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ECOLOGICAL SIGNIFICANCE AND CONSERVATION PRIORITIES
OF EUROPA ISLAND (WESTERN INDIAN OCEAN),
WITH SPECIAL REFERENCE TO SEABIRDS

Matthieu LE CORRE & Pierre JOUVENTIN*

INTRODUCTION

Insular ecosystems are of particular interest both for the evolution of species under isolation and for the absence of large terrestrial native predators. Most seabird species, requiring predator-free places to breed, are restricted to remote oceanic islands (Lack, 1968). Isolation has also made these islands very vulnerable to human disturbance, and the species composition of most islands have been modified since the early 18th century as a consequence of human colonization. The man-induced modifications of native insular ecosystems often led to the decline or local extinction of seabird populations (Burger & Gochfeld, 1994). Humans may act as a direct predator of breeding adults, eggs and fledglings (Feare, 1976, 1984). Destruction of native vegetation used as breeding habitat by seabirds is another common cause of local extinction (Burger & Gochfeld, 1994). Finally, introductions of alien mammals, both predators (Moors & Atkinson, 1984 ; Atkinson, 1985) and grazers (Coblentz, 1978 ; Calvopina, 1985 ; Micol & Jouventin, 1995) to oceanic islands have been identified as an important cause of destruction of insular ecosystems.

In the tropical Indian Ocean, all these factors have at some time caused the local extinction of some species (especially large Pelecaniformes) and the decline of most remaining populations (Feare, 1978, 1984). According to Feare (1978), all species of boobies (tropical sulids) breeding in the western Indian Ocean have lost at least half of their colonies while surviving colonies are reduced in size, and the Abbot's Booby (*Papasula abbotti*), now restricted to Christmas Island, is extinct in the western Indian Ocean (Nelson, 1974).

One of the priorities in planning a wide-scale seabird conservation programme in the Indian Ocean is to complete our knowledge of the major breeding places that still exist, and to identify the threats that endanger seabirds locally (Feare, 1984 ; Kepler & Scott, 1985). Located in the southern Mozambique Channel, Europa Island (22° 20' S, 40° 22' E, Fig. 1) is one of the least known island of the western Indian Ocean (Feare, 1984), in spite of the pioneer multidisciplinary study conducted by the University of Madagascar (Legendre,

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1966a). Although this island has been identified as an important area for the conservation of three seabird species (Barré & Servan, 1988), no detailed study had been conducted to census the breeding populations of seabirds, and published data are scarce and often incomplete (Voeltzkow, 1904 ; Poisson, 1923 ; Milon, 1948 ; Malzy, 1966 ; Legendre, 1966b ; Barré & Servan, 1988). Moreover, terrestrial habitats as a whole remain insufficiently known although this island is one of the least damaged in the western Indian Ocean.

The aim of this paper is to collate information and new data on the present state of the terrestrial habitats of this island, with a special emphasis on seabirds, and to estimate the past and future consequences of human settlement. A conservation programme, in progress since 1994, is also presented. New data are based on field work conducted during six visits (of 45 days each) in the island from March 1993 to April 1996.

NATURAL ECOSYSTEMS AND ECOLOGICAL INTEREST

Europa (Fig. 1) is a coralline island, 30 km² in area, resulting from the progressive filling of an ancient atoll which appeared in the Karimbolian (90 000 years BP ; Battistini, 1966). The central part of the island (12 km²) is occupied by a « lagoon » formed by the dissolution of the coralline deposits which initially filled the original lagoon during the last flandrian transgression (Battistini, 1966). This coralline origin has led to a very flat topography, the highest point being the south-east sand dunes (8 m above sea level).

The climate is subarid (Delépine *et al.*, 1976) with an average annual temperature of 21.3°C and 532.5 mm of annual precipitation (period 1951-1993, Météo-France, pers. comm.). Two seasons can be defined : a dry and cool season from April to October, and a warm season from November to March during which 76 % of the annual precipitation occurs. Because of its coralline substrate the island holds no permanent freshwater.

NATIVE FLORA

No naturalist visited the island before the first attempt to settle in the middle of the 19th century so we have no information on the original ecosystems. However, the descriptions of the vegetation by successive naturalists and explorers who visited the island during the 20th century (Voeltzkow, 1904 ; Perrier de la Bâthie, 1921 ; Poisson, 1923 ; Decary, 1938 ; Paulian, 1950 ; Capuron, 1966 ; Battistini, 1966 ; Delépine *et al.*, 1976) suggest that the present distribution of the different vegetation formations (Fig. 1) is similar to that observed since the early 20th century, except for places replaced by sisal plantation or airstrip (see below).

Our results combined with previous work suggest that, although the total number of native plants is low (33 to 46 species of angiosperms, Table I), the vegetation facies (Fig. 1) are various (Capuron, 1966 ; Delépine *et al.*, 1976). This variety results from differences in the structure and elevation of the coralline substrate (Battistini, 1966), ranging from dry forest dominated by *Euphorbia stenoclada* on the oldest and highest rocky part of the island, to herbaceous formation with the grass *Sclerodactylon macrostachyum* on the recent substrate (coralline mud deposit) which is only a few centimetres above sea level. The inner

Figure 1. — Vegetation types of Europa Island (modified from Delépine *et al.*, 1976).

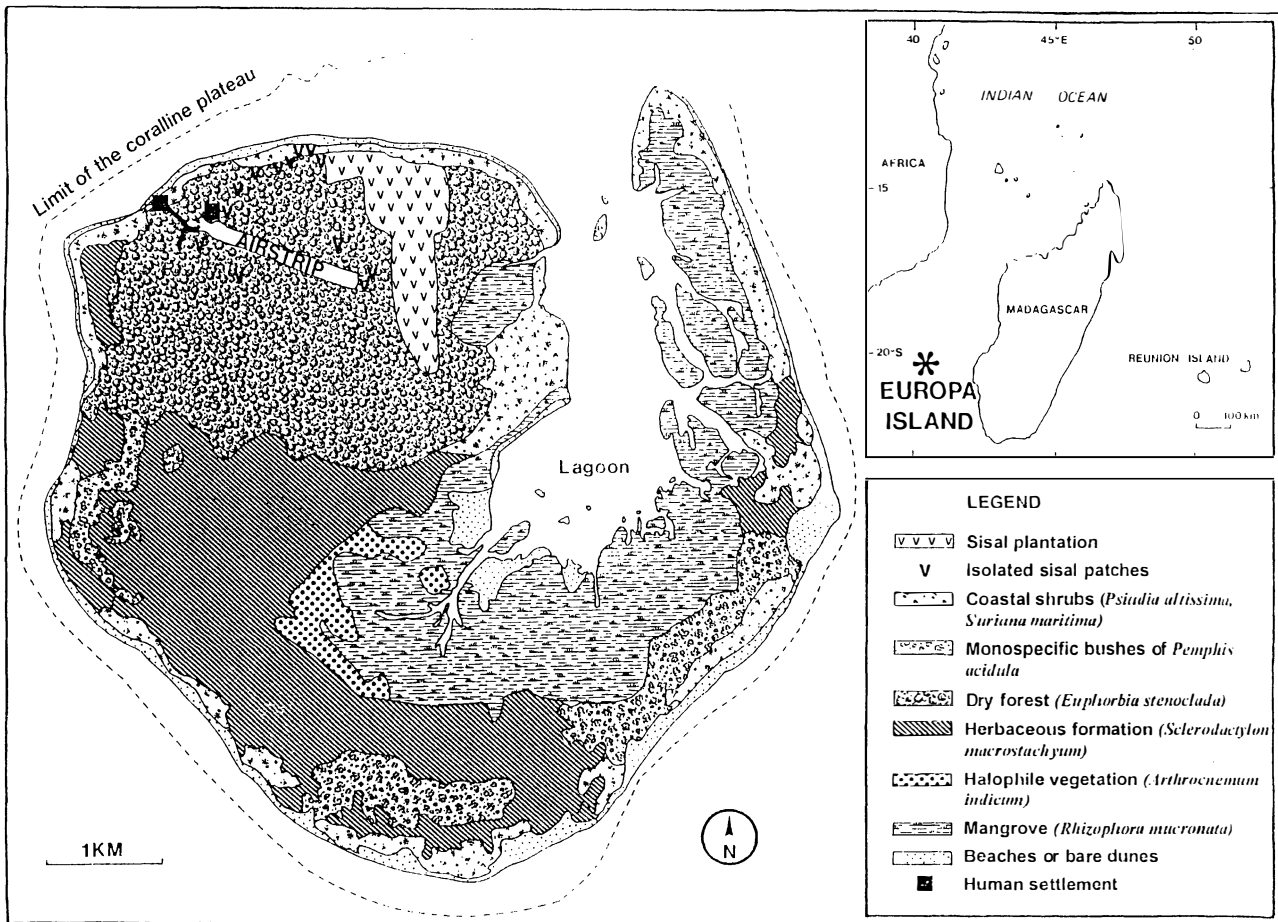


TABLE I

List of the plants (Angiospermes only) of Europa island.

Species	Status	Species	Status
AGAVACEAE		LECYTHIDACEAE	
<i>Agave sisalina</i>	I	<i>Barringtonia</i> sp.	N
<i>Furcraea foetida</i>	I	LYTHRACEAE	
AIZOACEAE		<i>Pemphis acidula</i>	N
<i>Sesuvium portulacastrum</i>	N	MALVACEAE	
<i>Trianthena pentandra</i>	N	<i>Thespesia populnea</i>	N
<i>Mollugo</i> sp.		<i>Abutilon</i> sp.	
AMARANTHACEAE		<i>Sida pusilla</i>	I
<i>Achyranthes aspera</i>		MORINGACEAE	
<i>Amaranthus</i> sp.	I	<i>Moringa oleifera</i>	P
<i>Decanema</i> sp.		MORACEAE	
cf. <i>Alternanthera</i> sp.	I	<i>Ficus marmorata</i>	N
ASCLEPIADACEAE		<i>Ficus</i> sp. (<i>non marmorata</i>)	N
<i>Cynanchum decaisnianum</i>	N	NYCTAGINACEAE	
ASTERACEAE		<i>Boerhavia diffusa</i>	N
<i>Psiadia altissima</i>	N	<i>Boerhavia</i> sp.	
AVICENNIACEAE		<i>Bougainvillea glabra</i>	P
<i>Avicennia marina</i>	N	<i>Pisonia grandis</i>	N
BORRAGINACEAE		PALMAEAE	
<i>Cordia subcordata</i>	N	<i>Cocos nucifera</i>	P
BRASSICACEAE		<i>Phoenix dactylifera</i>	P
<i>Seneberia integrifolia</i>		PLUMBAGINACEAE	
CAESALPINIACEAE		<i>Plumbago aphylla</i>	N
<i>Delonix regia</i>	P	POACEAE	
<i>Tamarindus indica</i>	P	<i>Panicum maximum</i>	I ?
<i>Caesalpinia bonduc</i>	N	<i>Dactyloctenium</i> sp.	N
CAPPARIDACEAE		<i>Eragrostis ciliaris</i>	N
<i>Capparis</i> sp.	N	<i>Eragrostis pilosa</i>	N
CASUARINACEAE		<i>Sclerodactylon macrostachyum</i>	N
<i>Casuarina equisetifolia</i>	I ?	PORTULACACEAE	
CHENOPODIACEAE		<i>Portulaca oleracea</i>	
<i>Arthrocnemum indicum</i>	N	<i>Portulaca</i> sp.	N
<i>Salsola littoralis</i>	N	RHIZOPHORACEAE	
CONVOLVULACEAE		<i>Rhizophora mucronata</i>	N
<i>Ipomea pes-caprae</i>	N	<i>Ceriops tagal</i>	N
CUCURBITACEAE		<i>Bruguiera gymnorrhiza</i>	N
<i>Cucurbitaceae</i> sp.		RUBIACEAE	
CYPERACEAE		<i>Guettarda speciosa</i>	N
<i>Fimbristylis</i> sp.		SCROFULARIACEAE	
EUPHORBIACEAE		<i>Striga asiatica</i>	
<i>Euphorbia hirta</i>	R	SOLANACEAE	
<i>Euphorbia stenoclada</i>	N	<i>Capsicum frutescens</i>	I
<i>Euphorbia thymifolia</i>	I ?	SURIANACEAE	
<i>Euphorbia pilosa</i>	N	<i>Suriana maritima</i>	N
<i>Euphorbia glaucophylla</i>	N	VERBENACEAE	
<i>Phyllanthus longifolius</i>	N	<i>Clerodendron</i> sp.	
		ZYGOPHYLLACEAE	
		<i>Tribulus cistoides</i>	I

(Status : N : native, I : introduced, P : planted. References : Perrier de la Bâthie, 1921 ; Bosser, 1952 ; Capuron, 1966 ; Delépine *et al.*, 1976 ; and this study – Systematic and nomenclature follow Friedmann, 1994).

part of the central « lagoon » is covered with an arborescent mangrove dominated by *Rhizophora mucronata* whereas the coastal vegetation is composed of bushes of *Pemphis acidula*, *Suriana maritima* and *Psiadia altissima*. Most plant species have a pantropical or indopacific range, although some species are typical of Madagascar (e. g. *E. stenoclada*, *Psiadia altissima*). There are no endemic plant species.

NATIVE FAUNA

In spite of the few studies on the invertebrates of Europa Island (Ardoin, 1966 ; Breuning, 1966 ; Derijard, 1966 ; Jarrige, 1968 ; Legendre, 1966c, 1966d ; Viette, 1966), the faunal inventory of invertebrates still has to be completed, by surveying the island at different periods of the year (Legendre, 1966d). The present synthesis (Fig. 2) only considers the vertebrate fauna, waiting for a global and long term investigation on invertebrates.

As shown in Figure 2, no strong evidence of extinction of native vertebrate species can be inferred from articles published during the present century on the fauna of Europa Island.

Voeltzkow in 1903 observed a group of flamingos with several fledglings which made him suppose that the species (*Phoenicopterus sp.*) was breeding on Europa (Voeltzkow, 1904). Later, Poisson (1923) cited a gull (*Larus cirrocephalus*) which has never been observed subsequently. Flamingos may have bred on Europa and probably became extinct due to human predation or disturbance, but this is far from clear as Voeltzkow only observed adults and fledglings which may have come from Madagascar or East Africa. The gull observed by Poisson may also have been a vagrant from Africa or Madagascar or it may have been confused with another seabird.

Figure 2 shows that the list of native vertebrates increased after each visit by naturalists, adding to the difficulty of assessing the vertebrate fauna when only visits of short duration are made. The native terrestrial vertebrates (Table II) are 4 species of reptiles (two scincids, both endemic subspecies and two geckkos ; Brygoo, 1966) and 13 species of birds. Two of the five species of land birds, the Pied Crow (*Corvus albus*) and the Barn Owl (*Tyto alba*) may have been introduced by the first colonists (see below) but they were already present in the early 20th century (Voeltzkow, 1904).

The seabird community (Tables III and IV) is composed of eight species, all of them being pantropical or indopacific. Table III reports the breeding habitats of each species and the different methods we used to estimate population sizes. One of these, the Audubon's Shearwater (*Puffinus lherminieri*), had never been recorded before on Europa, possibly due to its nocturnal behaviour at colonies and small population (Le Corre *et al.*, in prep.). Most of the other species have large to very large numbers (Table III), particularly the Sooty Tern (*Sterna fuscata*), the Red-footed Booby (*Sula sula*), the Red-tailed Tropicbird (*Phaethon rubricauda*, and the Great and Lesser Frigatebirds (*Fregata minor* and *Fregata ariel*). These numbers have probably been underestimated in the past (see Table IV, and Barré & Servan, 1988). This may be a consequence of heavy predation rate on nesting seabirds (see below), a large proportion of nests disappearing soon after laying. The comparison of the population sizes of seabirds of Europa with published data on the other populations of the western Indian Ocean (Table IV) clearly show that

Figure 2.—Chronology of the human settlement and scientific works on Europa terrestrial ecosystems with the native and introduced land vertebrates cited by the authors.

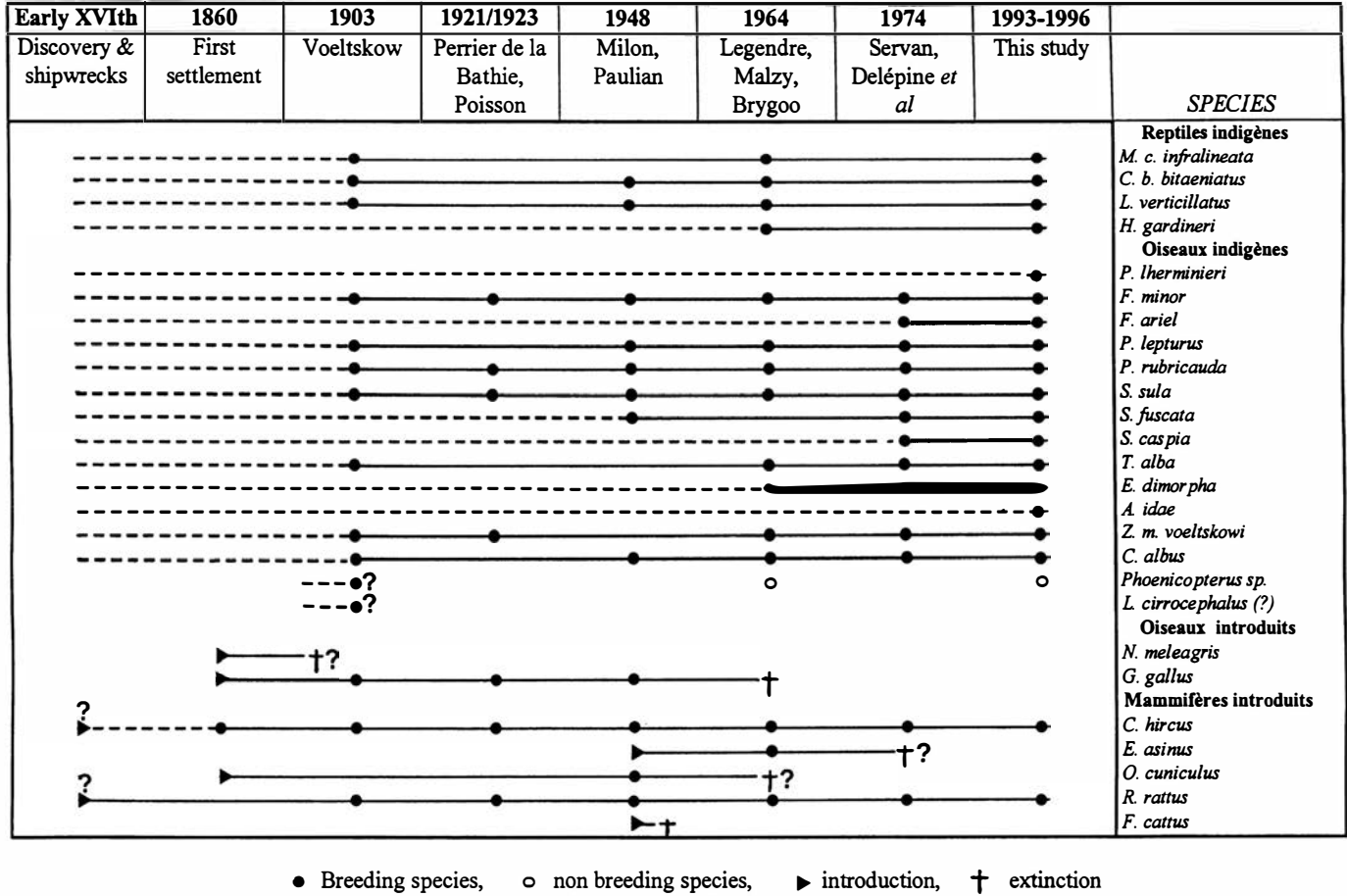


TABLE II

List of the vertebrates of Europa Island

Species	Distribution	Status on the island
Reptiles (marine)		
<i>Chelonia mydas</i>	Pantropical	Native
<i>Eretmochelys imbricata</i>	Pantropical	Native
<i>Caretta caretta</i>	Pantropical	Native
Reptiles (terrestrial)		
<i>Mabuya comorensis</i>	East Africa, Comoros	Endemic subspecies (<i>M. c. infralineata</i>)
<i>Cryptoblepharus boutonii</i>	East Africa-Polynesia	Endemic subspecies (<i>C. b. bitaeniatus</i>)
<i>Lygodactylus verticillatus</i>	Madagascar	Native
<i>Hemidactylus gardineri</i>	East Africa-Madagascar	Native ?
Birds		
<i>Puffinus lherminieri</i>	Pantropical	Native, taxonomic status unclear
<i>Fregata ariel</i>	Indopacific	Native
<i>Fregata minor</i>	Indopacific	Native
<i>Phaethon rubricauda</i>	Indopacific	Native
<i>Phaethon lepturus</i>	Pantropical	Native, endemic subspecies (<i>P. l. europae</i>)
<i>Sula sula</i>	Pantropical	Native
<i>Sterna fuscata</i>	Pantropical	Native
<i>Sterna caspia</i>	Cosmopolite	Native
<i>Gallus gallus</i>	Cosmopolite (Feral)	Introduced (now extinct)
<i>Numida meleagris</i>	Africa-Madagascar	Introduced (now extinct)
<i>Tyto alba</i>	Cosmopolite	Native ?
<i>Egretta dimorpha</i>	Madagascar	Native
<i>Ardeola idae</i>	Madagascar/Africa	Native
<i>Zosterops maderaspatana</i>	Madagascar	Endemic subspecies (<i>Z. m. voeltzkowi</i>)
<i>Corvus albus</i>	Africa-Madagascar	Native ?
Mammals		
<i>Capra hircus</i>	Cosmopolite (feral)	Introduced
<i>Equus asinus</i>	Cosmopolite (feral)	Introduced (now extinct)
<i>Felis catus</i>	Cosmopolite (feral)	Introduced (now extinct)
<i>Rattus rattus</i>	Cosmopolite (feral)	Introduced
<i>Oryctolagus cuniculus</i>	Cosmopolite (feral)	Introduced (now extinct)

(References : Voeltzkow, 1904 ; Paulian, 1950 ; Legendre, 1966b ; Servan, 1976 ; Barré & Servan, 1988 ; Hoareau, 1993 ; Le Corre & Jouventin, in press ; this study).

Europa is of major interest for seabird conservation in this area. Particularly, the population of Red-tailed Tropicbirds of Europa island is the largest population in the western Indian Ocean, while populations of Red-footed Booby, Great and Lesser Frigatebirds are second in size after those of Aldabra Atoll (see Table IV). Two species of seabird are of particular biogeographic interest on Europa Island, the Audubon's Shearwater (*Puffinus lherminieri*) and the White-tailed Tropicbird (*Phaethon lepturus*) (Le Corre & Jouventin, in press ; Le Corre *et al.*, in prep.). Particularly, we showed elsewhere that the White-tailed Tropicbird of Europa is distinct from all other breeding populations of the Indian Ocean and must be regarded as an endemic subspecies (Le Corre & Jouventin, in press).

TABLE III

Seabirds of Europa : breeding habitat and census methods.

Species	Breeding habitat	Census methods
Audubon's Shearwater	Rocky area covered with <i>P. acidula</i>	Counting of the returning birds at dusk, searching of burrows
Red-tailed Tropicbird	Dry forest, schrubs, sandy dunes	Census of nests in randomly chosen areas and extrapolation
White-tailed Tropicbird	Dry forest, schrubs, rocky areas	Census of nests in randomly chosen areas and extrapolation
Red-footed Booby	Dry <i>E. stenoclada</i> forest	Census of nests in a randomly chosen area and extrapolation
Great Frigatebird	Dry <i>E. stenoclada</i> forest	Census of nests along transects across colonies and extrapolation
Lesser Frigatebird	Dry <i>E. stenoclada</i> forest	Exhaustive census of nests in the main colony and its satellits
Sooty Tern	Herbaceous area	Census of pre-breeding groups, census of nests in randomly chosen areas and extrapolation
Caspian Tern	Coastal dunes and beaches	Exhaustive census of breeding territories

TABLE IV

Population size of the seabirds of Europa, and importance for the Malagasy area.

Species	1974*	1993/1996**	Regional rank***	Importance for the Malagasy area (%)***
Audubon's Shearwater	unrecorded	? <100	unknown	unknown
Red-tailed Tropicbird	>1 000	8 000 to 10 000 (3 000 to 4 000)	1	60
White-tailed Tropicbird	>1 000	? 1 500 to 3 000 (? 500 to 1 000)	unknown	unknown
Red-footed Booby	1 000	8 000 to 10 000 (2 800 to 3 800)	2	35
Great Frigatebird	1 500	2 500 to 3 500 (700 to 1 100)	2	30
Lesser Frigatebird	500	3 000 to 5 000 (1 000 to 1 200)	2	18
Sooty Tern	60 – 150 000	? >3 000 000 (? >1 000 000)	? 1-2	? (20)
Caspian Tern	40 – 50	25 to 35 (12)	unknown	unknown

(* : from Barré & Servan, 1988 ; ** : this study ; *** : Data from Newton, 1958 ; Nelson, 1978 ; Feare, 1978 ; 1984 ; Cheke & Lawley, 1983 ; Diamond, 1971 ; 1974 ; 1975a ; 1975b).

HISTORY OF THE HUMAN SETTLEMENT AND CONSEQUENCES ON THE NATIVE ECOSYSTEMS

HISTORY OF THE SETTLEMENT

The island was known as early as the 16th century, but was often mistaken for Bassas da India (Decary, 1938 ; Paulian, 1950), a flooded atoll located 150 km to the north west. Because of this confusion, numerous shipwrecks occurred, and the first inhabitants of Europa were probably castaways (Paulian, 1950). The first people who voluntarily occupied the island were probably fishermen and turtle hunters, and in 1860 a small colony was established. By this time, several attempts had followed one another and had failed probably because of the absence of fresh water (Paulian, 1950). Between 1903 and 1910 a family attempted to settle and tried to grow sisal (*Agave sisalina* and *Furcraea foetida*). The attempt was short-lived, as the colony was abandoned in 1910, but the sisal succeeded and it still exists. The island remained deserted from 1923 to 1948. In 1950, a meteorological station was established. Since then the island has been inhabited continuously by meteorologists. Two airstrips were built in the south (herbaceous formation) in 1950 and replaced in 1973 by another one in the dry forest (Malick, 1976). In 1973 a military camp was established, and the human population is now composed of 18 men (3 meteorologists and 15 military service men).

MAN-INDUCED CHANGES IN THE NATIVE VEGETATION

The sisal plantation caused the loss of about 10 % (0.8 km²) of the dry *E. stenoclada* native forest (Fig. 1). Several isolated patches of sisal exist on the island, suggesting that it may spread further into the native vegetation. At least 10 other species of plants have been introduced on the island (see Table I), deliberately or accidentally, but none of these plants appear to have the same invasive potential as sisal. The sisal plantation may have reduced the original breeding habitat of the Red-footed Booby, the two main breeding areas being separated by the plantation. Finally, the airstrip built in 1973 caused the disappearance of a part of the native dry forest (about 0.2 km², Fig. 1). Several fires have occurred naturally during the first half of the 20th century (Paulian, 1950) and the last one (1980) was of human origin (Hoareau, pers. com.). It occurred in the southern part of the island, in the herbaceous formation.

INTRODUCTION OF ALIEN BIRDS AND MAMMALS

Five species of mammals and at least two species of birds have been introduced to Europa since the first landing (Fig. 2) but only two mammals, Black Rats (*Rattus rattus*) and Goats (*Capra hircus*) managed to colonize the island. Black Rats may have reached the island by means of the shipwrecks which have occurred since the 16th century (Malzy, 1966). Their density seems to have fluctuated during the XXth century, following the successive human settlements (Legendre, 1966b). They now occupy all the island.

Feral Goats have been present at least since 1860. They may have been introduced at this period by the first inhabitants of the island (Paulian, 1950).

However their introduction might be more ancient, knowing the habit of the sailors to release goats, pigs and cows onto islands, to establish food reserves, as early as the 16th. Feral goats probably number more than 300 now (pers. obs.). They are distributed throughout the island except in the mangrove and on the islets, and graze on most vegetation types.

PRESENT THREATS AND CONSERVATION PRIORITIES

THREATS ON SEABIRDS

Introduced predators

Black Rats are known to prey on both the eggs and the chicks of several seabird species and even adults for the smallest species (Moors & Atkinson, 1984 ; Burger & Gochfeld, 1994). The small burrow-nesting or ground-nesting bird species are particularly at risk. On Europa, the breeding success of the two tropicbirds breeding on the dry *E. stenoclada* forest was less than 10 % during the 1994-1995 austral summer (Le Corre & Jouventin, in prep.). Although it is difficult to discriminate between the impact of the different predators (owls, crows, rats, land crabs), a rat-free islet experiment suggests that rats carry out most of the predation, especially on eggs and very young chicks (Le Corre & Jouventin, in prep.). Small procellariiformes such as Audubon's Shearwaters are also very vulnerable and the present very low population size of this species on Europa is probably a consequence of the heavy predation by rats. The introduction of other alien mammals, especially dogs and cats, represent an important potential risk for seabirds on Europa, as the island is frequented by sailors who can release domestic animals.

Predation by the Pied Crow and the Barn Owl

We have no detailed informations on the way these two species reached the island. Pied Crows are distributed through sub-saharan Africa, Madagascar and the Comoros (Goodwin, 1976). According to Langrand (pers. com.), this species is present in most islets off Madagascar with seabird colonies and may have reached Europa by its own.

Its population seems to have increased continuously since the first human settlement. Voeltzkow (1904) cited a « white-throated crow » which seems to be the Pied Crow *Corvus albus* but which he called *Corvus scapulatus*, as being rather rare and distant from the human settlement. Poisson, who spent one day on Europa, listed all the birds he saw (Poisson, 1923), but no crow is mentioned, which seems to indicate that the species was scarce, if it did exist. According to Malzy (1966), a group of 10 to 15 Pied Crows lived continuously around the meteorological station in April 1964, feeding on the refuse. In 1974, Servan estimated the total population between 50 to 100 birds, located around the human settlements (Barré & Servan, 1988). In April 1995, we estimated the number of Pied Crows as around 250 to 300 birds, using linear counts across the island. Most birds gathered around the human settlements, where they benefit from refuse and artificial reserves of fresh water. However, we observed them all over the island,

feeding on Green Turtle hatchlings on beaches, fruits of the native fig-tree (*Ficus marmorata*), insects, and nesting seabirds (chicks of the two tropicbirds species, Red-footed Boobies and Sooty Terns). On the seabird colonies, they behave both as scavengers and predators. This increase of the population size seems to be a direct consequence of the constant presence of men since 1950, as this species is well known as an opportunist and commensal of man (Goodwin, 1976). The same phenomenon has occurred on Aldabra atoll (Penny, 1992) where Pied Crows have benefited of the settlement of fishermen camps in the 19th century. There too, this species predated chicks and eggs of various seabird species, especially noddies, terns and boobies (Penny, 1992).

The Barn Owl was already present in 1903 (Voeltzkow, 1904). A preliminary analysis of pellets suggests that although its main prey are rats, some individuals seem to specialise on chicks of seabirds (Le Corre & Jouventin, in prep.). If the Barn Owl reached the island independently of man, one might wonder if this was before or after the introduction of rats. In the former, its diet probably evolved after rat introduction, this prey being more numerous than seabird chicks and present all year round. Consequently, the introduction of rats may have had an indirect effect on the insular predator-prey equilibrium by improving the year-round food resources of the Barn Owl, and thus, increasing its population. The number of birds specializing on seabirds probably increased with population, thus increasing predation by owls on seabirds. The same indirect effect of rat introductions has been identified on the island of Saint Helena where rats are an alternative food source for introduced cats, outside the seabird breeding season (Moors & Atkinson, 1984). The estimation of the predation rate of the Barn Owl on seabirds is in progress on Europa (Le Corre & Jouventin, in prep.). In the Seychelles and Hawaii, where Barn Owls have been introduced to control rats (Lever, 1987 ; Penny, 1992), they predate many seabirds (especially the smallest and more conspicuous species such as White Tern, *Gygis alba*) and have led some of them close to local extinction (Penny, 1992).

It is of interest that the seabird community of Europa Island lacks smallest species such as small terns (except the Sooty Terns which generally swamp predators) and burrow-nesting species such as shearwaters (except Audubon's Shearwater which may be close to local extinction, Le Corre *et al.*, in prep.). As we have no information on native seabirds, we cannot establish whether the present community is the original one or if it has changed since the 16th century, period when the first humans reached the island. The introduction of rats leading to predation on seabirds and increase of the Barn Owl population may have led to the local extinction of the most vulnerable species, which breed on other predator-free islands or islets in the western Indian Ocean. Paleontological investigations could help to answer this question.

THREATS ON THE NATIVE VEGETATION

Overgrazing by feral goats

By grazing very large spectrum of plants and destroying soil structure, feral goats may have a strong effect on native vegetation (Coblentz, 1978 ; Calvopina, 1985). No studies of the impact of the goats on the vegetation on Europa island have been conducted, but incidental observations show that they graze most plant

species, especially the young leaves of *Euphorbia stenoclada*. There is no apparent evidence of overgrazing by goats at the present time, as the dry forest and the southern herbaceous formation regenerate well. However, a detailed study, using a fencing experiment would be necessary to quantify the impact of goats accurately.

Accidental fires and invasion by alien

The frequency and effect of natural fires on the dynamic of the vegetation of Europa is unknown. However, because of the lack of permanent fresh water, the native vegetation, particularly the dry forest is very vulnerable to accidental fire. The permanent presence and circulation of people on the island conduct to an important risk of accidental fires.

The last threat for the native vegetation is the invasion by alien plants. Among the different alien plant species identified on Europa, at least two are potential invaders of the native vegetation, *A. sisalina* and *F. foetida*. However, the regular links between Europa and Madagascar or Réunion Island, by plane or boat for the release of the staff in the island increase the risk of accidental introduction of plant.

CONSERVATION PRIORITIES

Although some man-induced changes on vegetation occurred during the early 20th century, Europa Island still holds one of the least perturbed insular ecosystems of the western Indian Ocean. Particularly, this island appears to be a very important place for seabird conservation in this area (major breeding place for the Red-tailed Tropicbird, the Red-footed Booby, the Lesser and Great Frigatebirds and the Sooty Tern). Information on the biodiversity and endemism of the invertebrate fauna is lacking and one priority is to complete our knowledge of this part of the ecosystem.

Studying the seabird community, we identified several threats which may lead to the decline of the seabird populations. Future actions should be diverted to reduce them. Immediate and simple actions can quickly be effected, to put refuse and fresh water out of reach of the crows, goats and rats. Experiments must be started to quantify the impact of the various disruptive factors and to assess the risk of losing biodiversity.

The actions now in progress are :

1) an estimation of the impact of rats on breeding success and population dynamics of seabirds : rats of an islet of 3 ha have been eradicated in March 1995, using Bromadiolone (Le Corre & Jouventin, in prep.). This islet hold 35 to 45 breeding pairs of Red-tailed Tropicbirds each year. All adults and fledglings are ringed. The breeding success, breeding frequency and mate fidelity of the birds of this rat-free colony will be compared with an other colony of 126 breeding pairs of the main island, where adults and fledglings are also ringed ;

2) an estimation of the predation rate of the Barn Owl on the breeding seabirds : pellets of the Barn Owl are regularly collected and analysed since May 1994 in several roost and nest sites of owls, in order to estimate the proportion of seabird chicks and rats predated by owls. An estimation of the population size of owls is also in progress.

Future actions include :

- 1) a quantification of the impact of feral goats on native vegetation (by a fencing experiment enclosing different vegetation types) ;
- 2) an estimation of the predation rate on seabirds by Pied Crow ;
- 2) a study of the two species of sisal, these species being potential invaders of the native forest.

The results of these applied studies would be of interest not only for the conservation of Europa Island but also for the restoration of other more heavily damaged coralline islands of the area (e. g. Juan de Nova, Glorieuses, some islets of the Seychelles group, etc.).

The second step would be to restore the whole island, by eradication or control of harmful species. Large feral grazers such as cattle or goats are now quite easy to control or eradicate from small or medium-sized islands (Calvopina, 1985 ; Jouventin, 1994 ; Micol & Jouventin, 1995). The last 10 years have seen considerable advances in eradication of rats from small islands (0.09 to 2 km², Moors, 1985 ; Taylor & Thomas, 1993) and a faisability study is in progress on eradication of rats from Saint Paul Island (7 km²), a volcanic island of the southern Indian Ocean (Micol & Jouventin 1995). Further progress could allow conservationists to plan rat eradication campaigns on islands as large as Europa (30 km²). This would be of great benefit to the conservation of the biodiversity of the island.

Europa, as the Glorieuses, Bassas da India, Tromelin and Juan de Nova has been classified as a Nature Reserve by the Prefect of Réunion in 1974. However, this status is not sufficient and one of the urgent need is to classify these islands as National or International Nature Reserve.

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SUMMARY

Located in the southern Mozambique Channel, Europa is one of the least known islands of the Malagasy area. We made six stays on the island, between

1993 and 1996, in order to evaluate the terrestrial ecosystems, to census the breeding seabirds and to identify potential threats. Our results show that Europa is one of the least damaged islands of the Malagasy area.

The successive human settlements which occurred since the late 19th century resulted in the introduction of several plant and animal species. Furthermore, a little part of the native dry forest (10 %) has been replaced by a sisal plantation (*Agave sisalina* and *Furcraea foetida*) in the early 20th century. However, the major part of the island has not suffered from important disturbance since the first human settlement and, in that places, the vegetation is probably close to its pristine state. As a consequence, the native vertebrate fauna is rich (7 reptiles and 13 birds including 8 seabirds). The seabird populations are much larger than previously estimated, particularly those of the large Pelecaniformes (Red-tailed Tropicbird *Phaethon rubricauda*, Red-footed Booby *Sula sula*, Great and lesser Frigatebird *Fregata minor* and *F. ariel*) and of the Sooty tern (*Sterna fuscata*). Two other species, the Audubon's Shearwater (*Puffinus Iherminieri*) and the White-tailed Tropicbird (*Phaethon lepturus*) are of particular biogeographic interest. The main threat identified is the predation of seabirds by introduced Black Rats (*Rattus rattus*). The impact of the anthropophile Pied Crow (*Corvus albus*) and of the Barn Owl (*Tyto alba*) as predators of seabirds is discussed. The native vegetation, especially the dry forest (which includes the breeding sites of the arboreal seabird species) is still at risk from overgrazing by feral goats, fires and invasion by introduced sisal.

We suggest a conservation programme to prevent the loss of biodiversity. The first step, now in progress, is to quantify the threats. The second step is to restore the island as a whole by controlling or eradicating the species which may endanger the native terrestrial ecosystems.

RÉSUMÉ

Située dans le sud du canal de Mozambique, l'île Europa est l'une des îles les moins connues de la région malgache. Nous avons réalisé six séjours dans l'île, de 1993 à 1996, afin d'évaluer l'état des écosystèmes terrestres, de recenser les populations nicheuses d'oiseaux de mer et d'identifier les facteurs susceptibles de réduire la biodiversité de l'île. Les résultats obtenus montrent que l'île Europa est une des îles les moins perturbées de l'océan Indien occidental.

Les différentes tentatives d'occupation humaine ayant eu lieu depuis la fin du XIX^e siècle sont probablement à l'origine de l'introduction de plusieurs espèces de plantes et d'animaux. De plus, la réalisation au début du XX^e siècle d'une culture de sisal (*Agave sisalina* et *Furcraea foetida*) a provoqué la disparition d'une partie de la forêt sèche indigène (10 %). Cependant, la plus grande partie de l'île n'a pas subi de perturbations importantes depuis les premières installations humaines et la végétation actuelle est, dans ces endroits, probablement proche de son état originel. De ce fait, la faune des vertébrés est riche (7 espèces de reptiles et 13 espèces d'oiseaux dont 8 espèces d'oiseaux de mer). Les populations d'oiseaux de mer sont plus grandes que ce qui était estimé précédemment, en particulier celles des grands Pélécaniformes (Paille-en-queue à brins rouges *Phaethon rubricauda*, Fou à pieds rouges *Sula sula*, Frégate du Pacifique *Fregata minor* et Frégate ariel *F. ariel*) et celle de la Sterne Fuligineuse (*Sterna fuscata*). Deux

autres espèces, le Puffin d'Audubon (*Puffinus lherminieri*) et le Paille-en-queue à brins blancs (*Phaethon lepturus*) ont un intérêt biogéographique remarquable. La principale menace identifiée est la prédation des œufs et poussins d'oiseaux de mer par le Rat noir (*Rattus rattus*), introduit. L'impact du Corbeau pie (*Corvus albus*), espèce anthropophile, et de la Chouette effraie (*Tyto alba*) comme prédateurs d'oiseaux de mer est discuté. Trois autres sources de risques potentiels de modification de l'habitat, en particulier de la forêt sèche, ont été identifiées : le surpâturage par les chèvres, les incendies naturels ou accidentels et l'invasion du milieu par le sisal.

Nous proposons un programme de conservation pour éviter la perte de biodiversité. La première étape, actuellement en cours, consiste à quantifier les menaces. La seconde étape sera de restaurer l'île dans son ensemble, par le contrôle ou l'éradication des espèces animales ou végétales introduites pouvant mettre en danger les écosystèmes terrestres indigènes.

RÉFÉRENCES

- ARDOIN, P. (1966). — Contribution à la connaissance des Ténébrionides de l'île Europa (Col.). *Mém. Mus. Nat. Hist. Nat.*, 16 : 187-190.
- ATKINSON, I.A. (1985). — The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifauna. p. 35-81. In P.J. MOORS (Ed.) *Conservation of island birds. ICBP, Tech. Pub.*, 3.
- BARRÉ, N. & SERVAN, J. (1988). — L'avifaune des îles Eparses. *ICBM, Monographie*, 5 : 209-224.
- BATTISTINI, R. (1966). — La morphologie de l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16 : 7-18.
- BOSSER, J. (1952). — Note sur la végétation des îles Europa et Juan de Nova. *Le Naturaliste Malgache*, 4 : 41-42.
- BREUNING, S. (1966). — Un nouveau Lamiaire de l'île Europa (Col. Cerambycidae). *Mém. Mus. Nat. Hist. Nat.*, 16 : 185-186.
- BRYGOO, E.R. (1966). — Note sur les Reptiles terrestres récoltés à Europa en avril 1964. *Mém. Mus. Nat. Hist. Nat.*, 16 : 29-32.
- BURGER, J. & GOCHFELD, M. (1994). — Predation and effects of humans on island-nesting seabirds. *BirdLife Conservation Series*, 1 : 39-67.
- CALVOPINA, L. (1985). — The impact and eradication of Feral Goats on the Galapagos island. p. 157-158. In P.J. MOORS (Ed.) *Conservation of island birds. ICBP, Tech. Pub.*, 3.
- CAPURON, R. (1966). — Rapport succinct sur la végétation et la flore de l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16 : 19-22.
- CHEKE, A.S. & LAWLEY, J.C. (1983). — Biological history of Agalega, with special reference to birds and other land vertebrates. *Atoll research Bull.*, 273 : 65-108.
- COBLENTZ, B.E. (1978). — The effects of Feral Goats (*Capra hircus*) on island ecosystems. *Biol. Conserv.*, 13 : 279-286.
- DECARY, R. (1938). — Les satellites de Madagascar et l'ancienne navigation dans le Canal de Mozambique. *Bull. Acad. Malgache*, 20 : 167-188.
- DELÉPINE, R., MAUGÉ, L.A. & PADOVANI, A. (1976). — Observations écologiques et climatologiques dans les îles Europa, Glorieuses et Tromelin. *Travaux et Documents de l'O.R.S.T.O.M.*, 47 : 81-112.
- DERJIARD, R. (1966). — Note préliminaire sur les Crustacés Stomatopodes et Décapodes récoltés à l'île Europa du 6 au 24 avril 1964. *Mém. Mus. Nat. Hist. Nat.*, 16 : 159-180.
- DIAMOND, A.W. (1971). — The ecology of the seabirds of Aldabra. *Phil. Trans. Roy. Soc. Lond. B*, 260 : 561-571.
- DIAMOND, A.W. (1974). — The Red-footed Booby on Aldabra Atoll, Indian Ocean. *Ardea*, 62 : 196-218.
- DIAMOND, A.W. (1975a). — The biology of tropicbirds at Aldabra Atoll, Indian Ocean. *Auk*, 92 : 16-39.
- DIAMOND, A.W. (1975b). — Biology and behaviour of frigatebirds *Fregata spp.* on Aldabra Atoll. *Ibis*, 117 : 302-323.

- FEARE, C.J. (1976). — The exploitation of Sooty Tern eggs in the Seychelles. *Biol. Conserv.*, 10 : 169-181.
- FEARE, C.J. (1978). — The decline of Booby (*Sulidae*) populations in the Western Indian Ocean. *Biol. Conserv.*, 14 : 295-305.
- FEARE, C.J. (1984). — Seabird status and conservation in the tropical Indian Ocean. *ICBP Tech. Pub.*, 2 : 457-471.
- FRIEDMANN, F. (1994). — *Flore des Seychelles - Dicotylédones*. Collection Didactiques - ORSTOM Editions, Paris, 663 pages.
- GOODWIN, D. (1976). — *Crows of the World*. Comstock, Cornell University Press, 354 pages.
- HOAREAU, A. (1993). — *Les Iles Eparses. Histoire et découverte*. Azalées Editions, Saint Denis, 237 pages.
- JARRIGE, J. (1968). — Un Staphylinide nouveau de l'île Europa [Col.]. *Bull. Soc. Ent. Fr.*, 73 : 37-38.
- JOUVENTIN, P. (1994). — Past, present and future of Amsterdam Island (Indian Ocean) and its avifauna. *BirdLife Conservation Series*, 1 : 122-132.
- KEPLER, C.B. & SCOTT, M. (1985). — Conservation of island ecosystems. p. 255-271. In P.J. MOORS (Ed.) *Conservation of Island Birds*. ICBP. Tech. pub., 3.
- LACK, D. (1968). — *Ecological adaptation for breeding in birds*. Methuen and Co., London, 409 pages.
- LE CORRE, M. & JOUVENTIN, P. (in press). — Geographic variation in the White-tailed Tropicbird *Phaethon lepturus*, with the description of a new subspecies endemic to Europa Island, Southern Mozambique Channel. *Ibis*.
- LEGENDRE, R. (1966a). — Mission Scientifique à l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16.
- LEGENDRE, R. (1966b). — Le peuplement de l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16 : 213-219.
- LEGENDRE, R. (1966c). — Arachnides récoltés à l'île Europa en avril 1964. *Mém. Mus. Nat. Hist. Nat.*, 16 : 181-184.
- LEGENDRE, R. (1966d). — Liste des Invertébrés terrestres libres actuellement connus de l'île Europa (Hexapodes et Arachnides exceptés). *Mém. Mus. Nat. Hist. Nat.*, 16 : 211-212.
- LEVER, C. (1987). — *Naturalized birds of the World*. Longman Scientific and Technical, 615 pages.
- MALICK, M. (1976). — Notes sur les îles françaises de l'Océan Indien. *Travaux et Documents de l'O.R.S.T.O.M.*, 47 : 75-80.
- MALZY, P. (1966). — Oiseaux et Mammifères de l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16 : 23-28.
- MICOL, T. & JOUVENTIN, P. (1995). — Restoration of Amsterdam Island, South Indian Ocean, following control of feral cattle. *Biol. Conserv.*, 73 (3) : 199-206.
- MILON, P. (1948). — Notes d'observation à Madagascar sur le Paille-en-queue à brins rouges observé à l'île Europa. *Alauda*, 16 : 55-74.
- MOORS, P.J. & ATKINSON, I.A.E. (1984). — Predation on seabirds by introduced animals and factors affecting its severity. *ICBP Tech. Pub.*, 2 : 667-690.
- MOORS, P.J. (1985). — Eradication campaign against *Rattus norvegicus* on the Noises Islands, New Zealand, using Brodifacoum and 1080. *ICBP Tech. Pub.*, 3 : 143-155.
- NELSON, J.B. (1974). — The distribution of Abbott's Booby *Sula abbotti*. *Ibis.*, 116 : 368-369.
- NELSON, J.B. (1978). — *The Sulidae - Gannets and Boobies*. Oxford University Press.
- NEWTON, P. (1958). — Ornithological notes on Mauritius and the Cargados Carajos Archipelago. *Proc. Roy. Soc. Art and Sci. Mauritius.*, II-1 : 39-71.
- PAULIAN, R. (1950). — L'île Europa, Une dépendance de Madagascar. *Le Naturaliste Malgache*, 2 : 77-85.
- PENNY, M. (1992). — *Birds of Seychelles*. Collins Field Guide., 160 pages.
- PERRIER DE LA BÂTHIE, H. (1921). — Note sur la constitution géologique et la flore des îles Chesterfield, Juan de Nova, Europa et Nozy-Trozana. *Bull. Econ. Madagascar*, 31 : 170-176.
- POISSON, H. (1923). — Rapport de tournée à l'île Europa. *Bull. Econ. Madagascar*, 2 : 132-141.
- SERVAN, J. (1976). — Ecologie de la Tortue verte à l'île Europa (canal de Mozambique). *Terre et Vie*, 30 : 421-464.
- TAYLOR, R.H. & THOMAS, B.W. (1993). — Rats eradicated from rugged Breaksea Island (170 ha), Fiordland, New Zealand. *Biol. Conserv.*, 65 : 191-198.
- VIETTE, P. (1966). — L'Entomofaune de l'île Europa. *Mém. Mus. Nat. Hist. Nat.*, 16 : 191-210.
- VOELTSKOW, A. (1904). — Berichte über eine Reise nach Ostafrika zur Untersuchung der Bildung und des Aufbaues der Riffe und Inseln des westlichen Indischen Ozeans. 5. Europa-Insel. *Zeits. Ges. Erdkunde*, Berlin : 426-451.