the Mozambique Channel. Thus, the coral cover increases from North to South, with specific communities for each island, while an inverse gradient is observed for the algal cover and fish diversity. The diversity and biomass of fish communities were high on all islands, as well as the presence of large herbivores and predators (Chabanet et al., 2011b & 2012).

Among the other Eparses islands only a few observations have been published on Echinoderms. Vergonzannes (1977) studied them and mollusks from the Glorioso Islands situated in the north of the Mozambique Channel during a longer field study. The Glorioso Islands are composed of Grande Glorieuse, an oval-shaped, incomplete atoll of 3 km in diameter, Île du Lys or Petite Glorieuse of 0.6 km in diameter, two rock islands and two sand-banks exposed during low tide. Vergonzannes (1977) did a careful study of two leeward reef flats (RI and RII) and found 19 species on RI and 14 species on RII, with a total of 24 species. The maximum densities were on the dead corals providing cavities, up to 10 individuals/m^2. The ophiuroids were the most diverse (13 species), frequent and abundant. *Echinometra mathaei* was the only echinoid, *Linckia guildingi* Gray, 1840 the only asteroid and the eight small holothuroids were found under blocks. One crinoid species was found on another windward site, where the diversity was higher (25 species). Of the 11 ophiuroid species found by Vergonzannes (1977) only three (*Ophiothrix trilineata* Lütken, 1869, *Ophiocoma erinaceus* Müller & Troschel, 1842, and *Ophiocoma valenciae* Müller & Troschel, 1842) were found at Europa Island by our study. The first two species are widespread Indo-Pacific species, whereas *O. valenciae* is restricted to the Western Indian Ocean (Devaney, 1970). More recently, Mulochau & Conand (2008) presented an inventory of 22 species, based on four sites on the slopes and five sites on reef flats of the

Table 4. Echinoderms of the reef flats of Europa island. Occurrence on 14 sites, including lagoon entrance; abundance: x rare, xx a few individuals, xxx numerous.

Class	species	occurrence	abundance
Asteroidea	*Aquilonastra richmondi* O' Loughlin & Rowe, 2006	0.08	xx
	Aquilonastra chantalae O' Loughlin & Mackenzie, 2013	0.08	xx
	Linckia laevigata (Linnaeus, 1758)	0.08	x
	Oreasterid juv.	0.08	x
Ophiuroidea	*Ophiocoma scolopendrina* (Lamarck, 1816)	0.28	xxx
	Ophiocoma valenciae Müller & Troschel, 1842	0.08	x
	Ophiactis savignyi (Müller & Troschel, 1842)	0.21	xx
	Ophiocomella sexradia (Duncan, 1887)	0.08	x
	Amphipholis squamata (Delle Chiaje, 1828)	0.08	x
Echinoidea	*Echinometra mathaei* (Blainville, 1825)	0.58	xx
	Echinothrix diadema? (Linnaeus, 1758)	0.25	x
	Tripneustes gratilla (Linnaeus, 1758) (juv)	0.16	x
	Diadema sp	0.25	xx
	Eucidaris metularia (Lamarck, 1816)	0.16	x
	Echinostrephus molaris? (Blainville, 1825)	0.33	xx
	Diadema savignyi (Audouin, 1829)	0.08	x
Holothuroidea	*Stichopus chloronotus* Brandt, 1835	0.25	xxx
reef flats	*H. impatiens* (Forskål, 1775)	0.08	x
	Patinapta sp	0.08	x
	Holothuria atra Jaeger, 1833	0.16	xx
	Bohadschia atra Massin, Rasolofonirina, Conand & Samyn,1999	0.16	xx
lagoon entrance	*Bohadschia subrubra* (Quoy & Gaimard, 1834)	0.33	x
3 sites	*Stichopus chloronotus* Brandt, 1835	0.33	xx
	Bohadschia atra Massin, Rasolofonirina, Conand & Samyn,1999	0.33	xx
	Bohadschia vitiensis (Semper, 1868)	0.33	xx

Glorioso Islands, with ten holothuroid species, eight ophiuroids, four echinoids, no asteroid and no crinoid. The highest occurrence (0.55) and abundance was found for *Holothuria (Microthele) nobilis* (Selenka, 1867) a commercial species, not observed at Europa, but abundant in Mayotte (Pouget, 2005 ; Eriksson et al., 2012) and Comoros (Samyn et al., 2006) archipelagos, not far from the Glorioso Islands. These differences probably arise from the small size and geographic isolation of Europa, but the oceanographic conditions of the Mozambique channel, with the mesoscale eddies inducing spatial heterogeneity in an oligotrophic environment (Lutjeharms & Bornman, 2010) could also be important. It is likely that the continuous migration of mesoscale eddies along the shelf plays an important ecological role both in enhancing pelagic production and transporting coastal production offshore (Kolasinski et al., 2012). Therefore, they are possibly responsible for the episodic recruitment of pelagic larvae.

More field work is still necessary to improve this first inventory, explain the present status of the major populations of echinoderms, and follow them on a longer time scale.

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