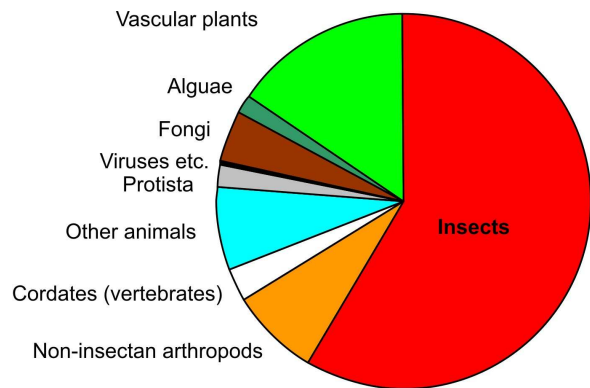


TERRESTRIAL INVERTEBRATE BIODIVERSITY OF REUNION ISLAND

Jacques ROCHAT, Insectarium de La Réunion

A world of insects

Arthropods represent two-thirds of the biodiversity (fig. right), mostly insects (Grimaldi & Engel, 2005). More than 80% of the terrestrial animal species are insects, *i.e.* about a million of known species – probably four times more in fact – whereas vertebrate animals represent only 2.7% of this biodiversity. These insects has coevolved with superior plants (about 200 000 species) for about 100 million of years; they are in all ecological niches, all habitats, and they have developed all kinds of lifestyles.



Flora and fauna unlike anything else in the world

La Réunion is one of the 25 hot spots of biodiversity, zones where, on 1.5% of the land, is located about two-thirds of the known species (Hilton-Taylor, 2000 ; Myers et al., 2000).

Because Reunion is far away from the continents and quite young, few species are present but a large proportion of the species are endemic of the island or endemic of this part of the Indian Ocean, *i.e.* these species exist only here and nowhere else in the world. Like in vascular plants, a third of the entomofauna is endemic of the island. This proportion is probably underestimated (Goodman & Benstead, 2005) ; it is only a few percent for continental tropical forests.



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Endemic giant stick insect (body length: 16 cm) (*Monandroptera acanthomera*, Phasmidae).



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Today only three specimens of this endemic moth are known (*Cymoriza upupalis*, Pyralidae).



© J. Rochat
Endemic spider from the rain forest (*Nephilingys borbonica*, Tetragnathidae)

About 2000 insect species are known from Reunion: 900 species of Coleoptera (with 400 endemic species) (Gomy, 2000), 560 species of Lepidoptera (with 190 endemic) (Martiré & Rochat, 2008), 20 species of Dragonflies (one endemic), five species of Stick insects (four endemic), more than 47 species of Orthoptera (50% endemic), etc. with a total estimated number of about 5000 species (Quilici et al., 2002 ; Bénard et al., 2008). In the same way, the number of spiders is estimated to about 500 species with 25% of endemic species (Ledoux, 2004, 2007, com. pers.). Among the terrestrial snails and slugs, about 80% of the 54 native species of Reunion are endemic (Griffith & Florens, 2006).

Varied origins

The plant and the animal species come from neighbouring islands and continents: Madagascar, Africa, but also Asia and Pacific region. The way these species could arrive is almost unknown; the main hypothesis are migratory animals (birds, insects), marine and atmospheric streams.

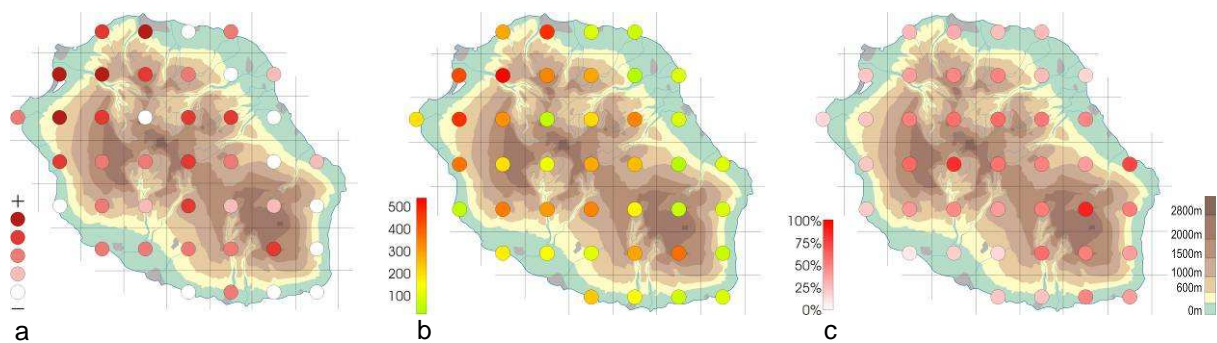
Whatever the way, the probability of transport, survival and arrival of an organism from its origin area to Reunion Island, followed by an actual settlement (that often requires several individuals) is extremely low. The successful establishment of a new genus of coleopteran in the mascarene Islands is estimated to occur every 30000 years in average (Blanchard, 2000). The species of butterfly that established by itself is the Monarch butterfly *Danaus plexippus*, a well known migratory species, that arrived in 1985 in Mauritius and Reunion from Hawaii and Australia. Moreover, In La Réunion there are no moth species of the families with bad flier short-living adults that do not feed (Martiré & Rochat, 2008).

More recently, the increasing carriage by surface and by air dramatically increases the probability of introduction of new species, that often leads to an ecological disaster for the native species.

A phenomenal speciation

The isolation of the local population leads these population to become different from their ancestors due to different environmental conditions. Ultimately, the evolution of the local populations gives new species, closely related to the original species but different enough to make crossbreeding impossible.

This speciation is more likely to occur a the population is isolated and placed in conditions for from those of the origin. Hence, with altitude, the climate gets a stronger selective force to tropical species: the number of plant and insect species decreased and the number of endemic species increases.



At Reunion Island, the number of known species of Lepidoptera (b) by 5 x 5 km square depends on sampling intensity (a) and habitat; the proportion of endemic (Reunion or Mascarene Islands) species of Lepidoptera (c) strongly depends on altitude and conservation rate of natural habitats (source : Martiré & Rochat, 2008).

In some taxa, starting from an ancestor, a large number of endemic species that spread in all habitats. Among insects, for instance there are dozens of different species of Cratopinae weevils.



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The weevils of the Cratopinae subfamily, endemic of Mascarene Islands, exhibit a large number of species at La Réunion (upper-left to lower-right: *Cratopus humeralis*, *Cratopus somptuosus*, *Cratopopsis bistigma*, *Cratopopsis nitidifrons*, *Cratopus septemvittatus*, *Cratopopsis alluaudi*, *Cratopus chrysochlorus*, *Cratopopsis coquereli*).

Among the terrestrial molluscs, 75% of the species are endemic of the Mascarene Islands, Mauritius being a centre of dispersion (Griffith & Florens, 2006). The sedentary lifestyle of these species and their high specialization to microhabitats leads to a kind of evolutionary dead-end; the large number of sub-fossils collected in Mauritius and Rodrigues show that many species went extinct before the colonisation of these islands by humans, probably due to climate changes.



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Today there are 17 species of terrestrial snails of the genus *Omphalotropis* (Assimineidae), endemic of the Mascarene Islands, eight at Reunion Island.



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Endemic snail with reduced shell (*Hyalimax maillardi*, Succineidae) strongly linked with the rainforest.

Last, in isolated islands the species are often modified because of the lack of specific resources, the presence of empty ecological niches, and the lack of some functional groups (absence of predators for instance): reduction of the fecundity, loss of flying ability, loss of escaping behaviour, giant species, enlarged diet, etc.; all those modifications make the island species unique but also very vulnerable to perturbations.

Strong relationships with species and habitats

Many endemic species are co-evolved with other endemic (or at least native) species. The most demonstrative cases monophagous species, like *Salamis augustina* butterfly (see below) and orchid flowers pollinated by a unique endemic animal species.



© J. Rochat
Hummingbird-hawkmoth, pollinator of the orchid *Calanthe sylvatica* (*Macroglossum milvus*, Sphingidae)



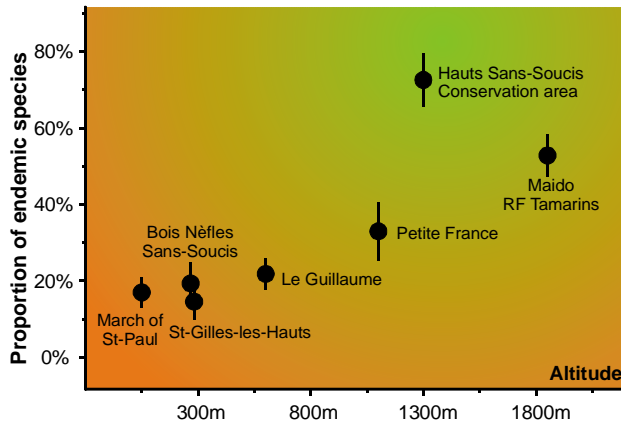
© J. Rochat
Key creeper
(*Hugonia serrata*, Linaceae)



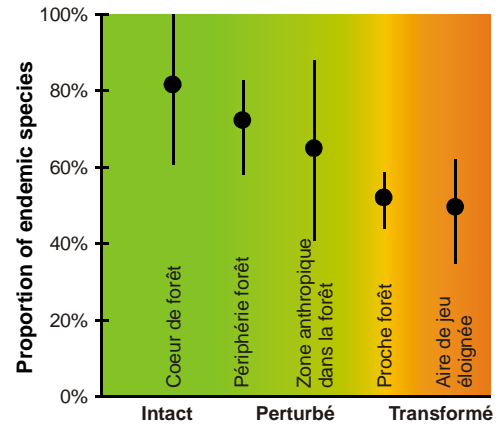
© D. Martiré
Reunion swallowtail
(*Papilio phorbanta*, Papilionidae)

The reproduction of many endemic plants is strongly based on specific insect pollinators.

Independently to the altitude, in Reunion Island the proportion of endemic species increases related to the level of conservation of the habitats.



Proportion of endemic species of Lepidoptera as a function of altitude in the commune of Saint-Paul (Reunion Island); the outstanding of "Hauts de Sans-Soucis" Conservation Area is shown off by its high endemism rate (from Rochat, 2005).



Proportion of endemic species of arthropods as a function of preservation rate of the habitat in and close to "Bon Accueil" Forest Conservation Area (Les Makes, Reunion Island) (from Gasnier, 2005).

Last, lava tubes are exceptional habitats, with very stable climate conditions, that permit evolution of troglitic arthropods. These species are particularly vulnerable to climate changes.



© J. Rochat
Looking for cave arthropods in "Tortoise Cave" (La Réunion).



© C. Guillermet / Insectarium
Troglitic hunting spider
Trogoctenus briali (Ctenidae)



© J. Rochat
Cave beetle
(*Neocolpodes poussereaui*, Carabidae).

Destruction of species and habitats

During the XVIIth century, before it was inhabited, the Reunion Island was described as totally covered, including the lowlands, by forest, plentiful of [vertebrate] animals (birds, tortoises, etc.) (Blanchard, 2000). Since the colonization by humans, the natural habitats strongly declined: use of the land for agriculture and housing, over-exploitation until extinction of edible or useful species. The transformed area increased with time, going from the seaside, to the lowland forests, then middle altitude rainforest. Today there are about 25 to 30% remaining natural habitats but the lowland habitats have been nearly completely lost and the highland habitats are well preserved due to their inaccessibility (Strasberg et al., 2005 ; Girard et al., 2006).



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Destruction of a preserved gully of low-land native plants in western Reunion in 2004.

If the mass extinction of the endemic vertebrate fauna in the Mascarene Islands after human colonization is well documented, very few is known about the invertebrate fauna during the same time. Even if none of the invertebrate has been exploited, the species that were strictly linked to extinct plants or habitats are very likely to be also extinct.



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This endemic grasshopper (*Pygacris decampsi*, unnamed family) is strictly associated with the red palm tree.



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Red palm tree (*Acanthophenix rubra*, Palmaceae, protected species) in its natural habitat (left) and specimen victim of poaching (right).



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Biological invasions

The biological invasions, by plants or animals, are said to be the first cause of biodiversity loss in islands, the second cause in the world being the loss of habitats (Hilton-Taylor, 2000). The impact of insectivorous imported animals (tenrec, toad, guppy fish...), by chance or on purpose, on the native entomofauna has not been quantified. Among the six more dangerous invasive ant species, four are in Reunion Island already; however they are located in anthropic low-land habitats and until now the native habitats seem to be resistant to their invasion (Blard, 2006).



© J. Rochat

The toad *Bufo gutturalis* is an imported generalist insectivorous species that has colonized all the habitats in Reunion Island.



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This Indian origin Blue butterfly (*Chilades pandava*) arrived in Mauritius and Reunion in 1999; its larvae feeds specifically on Cycas trees.



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The yellow crazy ant (*Anoplolepis gracilipes*) is an invading species involved in the decline and extinction of many animal species in islands (*in* Blard, 2006).

The impact of exotic invasive species is generally indirect: invasive plants, in addition to other factors, contribute to the loss of natural habitats and of the species strongly associated to these habitats; other [animal] species are competing with endemic species via shared resources or shared natural enemies (Holt & Hochberg, 2001).

The Salamid nymphalid (*Salamis augustina*, Nymphalidae) is an endemic butterfly of Reunion Island close to extinction because the decline of its unique host-plant, the Nettle tree (*Obetia ficifolia*, Urticaceae); the Mauritius sub-species *Salamis augustina vinsoni* became extinct by 1957 when the Nettle tree went extinct in this island (Williams, 1989). The dramatic decline of the nettle tree is related to the transformation of the native low-land habitats, where the plant grows, and the introduction of an alien invasive land snail that devours the young shoots of the tree.



© D. Martiré

The Salamid nymphalid (left) is an endemic butterfly of La Réunion critically endangered because of the decline of its unique host-plant, the nettle tree (centre), due to, among other factors, the presence of an exotic giant land snail, the Achatina.



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Consequences of climate changes

In the case of an increase of annual average temperature, habitats and species may be shifted to higher altitudes, with biodiversity loss at the lowest and the highest altitudes. This phenomenon has been observed in European mountains with, for instance, the extinction of Apollo butterflies populations of Auvergne (*Parnassius apollo arvernensis* and *Parnassius mnemosyne*). Terrestrial molluscs of the Mascarene Islands, with nearly 80% of endemic species, are particularly endangered as many species are extinct already due to past climate changes, and more recently due to aliens species like rats (Griffith & Florens, 2006).

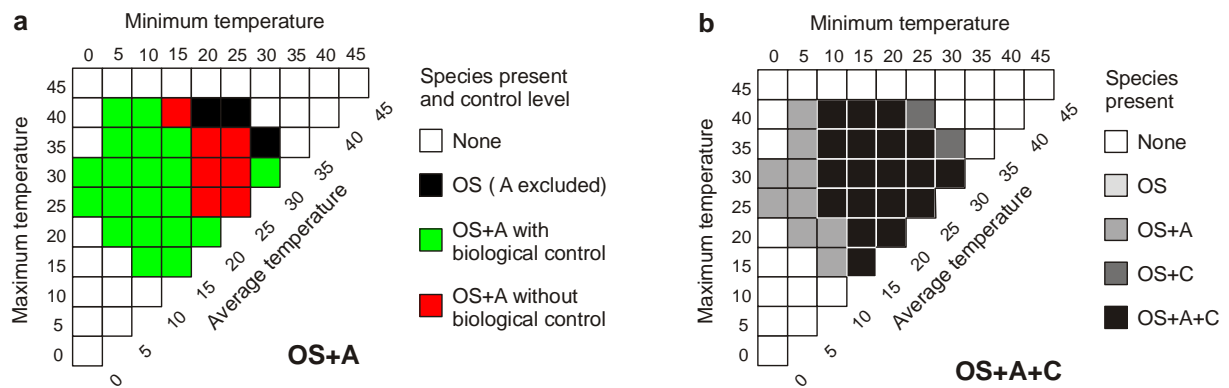
It has been demonstrated that the change in annual temperature destabilizes certain insect prey/predator interactions, leading to outbreaks of several insect pests, because of loss of effectiveness and loss of competitive ability and then exclusion of their natural enemies.

Insect parasitoids that control phytophagous insects are sensitive to tiny climate changes (right : *Aphytis* sp. parasitizing citrus red scale *Aonidiella aurantii*).



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The influence of annual temperature regime is a key factor of the stability of interacting insect population dynamics : for instance the biological control of the olive scale (OS) by the parasitoid *Aphytis maculicornis* (A) depends on climate conditions as average temperature and annual temperature range (below fig. a) ; furthermore, the competition and the coexistence of the two parasitoids (A et C) of the olive scale directly depends on the annual temperature variation (below fig. b) (from Rochat & Gutierrez, 2001).



The increase of the frequency and the intensity of the cyclones, as the length of the dry season (and consecutively the occurrence of the fire) are favourable factors for alien species to establish in disturbed or weakened native habitats.

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Insectarium of Reunion Island is a small approved NGO acting for the knowledge, the popularization and the conservation of the insects, and furthermore the terrestrial arthropods, and their environment. About ten employees and volunteers carry out these tasks, with the funding of French government and local communities.

Insectarium of Reunion Island is locally and internationally recognized as reference expert in the invertebrate fauna of natural terrestrial habitats of Reunion Island. Its expertise has been asked for trainings or lectures in entomology, for ecological studies of natural areas, for evaluating ecological restorations or environmental impacts, in collaboration with other research or environmental conservation organisms or within experts committees.

At Insectarium, the visitors can discover living arthropods and several vertebrates of the local common fauna as stick insects, cockroaches, ants or spiders; in the small garden, rare plants with specific relationship with insects, tamed chameleons, and a greenhouse with butterflies. Insectarium presents only native or naturalised species and explains to the public that alien species are serious threats for the unique and exceptional local biodiversity.

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