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Iles Eparses (SW Indian Ocean) as reference ecosystems for environmental research

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ABSTRACT

TAAF ensures since 2007 the management of 5 small tropical islands lying in the southwestern Indian Ocean: the Iles Eparses. These islands share an exceptional natural heritage including many marine and terrestrial endemic species. At a regional scale the Iles Eparses are some of the most pristine ecosystems, largely preserved from anthropogenic impacts due to their geographical isolation and a historically very limited human occupation. In this context, TAAF wished that Iles Eparses become unique natural laboratories for earth scientists and environmental process observation – like climate change impacts - but also sustainable biodiversity sanctuaries for which the scientific community should provide baseline ecological data to inform on appropriate conservation tools. An inter-agency research consortium emerged in 2009 to meet this commitment for the Iles Eparses. This program was intended to set a science framework in accordance with France' objectives for Research and Conservation. It enabled between 2009 and 2014 the implementation of 18 cross-disciplinary research projects ranging from geology to ecology and represented by the variety of the proposed articles in this special issue. Altogether research projects have dramatically increased knowledge on the Iles Eparses' ecosystems and have provided the first overview of their diversity, their functions and their dynamics and its determinants. In particular applied research efforts have supplied a significant amount of ecological evidence that is now available to develop optimal conservation strategy to ensure the Iles Eparses' long-term biodiversity value. These findings point out that the continuation of research activity in the Iles Eparses should be considered a priority.

1. Iles Eparses overview

The Iles Eparses are a collection of French overseas island territories in the Western Indian Ocean managed by the French Southern and Antarctic Lands (French: Terres Australes et Antarctiques Françaises, TAAF, Box. 1) since February 2007 (fifth district of TAAF along with Kerguelen, Crozet, Saint Paul and Amsterdam, and the Terre Adélie). They are composed of the following islands: Europa, Juan de Nova and Glorieuses archipelago (Grande Glorieuse, Roches Vertes and Ile du Lys) in the Mozambique Channel (lying between 11°S and 22°S), and Tromelin north of La Réunion. The barely emerged coral reef Bassas da India is also included within the Iles Eparses (Table 1 and Fig. 1).

All islands except Juan de Nova were classified as nature reserves in 1975. While the combined land area of the islands does not exceed 42 km^2, associated territorial marine waters represent a total of more than 640,000 km^2 (approximately 6% of the French maritime territory) (Table 1). The Iles Eparses are distributed along a climatic gradient ranging from sub-arid climate (Europa) to a more tropical wet climate (Glorieuses). Climate is characterized by the alternation of a warm and wet season (austral summer, from December to April) and a dry and cooler season (austral winter, from April to October). The Iles Eparses are all located in the regional pathways of depressions and tropical cyclones. In the Mozambique Channel, ocean currents are subjected to a very high spatial and temporal variability associated with the presence of many gyres (Schouten et al., 2003; Calzas, unpub. data). These oceanographic features significantly influence the dispersal ability

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Box 1
. TAAF Administrative organization.

TAAF are placed under the authority of a senior administrator, who is designated since 2005 among the body of prefects. The prefect is both the government representative and the executive authority for the administration. TAAF present the particularity of having no permanent population and therefore have neither voters nor elected representatives or local deliberative assembly. The Prefect can nonetheless rely on a Consultative Committee and is assisted by a Secretary General, a Chief of Staff, several District Commanders and numerous project managers. The Prefect is empowered to manage all resources of the territory and more specifically to ensure the sustainable management of fisheries. In particular he is responsible for managing fish stocks within its territory and thus is in charge of editing fisheries guidelines, delivering fishing licenses, fixing the total allowable catches (TAC) as well as the dates for fisheries opening, and finally of setting and raising fishing fees. The prefect is, amongst other things, bound to guaranty the environmental conservation. TAAF regulations therefore mostly aim to provide a better framework for human activities based on up-to-date scientific knowledge and in compliance with national or regional regulations (e.g. IOTC, CITES).

to stay on the islands, respectively, in the context of their research projects and their land management missions.

2. Biodiversity sanctuaries

The Iles Eparses are among the last sanctuaries of marine and terrestrial tropical biodiversity in the South Western Indian Ocean. Geographic isolation and historically very limited human occupation have largely preserved these territories. Despite the introduction of some exotic species they are home to a remarkable native flora and fauna (including many endemic species) and well-preserved complex ecosystems such as mangroves and coral reefs. Each island supports high levels of species richness (Table 2) some being endemic to these ecosystems and others reaching very high densities. For example, Europa is a breeding ground for 8 seabird species including one endemic tropicbird species (*Phaethon lepturus europae*) and Juan de Nova is hosting one of the largest sooty tern colonies in the Indian Ocean (500 000 breeding pairs, Orlowski et al., unpub. data). Many reptiles and terrestrial birds, such as the Snake-eyed Skinks (*Cryptoblepharus bitaeniatus*) and the Malagasy White-eye (*Zosterops maderaspatanus ssp. voeltzkowii*), are also endemic to these islands (Probst, 1997; Sanchez and Probst, 2014). The Iles Eparses are major breeding sites for endangered marine turtles (*Chelonia mydas* and *Eretmochelys imbricata*). Europa is especially regarded as the most frequented site by breeding females in the Indian Ocean (8000–10000 each year, Bourjea et al., 2011). The Iles Eparses are also regionally important refuges for large

Table 1
Main geographic characteristics of the Iles Eparses (surface of geomorphologic units: Andrefouët et al., 2008).

	Tromelin	Glorieuses		Juan de Nova	Bassas da India	Europa	Total
		Glorieuses archipelago	Geyser Banks				
Geographical coordinates	15°53′ S 54°31′ E	11°35′ S 47°18′ E	22°21′ S 40°21′ E	17°03′ S 42°43′ E	21°28′ S 39°42′ E	22°21′ S 40°21′ E	
EEZ surface (km^2)	285 300	43 614		61 050	123 700	127 300	640 964
Surface of each geomorphologic unit (km^2)	6.9	201.36	256.79	212.17	96.33	49.13	822.68
Land-mass	0.85	4.79	–	5.48	0.1	31.63	42.85
Coral reef	5.42	26.92	47.8	43.47	49.18	10.50	183.29
Lagoon	0.63	169.65	208.99	163.22	47.05	7	596.54

(larval and adult) and recruitment and thus the connectivity of many marine species (Bourjea et al., 2007; Muths et al., 2011, 2012; Visram et al., 2010). Ocean eddies also have a strong influence on the distribution of primary production areas and therefore that of associated top predator species like tuna and seabirds (Weimerskirch et al., 2004).

The Iles Eparses were discovered by Europeans in the sixteenth century. Several attempts of human settlements on the islands took place in the past but all were unsuccessful mainly due to the lack of freshwater and harsh living conditions. These occupations were responsible for the introduction of exotic animal and plant species, some of which are now invasive such as black rats (*Rattus rattus*), cats (*Felis catus*), Mauritius hemp (*Furcraea foetida*) or Australian pines (*Casuarina equisetifolia*). The exploitation of guano and copra on Grande Glorieuse and Juan de Nova also generated the disappearance of some native terrestrial habitats. Today, the Iles Eparses do not house permanent human populations. However, Grande Glorieuse, Europa and Juan de Nova have been occupied year-round since 1973 by rotating military detachments (15 people including one gendarme) every 45 days in order to ensure French sovereignty. Similarly on Tromelin three TAAF agents take turns on the island every 2 months. Scientists and TAAF officers are regularly required

number of migratory species (shorebirds, raptors, etc.) often facing severe threats along their migratory roads. The Mozambique Channel and especially the Iles Eparses exclusive economic zones (EEZs) are also frequented by many species of marine mammals and fishes. In particular several species of sharks and rays, benefiting from protection measures under various international treaties and conventions (Bonn, Washington Convention CITES International Whaling Convention, Nairobi Convention) cross off the islands year-round. While the sampling effort of marine fauna and flora was not the same for the different taxonomic group and for each island, the present known marine biodiversity is very large. For example, the Iles Eparses harbor near 10% of fish species richness of the Western Indian Ocean area (Heemstra, unpub. data).

3. Anthropogenic pressures and threats

Although Iles Eparses natural ecosystems have been little altered over the past centuries, they are now facing numerous threats. These threats, resulting from climatic phenomena or from past and present human activities, are commonly encountered with varying intensities in tropical islands. In the Iles Eparses, the level of pressure exerted on the ecosystems highly varies from an island to