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Red List ing reveals the true state of biodiversity: a comprehensive assessment of Seychelles biodiversity

Justin Gerlach

Nature Protection Trust of Seychelles, PO Box 207, Mahe, SEYCHELLES
133 Cherry Hinton Road, Cambridge CB1 7BX, U.K.
[*jstgerlach@aol.com*]

Abstract: The status of all terrestrial and freshwater multicellular organisms in the Seychelles islands is assessed based on IUCN Red List criteria. This covered 4,841 soecues if fungi, lichens, plants and animals. 34% of species were assessed as threated. Threat levels for most groups were around 30%, with exceptionally high levles of threats in molluscs (61%) and vertebrates (62%). Lower threat levels in other groups are partly due to higher levels of uncertainty in some groups, with Data Deficiency being over 50% in fungi, Bryophyta, Nematoda and Rotifera, and 38% in Arthropoda. Endemic species show higher levels of threat than indigenous species in almost all taxa, due to endemics being largely narrow range species and indigenous species including many that are widespread recent colonists. Species restricted to the coral islands show exceptionally high threat levels as a result of beign limited to low lying islands threatened by sea level rise. The main threat factors are identified and show a change from largely historical threats such as hunting and deforestation, to habitat degradation resulting from the impacts of invasive species and climate change. 23 species are considered to be Extinct, with a further 232 species possible extinctions. The causes of these extinctions are discussed.

The IUCN Red List has become the standard tool for evaluating the threatened status of organisms, the assessment criteria enabling individual assessments, comparisons between taxa, areas and time periods (Rodrigues *et al.* 2006). However, comprehensive assessments only cover a small proportion of the world's biodiversity, such as birds, mammals, amphibians, cycads and corals. Large scale, but still partial assessments have been carried out on selected freshwater taxa and random samples of other groups have been assessed. This still makes comparison between taxa difficult, particularly for the majority of the poorly known invertebrate taxa (Gerlach *et al.* 2012). Regional or national assessments are similarly limited, with most such assessments covering only a small proportion of the biota, usually easily recorded groups such as vertebrates, some plant groups and a small number of the larger invertebrates. The scope of such assessments needs to be expanded in order to make the Red List a fully functional tool in monitoring biodiversity conservation trends, both at local and global scales.

The Indian Ocean Biodiversity Assessment 2000-2005 (IOBA) was undertaken by Nature Protection Trust of Seychelles to assess the composition and status of all aspects of biodiversity in the Seychelles islands. This resulted in a series of monographs on the fauna of the islands (Gerlach 2007a, 2007b, 2008, 2009, 2011, 2013, Gerlach & Haas 208, Gerlach & Matyot 2006, Gerlach & Marusik 2010) which include Red List assessments for all native animal species. Assessments of the endemic Mollusca,

Vertebrata and Orthopteroidea have been included on the IUCN Red List, the other taxa are in the process of inclusion on the list. In addition to these assessments compiled by the author, all endemic granitic Seychelles vascular plants and pteridophytes are on the IUCN Red List (except for *Impatiens gordonii*). The only multicellular taxa not to have been assessed are the Bryophyta, Fungi and lichens, and the plants of the coral islands. Here I present a summary of the Red List status of all Seychelles species, including a provision assessment of the Bryophyta, Fungi, lichens and non-endemic plants, with an analysis of the status of the biodiversity and the main threat factors.

Assessments

IUCN Red List criteria (IUCN 2001) have been applied to all native taxa (indigenous and endemic). Taxa believed to be introduced have not been assessed. These assessments are based on historical collections and data collected during the IOBA on most of the 115 islands of the Seychelles group (Gerlach 2003). Quantitative data were collected in all main habitats on each island (methods are fully described in Gerlach 2003). These data allowed distributions and habitat associations to be determined for each species, and in some cases population sizes could be estimated. Historical data comprised distribution data from historical collections, comprising island records only (1892) or more precise localities within islands (1894, 1905-9, 1954-6, 1972 and 1984), these were compiled from literature or collection labels. These data allow distributions to be compared. They give no data on population sizes but may provide an indication of relative abundance, for example, where a species was collected in large numbers (at least 50 specimens) in 1908 but has only been found as isolated individuals subsequently a population decline can be inferred (but not quantified).

In assessing the Red List status of a species different criteria were useful for different types of organism, these are summarised in Table 1. Taxa were considered Extinct where extensive searches have been carried out in the known range and similar habitats and the species has not be located for 50 years. A shorter time period is used for species that have been monitored closely and decline has been observed, followed by a failure to find any surviving individuals despite intensive searching. Taxa not recorded for over 50 years but not subject to careful searches, or from taxonomically confused groups were considered Data Deficient.

Table 1. Red List criteria used in assessing different taxa

Criterion	Outline	Application
A	Population decline	vertebrates, molluscs, some insects and plants
B	Range/habitat decline	all taxa
C	Population restricted and declining	vertebrates
D	Population size	vertebrates, some molluscs and plants
E	Modelled extinction risk	vertebrates

Threat levels

34% of the 4,841 native species were assessed as threatened (Table 2). Of the multicellular kingdoms (Fig. 1) threat levels are highest for animals (32%) and lowest for fungi (18%), but this latter value is unreliable due to the high proportion of Data Deficient species (more than 50%). Plants have an overall threat level of 30%.

Of the plants, the bryophytes show the lowest level of threat (22%) due to the high proportion of Data Deficient species in this group; its true threat level is probably closer to that of the other plant groups, both of which have similar threat levels (37% for pteridophytes and 33% for angiosperms).

Total threat rate for animals is 36% and particularly high threat levels are recorded for Mollusca and Vertebrata (excluding the phyla with very small numbers of species). The moderately high level of threat for animals as a whole is the result of the data being skewed by the arthropods which make up 92% of Seychelles animal species and 85% of the arthropods are insects (Hexapoda). Within the arthropods Crustacea show the highest level of threat, and Myriapoda the lowest.

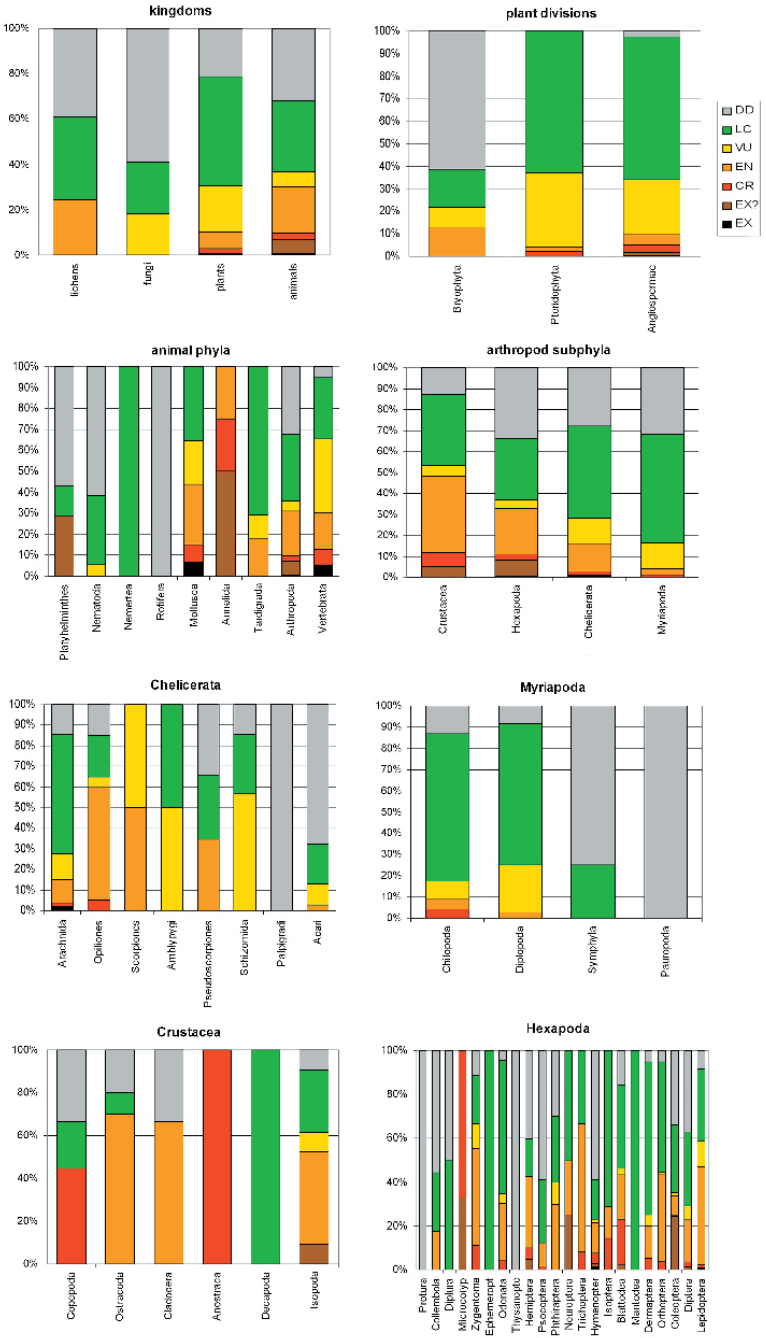
Global comparisons

It is difficult to determine whether or not this level of threat is unusually high as there are few comprehensive assessments available for comparison. At present the Red List is dominated by non-comprehensive assessments and the raw figures give misleading results, for example 63% of plants and 50% of fungi on the global Red List are threatened, as few non-threatened taxa have been assessed. The comprehensive assessments show a wide range of threat levels, for plants they vary from 30% (conifers) to 63% (cycads). Non-marine vertebrates range from 41% in amphibians, to 25% in mammals and only 13% in birds. For non-marine invertebrates only freshwater crabs

Table 2. Summary of assessment, threatened categories are EX?, CR, EN, VU

Taxon	EX	threatened	NT	LC	DD	total	% threatened
Lichens	0	99	0	148	158	405	24
Fungi	0	8	0	10	26	44	18
Bryophyta	0	53	0	40	148	241	22
Pteridophyta	0	36	0	61	0	97	37
Angiospermae	2	135	8	239	10	394	35
Platyhelminthes	0	2	0	1	4	7	(29)
Nemertea	0	0	0	1	0	1	(0)
Nematoda	0	3	0	17	32	52	6
Annelida	0	4	0	0	0	4	(100)
Mollusca	4	43	1	26	0	74	61
Rotifera	0	0	0	0	35	35	(0)
Tardigrada	0	4	0	24	0	34	29
Arthropoda	10	1305	1	1048	1277	3645	36
Vertebrata	7	66	3	32	6	114	62

Fig. 1. Comparison of threat levels faced by major multicellular taxa in Seychelles



have been assessed comprehensively at a global level. At a regional level (reviewed in Gerlach *et al.* 2012) European assessments are the most complete; these tend to show lower levels of threat than recorded here: in Scandinavia invertebrates have low threat levels – annelids <1-4% (varying in different country assessments), molluscs 7-13%, chelicerates 3-12%, myriapods 4-8% and insects 9-10%. Assessments from Germany and Poland have high threat levels, but these cannot be used comparatively as they are not fully comprehensive or use slightly different criteria.

The available comparative data suggest that Seychelles has a high level of threat for most major taxa; that ratio between the Seychelles threat level and that from comparative sites gives molluscs a 4.9 times higher threat level, chelicerates 2.3, myriapods 2, insects 3.7 and vertebrates at least 1.5. The comparative data are largely drawn from continental sites (most of the species in the global assessments and all of the comprehensive national assessments) and it is probable that at least a part of the elevated threat level of the Seychelles biota reflects island vulnerability.

The assessments are further divided into indigenous and endemic taxa, granitic and coralline islands and terrestrial and freshwater (Fig. 2).

Endemics and natives

For animals 43% of endemic species are threatened but only 26% of indigenous species. Endemic vetebrates are nearly twice as threatened as indigenous species (84% compared to 44%), slightly lower differences are found in molluscs (78% to 44%) and arthropods (42% to 27%). Within the arthropods endemic myriapods are more than five times as threatened as indigenous species (27% compared to 5%), crustaceans are more than twice as threatened (69% compared to 31%), chelicerates nearly twice as much (34% compared to 18%). Insects have the lowest level of difference with 43% compared to 29%.

Geographical system

All taxonomic groups show higher threat levels in the atolls than the granitics (mollusucs - 100% of endemic species and 40% of indigenous compared to 74 and 13%; arthropods – 80 and 53% compared to 35 and 35%; vertebrates 91 and 51% compared to 81 and 18%). Within the arthropods very high levels of threat in the atolls is found in the Crustacea (100 and 62% compared to 63 and 31%), high levels in insects (81 and 54% compared to 35 and 36%) and chelicerates (75 and 38% compared to 30 and 31%). The one oddity are the myriapods which are very scarce in the atolls, lacking endemic atolls species, they have 33% threatened indigenous species in the atolls, which is almost the same as in the granitics which have 27% threatened endemics and 38% threatened indigenous species.

Atoll species are all threatened by climate change, with sea-level rise being project to cause significant loss and degradation of habitat in these low-lying islands. Invasion is relatively low in the atolls (at least compared to the granitics) and this is only a minor, contributory threat to most species. Threats in the granitics (discussed futher below) are more diverse, and invasion is the main active threat.

Fig. 2. Comparison of threat levels faced by endemic and indigenous species systems of the proportion of species in each RL category

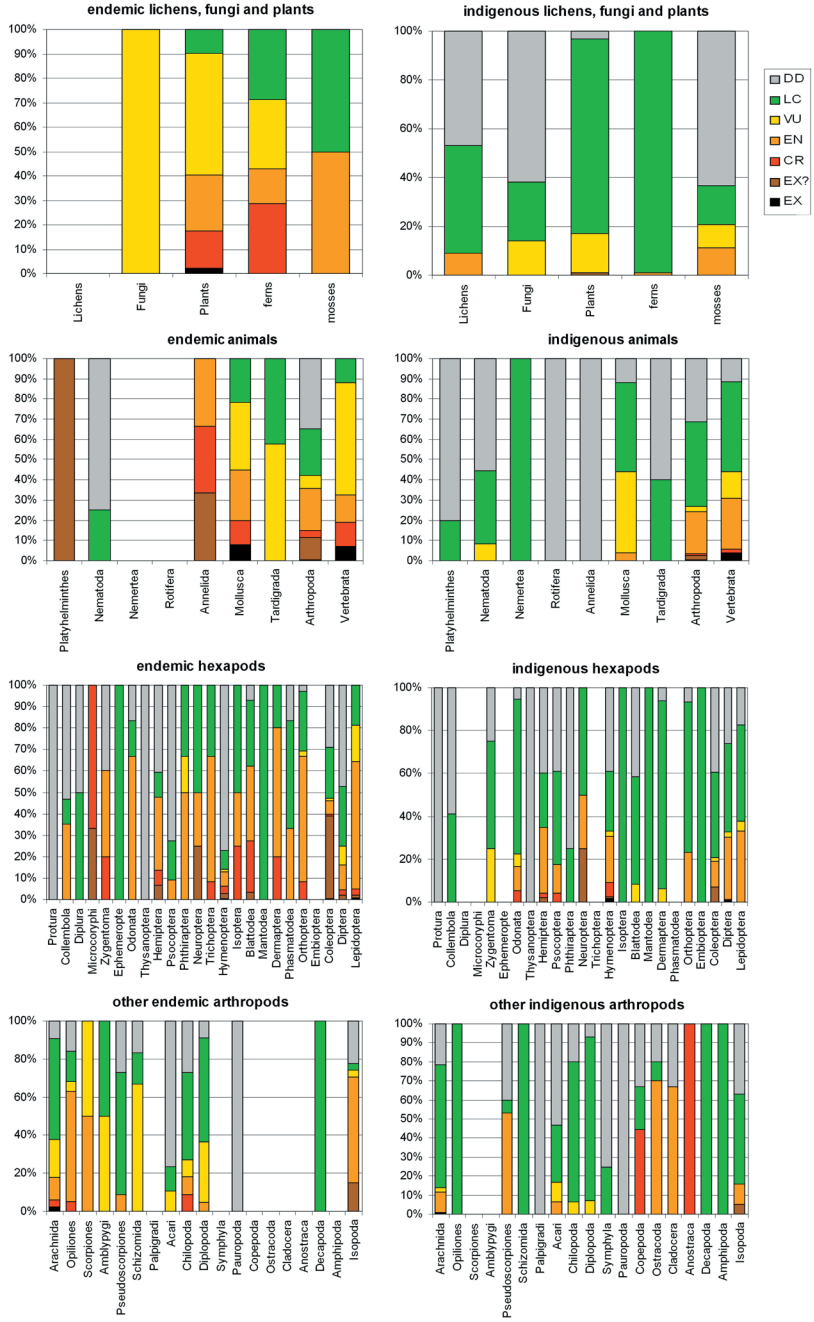
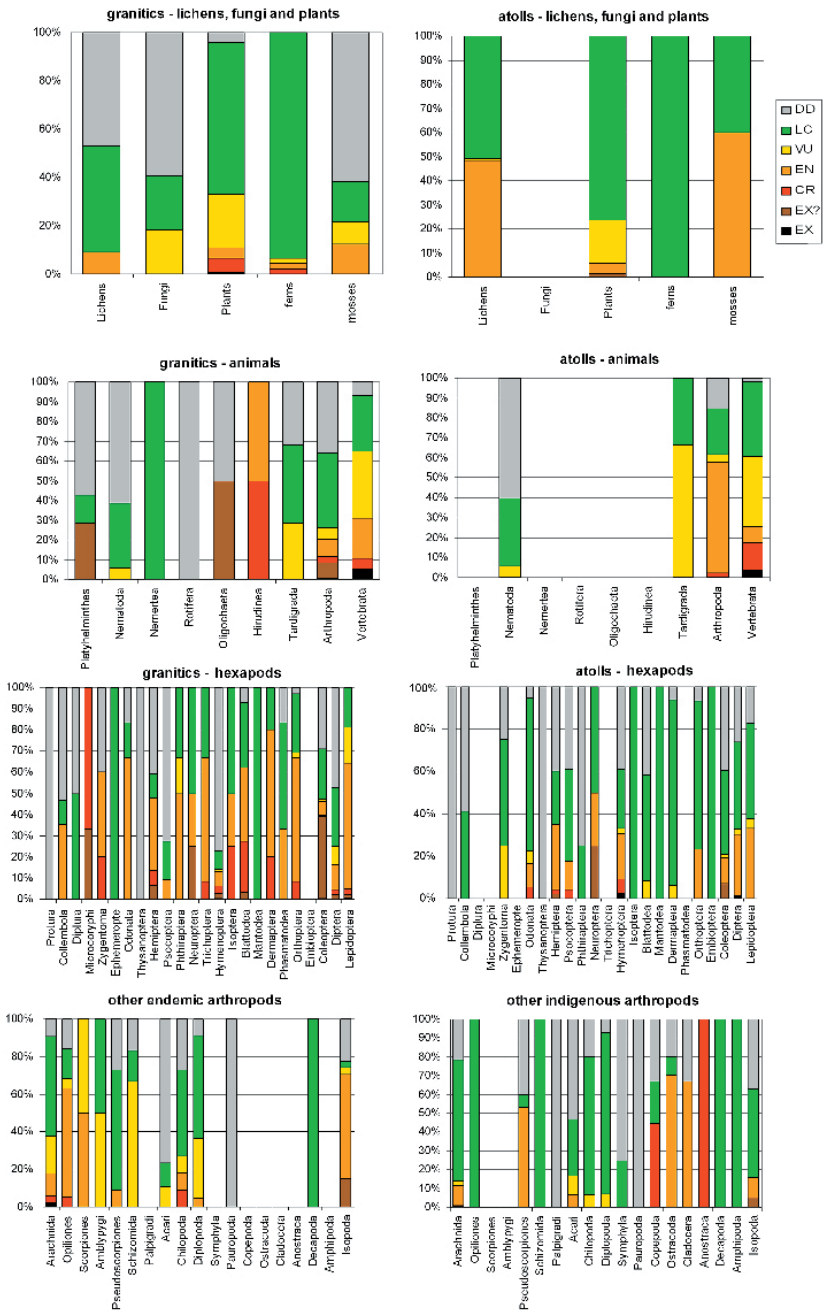


Fig. 3. Comparison between granitic and coralline islands of the proportion of species in each RL category



Terrestrial and freshwater

Differences between terrestrial and freshwater systems are minor, with animals having overall threat levels of 30% on land and 37% in freshwater. There are very few groups that have significant numbers of species in both systems; taxa with more than 10 species in each system are the vertebrates, which are 63% threatened on land and 33% in freshwater and several insect orders. The bugs (Hemiptera) are 42% threatened on land and 52% in freshwater, beetles (Coleoptera) 28% on land and 51% in water, flies (Diptera) 21% on land and 37% in water. This is notable in that vertebrates are more threatened on land than in water whereas all the insect groups are more at risk in freshwater, this is due to the freshwater vertebrates being mainly widespread Indo-Pacific estuarine fish or Data Deficient species. Data Deficiency in freshwater vertebrates is 50% compared to only 6% on land. Exclusively aquatic groups are also highly threatened (excluding the Data Deficient rotifers and very low diversity groups) – freshwater crustaceans having threat levels of 44-70% in the most diverse groups (Copepdoa and Ostracoda), 39% in Odonata and 67% in Trichoptera.

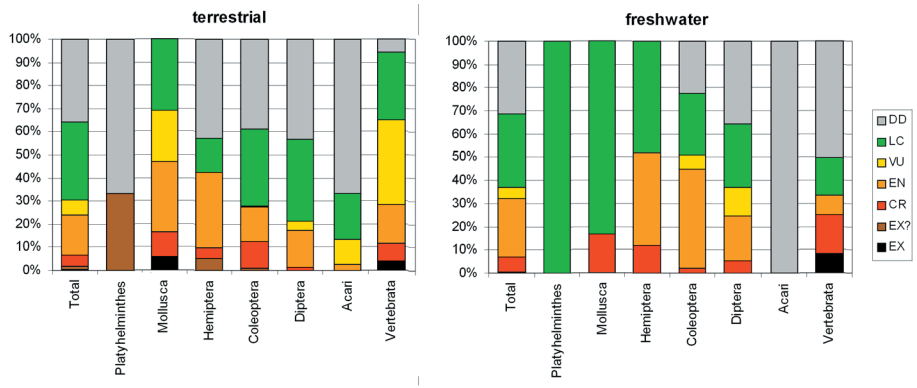
The general higher level of threat in freshwater than on land is due to the restricted nature of this system in Seychelles. This means that all populations are small and often very isolated, and as such are inherently vulnerable to extinction. This natural vulnerability is exacerbated by habitat degradation caused by invasive species in or near water courses, and by climate change affecting stream-flow.

Taxonomic patterns

Lichens

Lichen data is of reasonable quality for the larger islands (Mahé and Silhouette mainly, with some data from Praslin but very little from La Digue). Smaller islands are probably under-collected but diversity is extremely low on those islands that have been sampled. These have moderate levels of threat (24%) and Data Deficiency (39%).

Fig. 4. Comparison between freshwater and terrestrial systems of the proportion of species in each RL category



Fungi

Fungi are very poorly known in Seychelles and the 44 free-living species identified are clearly only a small proportion of the true level of diversity. Accordingly it is not surprising that Data Deficiency is very high at 59%. Identified threat level is 18% but this cannot be taken to be reliable.

Plants

Overall threat levels for plants are 31%, with a moderate level of Data Deficiency (22%). Most of the uncertainty for plants arises from the bryophytes where 61% of species are Data Deficient. This is due to a paucity of published data on this group, recent extensive collections have yet to be identified, when that has been completed a more accurate picture of the status of byrophytes, and plants in general, will emerge. For the pteriodphytes and angiosperms Data Deficient species make up 0 and 3% respectively, and in these groups threat levels stand at 35 and 37%.

Animals

Animals overall are 36% threatened with 32% Data Deficiency, both of which vary widely with different animal phyla. Data Deficiency is particularly high in the Rotifera (100%), Nematoda (62%) and Platyhelminthes (57%). Arthropods have a figure of 32%, but it is low for vertebrates (6%) and all species of other taxa have adequate data for assessment. Excluding the taxa with more than 50% Data Deficiency threat levels are highest in Annelida (100% but only four native species), followed Mollusc and Vertebrata (both 64%). Of the reasonably well assessed taxa Arthropoda have the lowest level of threat (36%). Within the arthropods crustaceans and chelicerates are reasonably well known (13 and 28% Data Deficient respectively), with poorer data in myriapods and insects (32 and 34% Data Deficient). Threat levels are highest in the crustaceans (53%) and insects (37%) followed by chelicerates (28%) and lowest in myriapods (16%).

Extinction (Fig. 5)

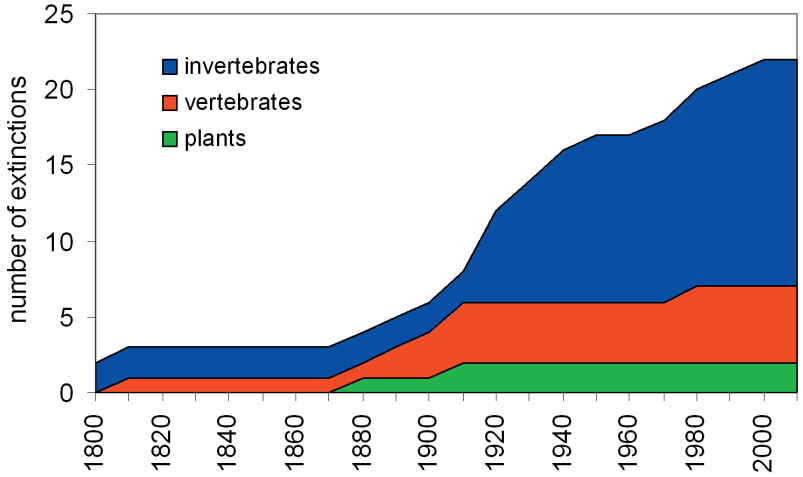
There are no historical data (i.e. pre 1900) with which to identify any extinct lichens, fungi or bryophytes. Although 19th century collections of ferns exist all are apparently extant. Two endemic species of angiosperms are Extinct: *Oeceoclades seychellarum* and *Vernonia seychellarum* were last recorded in 1902 and 1874 respectively; and a small number of indigenous species may have disappeared from Aldabra. These latter species were all isolated records (e.g. *Carissa spinarum*, present in the granitics but restricted to a single record from Aldabra) which may have been naturally rare, becoming extinct through stochastic loss, or may have been affected by climate change or by introduced predators. In the absence of any useful data the causes of extinction can only be speculative.

Recorded animal extinctions comprise 7 vertebrates (one terrapin, five birds and one crocodile) and 14 invertebrates. The vertebrates have been lost through hunting (*Psittacula wardi* [around 1900], *Pelecanus rufescens* [around 1910], *Papasula abbotti* [around 1915], *Crocodilus porosus* [around 1800]), habitat loss and predation (*Zosterops*

semiflava [around 1900]), and unknown causes (*Pelusios seychellensis* [around 1900], *Nesillas aldabranus* [about 1984]). These all date from at least 97 years ago except for the Aldabra warbler which disappeared in the early 1980s. The invertebrates comprise 4 snails and 10 arthropods. The snails were lost to early habitat loss (2 species in the early 1800s: *Pachnodus curiosus, P. ladiguensis*) and recent climate change (*P. velutinus* [1994]*, Rhachistia aldabrae* [1988]*, Glabrennea silhouettensis* [2010]). The arthropods are 4 Hymenoptera, 1 Coleoptera, 1 Lepidoptera and 3 Arachnida that disappeared sometime after 1909, probably due to ecological changes resulting largely from invasive species impacts. In addition one species of butterfly (*Phalanta phorbata*) became extinct around 1953, the cause of this is not known. On Aldabra changes in plant community composition since 1976 seems to have resulted in the extinction of the endemic butterfly *Acraea terpsichore legrandi* and a decline in the abundance of *A. ranavalona*.

In addition to these probable extinctions a large number of species have been categorised as 'Critically Endangered – possibly extinct': 2 Platyhelminthes, 2 Oligochaeta, 4 Isopoda, 1 Microcoryphia, 17 Hemiptera, 4 Neuroptera, 5 Hymenoptera, 1 Blattodea, 185 Coleoptera, 8 Diptera, 2 Lepidoptera, 1 Arachnida. Of these, the cockroach is *Margattodea amoena* which was endemic to Desroches atoll and is almost certainly extinct following extensive habitat loss on the island. Lepidoptera placed in this category are both very little known species – *Nephele leighi* from the granitic islands last recorded in 1969, and *Bataconema coquereli aldabrensis* from Aldabra in 1895. Several species were damp forest associated species which may have disappeared due to habitat change caused by invasive species, direct competition with invasives, or unidentified factors (flatworms, earthworms, the microcryphian species). The hemipterans were mainly phytophagous species, the majority forest planthoppers, with a smaller number of predatory species such as reduviids. The probably extinct Hymenoptera were all predatory (Ampulicidae, Crabronidae) or parasites of hemipterans (Encyrtidae).

Fig. 5. Increase in number of recorded extinctions since 1800



The Coleoptera were predominantly forest weevils (Curculionidae) and leaf-beetles (Chrysomelidae). In addition smaller numbers of darkling beetles (Tenebrionidae), scarabs associated with palms (Scarabaeidae) and a longhorn beetle (Cerambycidae) may have been lost as a result of close associations with particular plant species. A small number of possibly extinct species were predators in the Carabidae, Cleridae, Coccinellidae, Cleridae and Histeridae, with the exception of the carabid species these would all have been predators on vegetation and may have been affected by changes in prey communities. The flies were forest predators (Asilidae: *Heligmonevra insularis, Laphria cyaneogaster*; Muscidae: *Coenosia extincta*) or parasitoids of planthopper bugs (Pipunculidae: *Microcephalus depauperatus, Clistoabdominalis nitidifrons, Eucorylas semiopacus, Tomosarella sylvaticoides*) with the exception of the little known tephritid fruit fly *Taomyia ocellata*. Thus the possibly extinct invertebrates cover leaf-litter and soil and foliage inhabiting species from widely differing taxonomic groups, united only in being forest associated (as is most of the invertebrate fauna).

Critically Endangered species make up only 3% of Seychelles animals as a whole and are found in a wide range of taxa, with particularly high levels in the Annelida (25%), Copepoda (44%), Anostraca (100%), Microcoryphia (40%), Zygentoma (20%), Isoptera (14%) and Blattodea (21%). These figures are misleading as all except the Blattodea are very species poor (fewer than 10 species), the Copepoda and Anostraca are unusual in being largely restricted to freshwater pools on Aldabra, a very restricted and threatened habitat, but the species themselves are widespread outside of Seychelles. The figures for Blattodea are notable however; these are largely high forest species threatened by climate change causing degradation to their highly restricted habitats.

Threat factors

Five threat factors have been identified in the Red List assessments for Seychelles: hunting, predation, habitat loss, habitat degradation caused by invasive species and habitat degradation caused by climate change.

Hunting is a historical cause of extinction and direct consumption of the surviving species is very limited (although still occurring with the fruit bat *Pteropus seychellensis*, various seabirds and the tree *Deckenia nobilis*). Predation is similarly historical threat, although it may prevent recolonisation of historic ranges for some species. Direct loss of habitat through clearance for agriculture and development has been significant in the past and the urban development aspect is recurring as a threat to lowland species, although affecting only a small percentage of species. Habitat change as a result of invasives has been identified as a contributory factor to almost all threatened Seychelles species. Habitat change as a result of climate change is a significant threat to the Critically Endangered high forest species and to those restricted to low-lying islands where sea level rise will be a major issue. Comparisons of the threats affecting granitic and coral island species are shown in Fig. 6, highlighting the over-riding nature of sea-level (climate change) rise in the coral islands and the more diverse nature of threats in the granitic islands. Invasive species are the predominant threats in the granitic islands although this is now combined with climate change.

Assessing historical changes in threats is not practical for most taxa due to a

paucity of early data. Vertebrates have relative good data, with locality records dating from the mid 19th century which enable early threatened status and threat factors to be identified. Molluscs lack good locality records until 1894 but a good subfossil record allows historical distributions to be reconstructed. These two groups provide indications of how threat factors have changed over the past 200 years (Fig. 7).

Discussion

The analysis of the status of the biodiversity of Seychelles presented here uses the IUCN Red List criteria to provide a comprehensive assessment of the state of biodiversity and to identify the main threatening factors across all species. This shows that habitat factors are the most important influences of extinction risk for the vast majority of species, with invasive species and climate change being the main causes of habitat deterioration.

Fig. 6. Threat factors identified in the granitic and coral islands

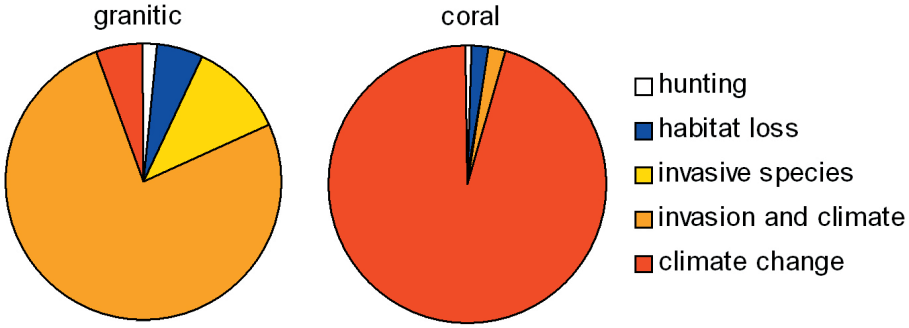
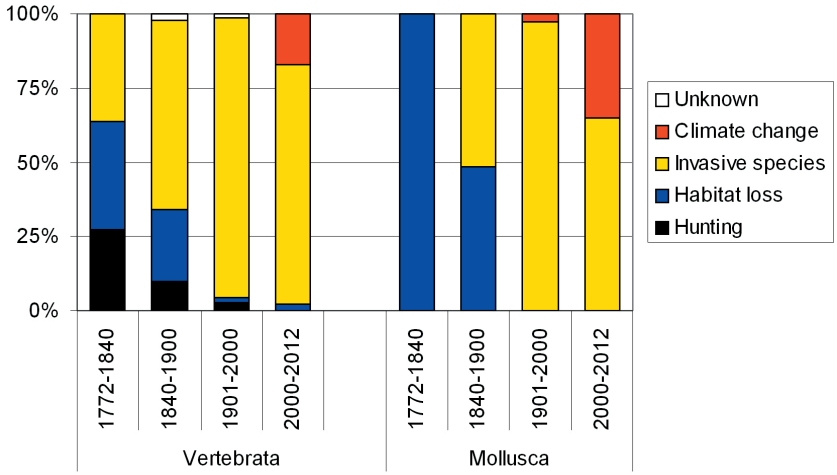


Fig. 7. Threat changes over time in groups with useable early records in the granitic islands.



At present 34% of species in Seychelles are at risk of extinction, with at least 23 species having been driven to extinction already. True levels of exinction are probably considerably higher, with 232 species being identified as 'Critically Endangered – possibly extinct'. There would also have been an unknown number of species having been lost before scientific collections started, for example, of the molluscs two of the extinct species are known only from subfossil shells. This level of threat is indicative of a true 'biodiversity crisis' and demonstrates the need for urgent action to reduce the impacts of invasive species and climate change.

Acknowledgements

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