Past and present human impacts on the biodiversity of Socotra Island (Yemen): implications for future conservation

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Abstract. The Socotra Archipelago (Yemen) is globally recognized for its outstanding biodiversity and endemism, designated on this basis a UNESCO World Heritage Site in 2008. The island underwent long geological and political isolation, ensuring preservation of unique ecosystems until the start of the new millennium. Now, Socotra Island is undergoing rapid development, out of balance with conservation. Major causes for biodiversity loss in other global insular ecosystems such as habitat fragmentation and degradation, pollution, invasive species and the impact of tourism, are becoming pressing issues that deserve close attention. Unsustainable resource use, the loss of traditional land management and illegal trade in biota are worrying phenomena that further increase the pressures on Socotra's ecosystems. We provide the first comprehensive review of potential human impacts on Socotra before the 21st century, an updated discussion of some of the principal threats to its biodiversity in recent times, discussing local examples within a historical context of known extinction processes on islands, and underline the importance of traditional knowledge in the protection of Socotran ecosystems.

Key words. Socotra island, conservation, human impact, extinction, biodiversity, invasive species, tourism.

> "Can it be true that only a few years after only being visited by a few more than the occasional sailor or botanist, harmless painter or devoted ant specialist, Soqotra may irrevocably become a paradise lost?" (GLANDER 2009 comparing impressions on Socotra to impressions of 2005)

Introduction

The United Nations declared 2010 as the International Year of Biodiversity, "*a celebration of life on earth and of the value of biodiversity for our lives*" (CBD 2010). At the same time, our planet is facing a new biodiversity crisis, dubbed by some as the sixth mass extinction, caused by human activities (PURVIS et al. 2000a, NOVACEK 2009). Rates of extinction are presently regarded as 1,000-10,000 times the geological background rate (PIMM et al. 1995). Protecting biodiversity has never been as pressing. Nowhere on earth is biodiversity more apparent and in need of urgent attention than on islands (PAULAY 1994). Recently illustrated by DA FONSECA et al. (2006), islands cover 5% of the global land surface, yet their number of endemics is highly disproportionate: about 20% of the world's vascular plant diversity and 15% of the world's mammals, birds and amphibians are found only on islands. Island

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plants and terrestrial vertebrates are more likely to be classified as endangered than those on continents (Groombridge 1992). Considered biological hotspots and evolutionary engines, islands receive much attention in conservation because of their high taxonomic uniqueness, endemism and habitat rarity (da Fonseca et al. 2006). However, island biotas are more prone to extinction than continents due to their isolation and small population sizes. Island endemics are likely to have small geographical ranges and hence small populations, mostly evolved in isolation from predators/competitors (including humans) hence more vulnerable to exploitation and introduction (Pimm 1991). Small populations are more likely to die out than large ones due to genetic factors (Frankham 1997; Purvis et al. 2000a). Different approaches are needed in conservation of islands versus continents (Whittaker 1998). Human-mediated disturbances have catastrophic effects on island ecosystems over short timescales, regardless of the fact that insular biota evolved and persisted under extreme climatic conditions over long periods (Cronk 1997). "*It is only when we turn to islands that man's negative impact on biotic diversity can be truly appreciated so far*" (Olson 1989). There are four main mechanisms through which humans reduce island biodiversity (Whittaker 1998): (1) direct predation, (2) introduction of non-native species, (3) spread of disease caused by exotic competitors, and (4) habitat degradation. The relative importance of these mechanisms is subject to debate. In a global context, habitat loss and degradation together with fragmentation are commonly seen as the major threat to biodiversity, yet on islands introduced species may perhaps be even more important (e.g. Groombridge 1992; see below). The synergy between impacts and possible cascade effects results in an inevitable loss of biodiversity on islands. On most of the world's islands, basic studies on the impacts and relationships with biodiversity have been carried out and situated within a historical context. On Socotra, such focused studies have not started yet.

The Socotra Archipelago (Yemen) is the largest, biologically most diverse island group in the Arabian Region. It is located 380 km southeast of the coast of Yemen and ca. 100 km east of the Horn of Africa. For recent descriptions and maps of the island, we refer to Van Damme (2009), Cheung & DeVantier (2006) and Miller & Morris (2004), basic sources for this paragraph. The archipelago consists of a major island in the east (Socotra Island), ca. 130 km long and 40 km wide, three smaller islands Samha, Darsa and Abd al Kuri to the west and a few rocky limestone outcrops. The largest island is populated by at least 50,000 inhabitants (Elie 2008, IUCN 2008, UNEP/WCMC 2008a, Klaus et al. 2003), with the highest concentration in the towns of Hadiboh and Qalansiyah. The population is increasing and there are high numbers of seasonal immigrants from the mainland, with yearly urban expansion. Socotra can be considered an insular hotspot with exceptionally high marine and terrestrial biodiversity, internationally recognized for its uniqueness: a UNESCO World Heritage (2008); UNESCO MAB (2003); WWF Global 200 Terrestrial Ecoregion (Socotra Island xeric shrublands); WWF Freshwater Ecoregion (n°52); Plantlife International Centre of Plant Diversity and part of Conservation International's Horn of Africa Hotspot. The island is continental, not oceanic.

The Socotra Archipelago lies on an ancient granite block, formed during the Palaeozoic and part of the Southern Arabian land mass. Separation is related to the opening of the Gulf of Aden with final separation of Socotra at ca. 18Mya (Leroy et al. 2004, Van Damme 2009). The geology of Socotra is described in Kossmat (1907) and Beydoun & Bichan (1970), with comprehensive updates in Fleitmann et al. (2004) and Cheung & DeVantier (2006). The main island consists predominantly of Paleogene karstic limestone plateaus (on average 700-800 m and max. 1000 m), bordered by coastal margins and a central depression, joined on a granite base which outcrops in the main Haggeher Mountains, ca. 1550 m in altitude. The climate is mainly arid, yet strongly influenced by the Indian Ocean monsoon system creating local semi-tropical conditions; see climate in MIES (2001), MILLER & MORRIS (2004), SCHOLTE & DE GEEST (2010) and CHEUNG & DEVANTIER (2006). Millions of years of isolation, a varied topography and geology and centuries of sustainable land management, have helped to retain a rich biota on Socotra. The large spatial, seasonal and even inter-annual climate variability on the island, influenced by seasonally reversing monsoon winds and other climate phenomena, is also a major factor behind the large natural diversity, driving evolution on Socotra (SCHOLTE & DE GEEST 2010, BANFIELD et al. in press). In contrast to most of the mainland to which it once belonged, Socotra retains an important amount of water due to its oceanic position, the presence of its central mountains creating a rain shadow, and the percolation through karstic limestone. Orographic rainfall and the occurrence of fogs, created '*wet refugia'*, maintaining biodiversity, allowing relicts to survive and several endemics to evolve (term by A. MILLER: MILLER & MORRIS 2004, BANFIELD et al. in press).

The ancient continental origin, climatic conditions and varied topography have resulted in remarkable radiations and diversity. BANFIELD et al. (in press) note that if we consider the number of endemic plant species per km², Socotra Archipelago is among the top five richest islands in the world, equalling the plant diversity per surface area of the Canary Islands and Jamaica. Endemism in the Archipelago is high at species level: in plants with 308 out of 835 species (37%; 15 endemic genera), reptiles (ca. 90%), terrestrial molluscs (ca. 95%; 75% of genera endemic, with major radiations), isopods (73%) and arachnids (ca. 60%) (MILLER & MORRIS 2004, CHEUNG & DEVANTIER 2006, NEUBERT 2006, 2009, TAITI & FERRARA 2004). The Archipelago holds a total of seven endemic bird species, of which the Socotra Buzzard *Buteo socotraensis* was given full taxonomic status just recently (PORTER & STONE 2006, PORTER & KIRWAN 2010). Many groups await further investigation, updates or molecular revision. Locally high endemism was the major argument for its designation as a UNESCO World Heritage Site (IUCN 2008, UNEP/WCMC 2008a). There are no indigenous mammals, save perhaps one shrew; primary freshwater fish and amphibians are absent (CHEUNG & DEVANTIER 2006, WRANIK 2003). It is most likely that the island's fauna evolved in the absence of large mammals (CHEUNG & DEVANTIER 2006).

As with most island biotas, many Socotran endemics have limited areas of occupancy, which increases their vulnerability to human-induced changes such as habitat destruction. For example, in the endemic terrestrial mollusc genus *Dioscopoma*, a small radiation is present in the Haggeher and adjacent limestone plateaus, having localized endemics with small areas of occupancy (a few square km), for the species *Dioscopoma ornatum, D. politum* and *D. vandammei* (NEUBERT 2009). Some endemic reptiles have very limited distributions and radiations have occurred in the genera *Hemidactylus* and *Pristurus*. An example with limited distribution is *Hemidactylus dracaenacolus*, only discovered in 1999 (see ROESSLER & WRANIK 2002), which seems to occur only in a small portion of *Dracaena* woodland on the Diksam Plateau (F. PELLA unpubl.). In terrestrial arthropods, such as isopods, local radiations have taken place, with no less than seven genera endemic to the archipelago. Several cave endemics only occur in the type locality, such as two species of the genus *Paradoniscus*; *P. degeesti* is restricted to a single lake inside Hoq Cave (TAITI & FERRARA 2004, TAITI & CHECCUCCI 2009). For the endemic birds, some species have limited population sizes, such as the Socotran Buzzard (250 pairs) and Socotra Bunting *Emberiza socotrana* (ca. 4,000 individuals), the latter with specific habitat preferences (PORTER & KIRWAN 2010,; PORTER & SULEIMAN in prep.). The same can be noted for plants, where some species have very limited areas of occupancy, like *Euphorbia abdelkuri, Duvaliandra dioscoridis,* *Erythroseris amabilis* and *Pulicaria dioscorides* (MILLER & MORRIS 2004); for example, 95% of the population of *Begonia samhaensis* is restricted to an area of less than 50 m² on Samha (HUGHES et al. 2003).

In the last decade, an ancient isolation has been breached and the percieved balance between nature and man through sustainable management by the indigenous population has changed. Globalization is impacting on the archipelago, exemplified by increased trade activities by sea and air and a modern road network, population expansion, changes in traditional land management and rapid uncontrolled development of the tourism industry. Such new developments are expected to have an influence on Socotra's ecosystems, yet focused studies correlating impact with biodiversity are lacking.

This paper presents an updated summary of threats to Socotra's biodiversity, including local examples and some new observations. Although much work has been done on the many aspects of Socotra's unique biodiversity, special focus on current threats to the Socotran biota are few in comparison. The most important research notes on conservation are included in a few major recent studies concerning Socotra: the manual of traditional land use by MORRIS (2002), the ethnoflora by MILLER & MORRIS (2004) and the compilation of Socotra's natural history by CHEUNG & DEVANTIER (2006). MILLER & MORRIS (2004) discuss five types of threats to the Socotran flora, which can be applied to the fauna as well and which are expanded in the current paper: (1) development of infrastructure (e.g. roads); (2) breakdown of traditional land management practices (and subsequent impacts such as overgrazing, etc.), (3) introduction of exotic species, (4) collection of biota and (5) climate change. The above main threats and impacts on the marine environment, were included in the IUCN report for Socotra's World Heritage Nomination (IUCN 2008). We present a historical account of human impact, records of extinction, an update of the current threats on Socotra in continuation of the work cited above and local examples of impacts known to have negative effects on island biodiversity worldwide. When referring to Socotra throughout the paper, the main island of the archipelago is meant, unless explicitly stated otherwise.

History of Human Impact and Extinctions on Socotra (Pre-21st Century Human Impacts)

Historical factors influenced the world's island ecosystems long before the arrival of modern impacts such as tourism (GÖSSLING 2003). Fundamental changes to insular environments have occurred in historical times through the effects of trade and colonial history on traditional resource use (WATTS 1993, BAHN & FLENLEY 1992). Islands roughly underwent two major waves of human-mediated extinction: (1) after initial human colonization and (2) after contact with European civilization and trade (WHITTAKER 1998). The results of such impacts are known to be devastating. On most islands, human impacts have been well studied and are visible today. Striking examples are the extermination of the Dodo (*Raphus cucullatus*), the deforestation of Mauritius Island (Mascarenes) and the complete ecological disasters on Easter Island and Guam, leading to loss of biodiversity through habitat destruction, deliberate extermination and the introduction of exotic species (see BAHN & FLENLEY 1992, CHEKE & HUME 2008, FRITTS & RODDA 1998, GILLESPIE & CLAGUE 2009, WHITTAKER 1998). On each island, a major, human-mediated extinction wave occurs at a different time, transforming natural ecosystems into landscapes with reduced biodiversity. An example is Hawaii, where the first extinction wave occurred with the arrival of the Polynesians 1600 years ago, and a second with European contact in the 18th century, each with a different causal mechanism (OLSON & JAMES 1982, BOYER 2008). During early periods of human population growth and settlement, species extinctions were largely the result of overhunting; later civilizations introduced exotic species and today, high population densities result in rapid habitat change as extensive areas are cleared for cultivation and settlement, further threatened by climate change (PURVIS et al. 2000a).

An anthropogenic tsunami currently seems to be sweeping over Socotra. Though this event only started towards the end of the 20th century, the magnitude of its impact on Socotra's natural and cultural heritage may know no precedent. However, millennia of human presence on Socotra have put an earlier mark on the landscape and the significance of current impacts should be seen and assessed within this historical context.

The first known colonization by *Homo* on Socotra dates back to the Lower Stone Age, 1.4-2.5 million years ago (Oldowan culture; SEDOV et al. 2009). Impacts were likely minimal, and it cannot be seen as a first, vast colonization wave. The Early Palaeolithic population was limited, its presence unaccompanied by cultural evolution and therefore short-lived (SEDOV et al. 2009). A second colonization by human settlers from Southern Arabia occurred on Socotra in the early Holocene, maximally 11,000 years ago based on molecular clock estimates (CERNY et al. 2009). In the late Holocene, a Neolithic expansion is apparent, possibly as recent as ca. 3,000 years ago (CERNY et al. 2009). During this period, around 1,000 BCE, Socotra had a wetter climate than present (DE GEEST et al. 2006, DE GEEST, unpubl.), hence conditions for population expansion were favourable. Dominant use of shorthorn cattle as livestock on the surrounding African and Arabian mainland, to which the dwarfish Socotran Shorthorn is closely related, dates from a similar period (1500 BCE; GWYNNE 1967). The Socotran thin-tailed Sheep may be a much older race and goats are also likely to have been imported in ancient times (MORRIS 2002, CHEUNG & DEVANTIER 2006). We have no estimates of Socotra's pristine vegetation cover before the first settlers, yet we may consider the late Holocene as the period of the first wide human impact on the island. Changes in vegetation cover in coastal areas and the limestone plateaus are likely to have followed human population expansion, coupled with the introduction and expansion of livestock that come with initial colonization/settlement. An initial transformation of the landscape, particularly in the more fertile regions, may have taken place on a wider scale. Agriculture and the emergence of land use systems combined with the introduction of livestock, using the island's resources, a mixture of cultivation, nomadic, pastoral and fishing would have impacted on the island's original ecosystems. These century-old traditional practices survived until modern times, sustaining ancient human-mediated landscapes.

In the following centuries, Socotra mainly served as part of an important Arab-controlled market for local products in the incense and medicinal herb trade, such as aloe, dragon's blood and frankincense (GROOM 1981; refs in CHEUNG & DEVANTIER 2006, CASSON 1989). As early as the 7th century BCE onwards, Socotra was a plantation colony for the provision of incense and inhabited by migrants from Eastern South Arabia (ELIE 2009 and references within). The incense trade was well developed around 500 BCE and expanded considerably in the first two centuries CE (GROOM 1981). Such trade, which lasted for hundreds of years and in which Socotra played an important role, and the ever-increasing demands for local products, undoubtedly had effects on the island's terrestrial environment. It may also have led to the transportation of desired plant species to more accessible areas, obscuring natural distribution patterns. The incense trade culminated in contact between Socotra and European civilizations, during early Greek and Roman times and, mainly due to aridification, gradually declined until the trade ceased in the 4th century (GROOM 1981). Early human transformation of the Socotran landscape can also be illustrated by the enigmatic wall alignments on the plateaus. Throughout the island, these alignments can be traced running through the Haggeher Mountains and deep wadis behind as well (MORRIS pers. comm.) Although function and timing remain unknown (WEEKS et al. 2001), Socotra's walls are current-day proof of wide-scale, ancient land use. Agriculture, of which there is currently little, was more intense in the past, apparent from remnants of former irrigation systems and walling for soil protection (MORRIS 2002).

Human exploitation of Socotran biota may have directly driven species to extinction. However, we lack concrete data and have to rely on written sources and anecdotal evidence to provide true insights into the island's condition before the 19th century. In a reliable Greek trader/traveller's account dating from the first century CE, the *Periplus of the Erythraean Sea*, Socotra is described as having snakes, giant lizards, crocodiles and three species of land tortoise (CASSON 1989). The tortoises, one of which was a large mountain species, were hunted for their shells, which were exported for the production of Roman tableware; other reptiles served for consumption of meat and fat (CASSON 1982, 1989). Except for two known endemic snake species *Ditypophis vivax* and *Hemerophis socotrae* that live on the surface in Socotra (the rest are fossorial snakes; ROESSLER & WRANIK 2004), none of the vertebrates mentioned in the *Periplus* are present on the island today. No targeted archaeological research has been carried out that can confirm their former presence, yet we cannot exclude the possibility that some reptiles may now be extinct (FORBES 1903, WRANIK 2003, CHEUNG & DEVANTIER 2006, VAN DAMME 2009). For example, giant tortoises which were once widely distributed and well diversified over the Indian Ocean islands, are now extinct on all except one island, due to human exploitation (GERLACH 2004). Other species have been exploited in regions at times of food shortage until recent times. According to oral tradition, demographic expansion and crashes of human populations have occurred, with most reductions related to heavy droughts (MORRIS 2002). Human stress on the environment at the onset of drier periods has probably had severe consequences due to essential shifts in diet for both human and livestock. In times of stress, land crabs (*Socotra pseudocardisoma*), land snails (*Socotora naticoides*) and several land bird species were actively collected for food, even in recent times (MORRIS 2002). Direct consumption of birds on Socotra by traditional trapping, liming or nest robbing (MORRIS 2002) was practiced on the island even until the first international conservation efforts for birds a decade ago. As we lack paleontological evidence, no bird extinctions have been recorded from the island.

Trade continued between Socotra and the outside world in medieval times in continuation of the incense trade and on mainly the same products. There was a Portuguese presence on the island in the 16th century but this was limited and short-lived and later European influence did not bring about major changes. Descriptions of pastoral and fishing communities in shipping accounts from the 17th century (KERR & EDIN 1811-1824) are similar to the traditional practices today (MORRIS 2002). Such observations, however, were principally confined to coastal areas – there are no accounts of any reliable observations on the way of life of people in the interior, who were afraid of and avoided the coast, hiding from strangers and incomers (MORRIS, pers. comm.). An increased interest by the British in the 19th century to use Socotra as important point for trade was diverted to Aden (see references in CHEUNG & DEVANTIER 2006). In addition to resource exploitation and the introduction of livestock, exotic mammals such as rats, mice, cats and civet cats, introduced to the island during centuries of trade, are certain to have affected local environments as well. However, no data are currently available on when these species entered exactly or their effects on local biota.

Exotic plant species such as tobacco, tamarind, orange trees, cotton bushes and date palms were also introduced centuries ago (MORRIS 2002).

The first scientific interest and biodiversity surveys occurred relatively late - in the late 19^{th} and early 20^{th} centuries. Schweinfurth visited in 1881-1882, Balfour in 1880 (BALFOUR 1888) and Forbes and Ogilvie-Grant in 1899 (FORBES 1903) (see also WRANIK 2003 and CHEUNG & DEVANTIER 2006). Socotra therefore already consisted, during the time of first botanical and zoological data collection, of impacted ecosystems with human-influenced landscapes, sustained by traditional land management practices (Figs 1A-B). Cliff faces remained largely untouched, protected by topography. Extinctions postdating the 19^{th} century may have occurred, but this needs more research. Seven have hitherto been reported. Four plants are currently classified extinct according to IUCN listings and have not been observed since their first collection in the 1880s (MILLER & MORRIS 2004), yet surveys in unexplored regions may reveal their presence. In addition, 26 plant species recorded from Socotra during 19^{th} century expeditions have not been reported since, although there is not enough evidence to declare them extinct (MILLER & MORRIS 2004). Two primary freshwater fish from museum collections have not been found on the island since 1883, yet again may still be present in remote areas (alternatively, the specimens could be mislabeled) (KRUPP et al. 2006). The dragonfly *Rhyothemis semihyalina* (Odonata), widespread in Africa, was formerly present on the Hadiboh Plain (MCLACHLAN 1903), but has not been found since 1953 despite intensive surveys (DUMONT & SCHNEIDER 1998; RISERVATO et al. 2010) and may be considered locally extinct (Fig. 2A). However, none of Socotra's endemic bird, reptile or terrestrial mollusc species, three indicative groups for island extinctions that were mentioned in FORBES (1903) became extinct before the surveys of the late 20^{th} century. Shifts in the economy towards the end of the 20^{th} century have had a major impact on transhumance and local priorities. Changes in traditional practices on Socotra were initiated in recent times (20^{th} century). For example, during the late 1960s-1970s, the loss of ghee as an important Socotran export product and the development of a local fishing sector led to the shift of pastoralism from a core to a supplementary economic activity and resulted in population movements from the interior to the coast (MORRIS 2002, ELIE 2009). Development projects started in the first half of the 1970s, providing basic roads, schools, health services and transport of goods was done by plane (Mukallah, Aden) or boat. Finally, tourism started towards the onset of the 21^{st} century. Immigration, travel and the import of goods have been facilitated by the construction of Mouri Airport in 1999-2000. Before that, flights were principally military and irregular. Socotra was reachable mainly by boat, effectively isolated during the four months of the monsoon when navigation was risky. Since then the number of flights has now increased from twice a week to every day, depending on the season. Civil aviation is a major pathway for tourist influx that began to affect most islands in the world in 1960s (GÖSSLING 2003). This change affected Socotra only the last decade.

Despite the above, Socotra still merits the status of a relatively pristine island in comparison to the majority of islands in the world, with limited effects by modern development before the onset of this millennium. Due to its isolation, impacts of modern development only really began at the end of the 1990s, but had started as early as the end of the 1960s. Before this time, traditional land use most certainly has played a role in helping to maintain landscapes in a sustainable way – where traditional grazing systems break down on the island, severe land degradation can take place within a few decades (PIETSCH & MORRIS 2010; see below). The fact that Socotra has currently lost none of its reptile, bird or terrestrial mollusc species in the last century is remarkable. On most other islands in the world, extinctions have increased rapidly from early to mid-19th to mid-20th century (GROOMBRIDGE 1992).

There are several reasons why Socotra is still in such a relatively good state compared to other islands in the world. (i) the indigenous population and their livestock arrived early, are still present and have come to new equilibria with the ecosystems, having depended on them for their survival and having devised complex systems for land management and use through a process of trial and error. Whereas other ancient peoples expressed their culture in art, Socotrans have expressed theirs mainly in language and conservation. Goats and other livestock may have strongly impacted the island but have done so for over 800 years, therefore anything present now has already passed through earlier extinction filters. (ii) The monsoon system effectively isolates the islands for about half the year, cutting off the local population from the outside, and obliging them to survive on the resources present. This limited imports of goods and visitors until the last decade. Also, the monsoons have influenced the inhabitants into adapting to semi-nomadic lifestyles, switching between pastoralism and fishing, a rotation system that ensured that impacts were never continuous over a limited area for the whole year. (iii) Strong waves of immigration have not been extensive until now, and the largest area of the island has been managed by the indigenous population through most of its human history – a recent molecular study (CERNY et al. 2009) showed that the Socotrans are not a genetic mixture of immigrants and local people, as previously believed. (iv) The late arrival of modern development, which started in the late 1970s but received a boost in the 21st century – tourism only began in 2000. (v) Political instability in Yemen, with a civil war until 1997, and a region that suffered from war, poverty, piracy and terrorism greatly limited outside impacts and, in a way, preserved it as well. (vi) The varied topography of the island - Socotra is quite large, and the many cliffs and escarpments provide a significant refuge for species; development, as in most islands, is mainly concentrated in coastal areas, but has now extended with the roads.

Whereas initial colonization and later contact with world trade may have adversely affected Socotra's biodiversity, the endemics that survive now have withstood this, as well as earlier climatic and human-induced impacts until today. Species that go through several "extinction filters" may be regarded among the more resilient (BALMFORD 1996), yet remain more prone to extinction on islands when compared to continents (CRONK 1997) due to species attributes that correlate with extinction vulnerability (MCKINNEY 1997, PURVIS et al. 2000a, b). The relative importance of factors in recorded extinctions varies according to the taxonomic group (FRANKHAM 1997). Species become extinct because their adaptations no longer fit the environment, or because the environment changes (PURVIS et al. 2000a). The question now is whether Socotra will be able to retain its unique status and maintain its biodiversity, given the sudden impacts of modern development. Will the long-stressed ecosystems retain their natural resilience in the face of natural phenomena (e.g. climate change)? After the first human settlements and the incense trade, we can consider the 21st century developments, described below, as a third wave of impacts reaching Socotra. The effects, i.e. extinctions, will only become visible later. A so-called *extinction debt*, time-delayed but deterministic extinction, a lag between cause and effect, may take from decades to centuries to become visible after the original impact (TILMAN et al. 1994, VELLEND et al. 2006, MALANSON 2008, CHIBA et al. 2009, TRIANTIS et al. 2010). Due to this time-effect and gaps in historical data, extinction of a species can rarely be correlated to the exact cause (GROOMBRIDGE 1992). Several of the current Socotran species seem in steady decline and populations are overmature, such as the flagship species *Dracaena cinnabari* (MILLER & MORRIS 2004, ATTORRE et al. 2007, HABROVA et al. 2009; discussed below). In addition, '*silent extinctions*' occur, i.e. many invertebrate species become extinct without ever being recorded (FONSECA 2009, RÉGNIER et al. 2009). The latter add to the breakdown of entire ecosystems through chains of extinction. Species higher up the food chain are more vulnerable to the cumulative effects of disturbance to species lower down the food chain (DIAMOND 1984, PURVIS et al. 2000a). Socotra has never before faced the human-induced challenges of modern development, part of a major global extinction wave. A summary of some current challenges is discussed in the sections below.

Threats to Socotran Biodiversity Today (21st Century Impacts)

Pollution/Waste

Macro-waste on Socotra is an important source of pollution, already evident in urban areas and increasing rapidly beyond. An unpublished report estimates an expected increase of ca. 8,650 t to 10,900 t of waste by 2015 (LORETZ & MARTIN 2006). Khor Qalansiyah, a large lagoon in the west of the island near the second largest city of Socotra, is a striking example of littering and rubbish accumulation in the last few years (Fig. 2B). Even in the late 1990s, Khor Qalansiyah was still an unspoiled water body. Waste expands with urbanization and tends to concentrate along roads. The problem has several effects besides the aesthetic, frequently noted by (eco)tourists, such as health issues through the attraction of pest species and diseases. Waste accumulates rapidly on the island and solutions hitherto proposed have proven insufficient. Tourism and local agriculture are considered major sources of waste on Socotra (LORETZ & MARTIN 2006). A long-term, sustainable system for waste disposal or removal may not be sufficient – a change in urban areas aimed towards littering is also needed. Dumping of plastic bags is very common in Socotra's urbanized areas Hadiboh and Qalansiyah (Fig. 2B). After rains, thousands of plastic bags become small breeding grounds for mosquitoes and thus pose a health risk (GÖSSLING 2003). Waste accumulation and pollution in lagoons could be important factors leading to a reduction in biodiversity and may have contributed to the local extinction of *Rhyothemis semihyalina* (Odonata) in the Hadiboh Plain.

Biocides are a type of pollutant in increasing use. Insecticides are used in domestic gardens on Socotra to produce vegetables or fruits, yet with their expansion in size and number, the effects may accumulate. Home garden projects exceeding the scale of traditional home gardens may concentrate more pests and require increasing use of pesticides. The interest in such home garden projects for development is increasing (CECCOLINI 2002), yet is not accompanied by any environmental impact assessments. Other biocides are used in aquatic ecosystems annually on a wider scale on Socotra. In September-October 2000, as part of an anti-malaria campaign, insecticides were administered in Socotran wadis by the National Malaria Control Programme without consulting international biodiversity experts. During the campaign, 35 men were sent out to administer 56 g/ha of temephos (Abate) for weeks, a total of 35 l/month covering 175 km of wadi/week (NMCP 2003, WHO 2005). This extensive insecticide spraying continues annually. The dangers of this organophosphate pesticide to non-target organisms are widely known, with their ecotoxicity effects on freshwater invertebrates such as crustaceans and even on birds (EXTOXNET 1993). Possible long-term negative effects include sediment- and bio-accumulation. Furthermore, wadis are not the typical ecosystems where mosquito larvae reside, which prefer stagnant water. In lentic systems, the health of predator populations throughout the year is more important than the effect of short-term administration of biocides. Non-target invertebrates play very important roles in the aquatic ecosystem. Predators provide biological top-down control of lower trophic levels. Endemic top predators in the Socotran freshwater ecosystems, such as the freshwater crab *Socotrapotamon socotrensis* and the dragonfly *Azuragrion granti* (syn. *Enallagma*) belong to groups that actively feed on aquatic larvae, especially as young instars. Larger invertebrates may now be impacted because of the high bioaccumulation potential and toxicity of the compound, although ecotoxicity tests have yet to be carried out. Freshwater crabs were nearly absent in Wadi Ayhaft during a visit in March 2010, though they had been abundant in February 1999. Locally high abundances for this species are also shown in WRANIK (2003). This requires urgent follow-up. Unfortunately, except for observations and photographs, no exact population estimates exist for these organisms that can be used to monitor the evolution of impacts over the last decade. In Europe, the European Commission is now encouraging countries to develop alternative solutions to temephos, recognizing the dangerous impact of this organophosphate on the environment. Pesticides such as organophosphates have an effect through the food chain and affect non-target animals such as freshwater crabs higher up the food chain (PATIL et al. 2008) or reproduction in birds (MINEAU 2005). Even though the number of freshwater endemic species seems relatively low in comparison to the terrestrial biota, Socotra is globally recognized as one of the world's Freshwater Ecoregions (WWF; THIEME et al. 2005) therefore strong impacts on these ecosystems should be avoided.

A third important source of chemical pollution may be derived from the now extensive road network in Socotra. Heavy metals, such as wear of tires containing lead oxide, result in contamination of roadsides. Taken up by plants in the direct vicinity, lead may have severe toxic effects on consumers, reducing overall fitness higher up the food chain where the accumulative effect increases risks for extinction.

Tourism and the impacts of the 'Island Paradise Effect'

Islands elicit stereotypical responses – generally attractive, evoking a sense of mystery, escape, solitude and self-sufficiency (BAUM 1997, RESH & RESH 2009). The very idea of an island conjures the image of a microcosm (BIAGINI & HOYLE 1999). Clear physical borders constitute psychological borders, visitors seeking refuge from responsibility and routine in search of a paradise idea that goes back to Romanticism (GÖSSLING 2003). The image is brought about by the uniqueness of landscapes and biota combined with the effort visitors must make to reach their destination, thus appealing to escapism (Figs 3A-B). Adjectives linked to Socotra range from bizarre, beautiful, mysterious and otherworldly to pristine and untouched. For example, Socotra has been listed as one of 40 '*unforgettable islands to escape to before you die*' for adventurous travelers in search of paradise, advertising beautiful white beaches (DAVEY & SCHLOSSMAN 2007, Fig. 3A). This '*Island Paradise Effect'*, an idea brought about by mass consumption and the need for escape, affects reality *in situ* and the unrealistic concept is actively publicized and exploited by tourist industries. An oasis in a country suffering from poverty and negative media attention, Socotra has now become the number one tourist spot for Yemen. However, the original concept of ecotourism currently does not seem to work in Socotra because of traits inherent in the tourism industry, the search for a 'paradise' destination, combined with a low degree of tourist infrastructure and high visitor numbers. Attraction comes with a cost. The prefix "*eco*" is only for publicity purposes, without the majority of tourists or investors considering what this term should involve in practice. The difference lies in the concept that "*tourists flirt, ecotourists care*". Socotra now receives few of the caring kind, according to a recent study (MAYER 2009). Efforts to combine tourism with nature protection have failed on Socotra, as well as effective management of the sector (MAYER 2009). Beyond the island's capacity, the travel influx results in violation of environmental articles 8 and 9(partim) of PD n° 275 (the "Socotra Zoning Plan"), stating (art. 8) that: "*Travel to and from the Socotra islands should be regulated according to the capacity of these islands*". The current tourist development does not follow any planning concept – employees in the sector are untrained or unaware of the fragility of the island's ecosystems whereas the majority of tourists do not grasp the importance of respecting local culture and nature (MAYER 2009). Yet the number of tourists has risen sharply in the last decade, with local tourist police estimating over 4,000 foreign visitors in 2008 (SCHOLTE et al. in press), nearly a tenth of the total population of Socotra. In 2000, the number of international tourists on Socotra was only about 140, increasing to 451 in 2004 (ZANDRI & DIGHT 2006). Though more recent figures are inaccurate (counting is done visually, during each arrival of a flight containing visitors), our interviews with local airport authorities suggest an estimated number reaching 5,000 visitors in 2009, including visitors from Gulf States. If these numbers cannot be managed in a sustainable way, the number of visitors will adversely impact the environment while their needs will not be met due to a lack of infrastructure (N. TALIB in MAYER 2009: 118). Though individual contributions may seem minimal, sheer numbers of tourists have an effect on localized areas in limited times of the year. During the monsoons, tourism drops down to zero and increases again towards the cooler end of the year. On Socotra, negative effects accumulate in touristically attractive yet highly sensitive, small localities such as protected areas or Hoq Cave. This cave, which is an insular ecosystem within the island, is an example of a place where tourist numbers concentrate, and which in the absence of management or control, inevitably leads to gradual degradation (see below) (Fig. 3C). Tourism may also work counterproductively by affecting the authenticity of the local culture and environment, transforming local needs and making it actually less attractive for future visitors, thus reducing chances of future local income.

In the 21st century, tourism is one of the major factors contributing to environmental change on islands, often competing with traditional practices and scarce resources, affecting biodiversity and disrupting social structures (GÖSSLING 2003, ROYLE 2001, DEIDUN 2010). Effects on biodiversity are virtually impossible to determine based on pure data (VAN DER DUIM & CAALDERS 2002). Rather, we should evaluate the possible side effects on Socotra in the long term through a process of logical extrapolation from observable present trends.

Trend 1: Tourist infrastructure is in a stage of unregulated and unplanned expansion, for the moment mainly concentrated in the Hadiboh plain (MAYER 2009). Developers are already prospecting in other regions. Demands on freshwater supplies increase in the presence of a high number of visitors during the peak season.

Trend 2: Tourism adds directly to the change in priorities from traditional and sustainable land management and long-term resource use towards consumption and short-term profit. In the 21st century, most islands have become part of a globalized world economy through adaptation of the '*plantation tourism model*', where traditional economies are replaced by tourism (GÖSSLING 2003). Indeed, the implementation of environmental protection and the development of ecotourism on the island are major causes of an accelerated cultural impact, resulting in a loss of tradition as Socotra is rapidly assimilated into a world economy (ELIE 2008, MORRIS 2002). The effects are diverse. Local work forces, including those working in conservation management with a good knowledge of endemic biota, turn to tourism for extra income. In general, however, with the exception of people directly working in tourism sectors, the local population hardly benefits from the industry, although it may increase their overall standard of living (MAYER 2009). Investors, without any knowledge of the local environment, even attempt to keep tourists actively away from indigenous populations – "*Now everything is organized to avoid meeting the population and you are "kindly asked" to go where the hotels want you to. They know best what you should see and explore. Whomever you meet the overall purpose will be to extract money from you*." (GLANDER 2009). The local inhabitants, who take pride in their unique language and vast knowledge of the environment, are often considered as 'backward' by immigrant populations (MILLER & MORRIS 2004), many of which are attracted to the tourist sector. In this respect, the expansion of tourism on Socotra is directly linked to a reduction in local culture, thus putting additional stress on the environment through the loss of invaluable traditional knowledge that ensures conservation at the basic grassroots level. The same sad phenomenon has been described on other islands, attributed to the approaches of companies dominating tourist industries and placing indigenous people in a subservient position (ROYLE 2001).

Trend 3: Traffic on Socotra between previously remote areas has increased greatly, risking direct pressures on unique ecosystems and the spread of exotic species or different genotypes. Increased access also allows further infrastructure development along roads and the consequent increase in rubbish. Many protected areas designated in Socotra's Zoning Plan (see map in CHEUNG & DEVANTIER 2006), originally selected by scientists for their exceptional biological features, with the explicit recommendation that human impacts should remain minimal, are now major tourist destinations. It is ironic how measures of biodiversity protection at different levels on Socotra and emphasis on their uniqueness and importance, have actually increased the attraction of developers and tourists, hence facilitating exploitation. Other sensitive areas, not listed in the Zoning Plan, also receive high attention. Hoq, a unique Socotran cave with ancient archaeological treasures and locally endemic species, was virtually unknown to the modern world until 1999. Media attention and relatively easy access have now placed Hoq on the tourism map. Based on local logbooks, the cave received over 700 reported visitors in the six months between September 2009 and March 2010 (DE GEEST, unpubl. report). Tourists enter with local but untrained guides and a number of visitors ignore the designated path inside. The first signs of damage to the cave's unique geological structures and ancient writings are now obvious (Fig. 3C) – stalactites have also been found on tourists at airports. Another region is the beautiful site of Erher on the NE coast, which during peak moments in the last few years has looked like a European camp site. Widely considered to be one of the most aesthetic places on the island, it is nevertheless now threatened by concrete road construction and waste accumulation by tourists. Very popular too is the use of marine Nature Sanctuaries on Socotra for snorkeling and beach tourism, both of which require responsible management.

Despite these negative effects, the added value of tourism through economic benefits and allowing people from outside to connect with nature's marvels, thus raising awareness and public support for conservation, cannot be ignored. The relationships between tourism and the environment are highly complex - tourism is in an ambivalent position in relation to biodiversity, with both direct and indirect negative and positive effects (VAN DER DUIM & CAALDERS 2002). The current situation on Socotra is, however, unsustainable. In the absence of an enforced legal conservation framework, ecotourism is a "Trojan Horse", moving rapidly from low impact to larger scale and higher impact tourism (BUCKLEY 2009). Instead of attempting to further expand the infrastructure and attract more investors, which clearly is the trend for the immediate future, it may be far more sustainable to limit the number of tourists and therefore the effects they have on the island (including facilities); properly train a new generation of skilled Socotri guides, selected for their respect for the local environment; establish a system of 'ecolabels' for travel agencies and establish stratagems to ensure benefit for local communities. New guides require basic training and encouragement to respect the local environment and culture in order to safeguard the environment from the negative impacts of tourism. Although beguiling in theory, we have to remain realistic: it may be impossible to re-direct most tourists' search for "unspoiled paradises" or to restrict the developers' greed in selling the idea, both short-term human goals that may affect the island for generations to come. However, the *"Paradise Effect",* enhanced by unrealistic popular media, disregarding the impact on Socotran ecosystems, has strong impacts on expectations of visitors and also increases a market value in Socotran products in illegal trade, discussed in the next section.

Collection and illegal trade – Socotra as a label

With a steep rise in visitor numbers and an increase in overall attention, the illegal export of live organisms, *ex situ* breeding for commercial benefit and trade in Socotran endemics is increasing rapidly. The phenomenon is not new. A few Socotran plants have historically been exported and were commercially exploited for horticulture, such as *Exacum affine* (Persian Violet) and *Begonia socotrana*, both widely sold in European markets (MILLER & MORRIS 2004). Yet the number of Socotran endemic species currently offered by online plant shops in Europe and the United States is alarming. In April 2010, a *Dracaena cinnabari* seedling was posted on Ebay at a starting bid of US $160 - a four year old plant for direct sale from the same buyer cost about $300. Other plants are available sporadically, from direct collection or regularly, through breeding. *Dorstenia gigas*, for example, can be found for about $41, *Dendrosycios socotrana* for $35, *Boswellia dioscoridis* for $125, all propagated in the US, *Aloe perryi* for $6 and *Euphorbia abdelkuri* for up to $225, on Ebay (Fig. 4B). The latter species is endemic to Abd al Kuri, where only ca. 250-300 mature individuals occur at a single locality of less than 10 km² – the only perceivable threat to this species is by collecting and climate change (MILLER & MORRIS 2004). *Duvaliandra dioscoridis*, Critically Endangered and potentially in decline (BANFIELD unpubl. data), is also periodically advertised by succulent collectors. In the wild, this plant occurs in an area less than 100 m², with collection by enthusiasts considered a major threat (MILLER & MORRIS 2004).

Much botanical material was removed from the island in earlier times when such activities were not considered illegal, and sellers often claim that the material being sold is derived from these collections. Material is sold without providing income for species-oriented protection in the wild, or any benefit-sharing at a national or local level, thereby contravening benefit-sharing aspects of the Convention of Biological Diversity where applicable (see below). Stimulating this trend for collecting, books are produced by succulent enthusiasts indicating where to find and how to grow Socotran endemics (CHRISTOPHE 2005, LODÉ 2010). The former illustrates a booming market for this particular kind of botanical interest.

Endemic animals are being exported alive and bred for sale. This is a new phenomenon. *Haemodracon riebeckii* appeared in the European gecko trade two years ago and is now available for prices between US $65 (e.g., Tierbörse, Germany) to about $150 per specimen in specialized pet shops (e.g., Tropic Paradies, Germany, 2010). In March 2010, images of two newly-bought juveniles appeared on a forum of Italian gecko collectors, boasting about the rare acquisition (Fig. 4C). The species arouses interest by its large size (30cm) and its 'exotic value'. The endemic *Chamaeleo monachus* can also be found sporadically in online exotic pet shops as well. One of the most expensive Socotran endemic animals ever to be sold in numbers is probably the Tarantula *Monocentropus balfouri*. This first appeared on the international market in 2007 for about $300 per specimen, with prices up to $400-500 (one adult was even offered in the US for $650 in May 2009). As the market has become saturated, prices have dropped to just below $100 for young animals, but prices over $300 can still be found. Nevertheless, popularity of the animal has increased rapidly in the last decade which shows that the export is very recent: a search for *Monocentropus balfouri* revealed only 10 Google hits between 1999-2003 compared to 31,800 in May 2010. *Monocentropus balfouri* is sought for its rarity, beauty and reduced aggression. According to online discussion boards of arachnid collectors, this Socotran endemic is now the most expensive tarantula in the trade. It is sold as the Socotra Island Blue Baboon or Blue Baboon or under a pet name '*balfi'*. Other animals are found on a smaller scale – the endemic scorpion *Hottentotta socotrensis* and the centipede *Scolopendra balfouri* are offered in exotic pet shops (see below) for about $40, but are not widely sold or bred (yet); shells of marine molluscs, such as rare color morphs of *Cypraea stolida* from Socotra appear for $90 from Italy (Ebay). Endemic terrestrial molluscs such as *Achatinelloides tigris* are sold for $25, *A. hadibuensis* and *Passamaella compressa* for $42 and other species are offered for auction, for example, *A. balfouri* and "*Tropidophora" socotrana* (shellauction, 2010). The highest price for a Socotran land snail was recently offered for *Socotora naticoides* (syn. *Revoilia naticoides*), presented at a starting bid of $350 and finally sold at $900 (shellauction, 2010). For entomologist collectors, two endemic species are offered for sale online: the butterfly *Charaxes candiope* ssp. *velox* (Nymphalidae) for prices between $76 and $140 for suboptimal specimens and the beetle *Julodis cloutei* (syn. *clouei*) (Buprestidae) at $28 for second choice specimens, up to $140 for specimens in top condition (Chaminade, France), the latter also on Ebay (France) at starting bids of $83 (Fig. 4A). Within their respective families, both species are among the most expensive found worldwide, as can be seen in catalogue lists of the entomologist online shop (Chaminade, France). A worrying phenomenon is that Socotran animals of different taxonomic origin are offered simultaneously and appear to be exported either in bulk or are being collected on repeated visits, of which some occurred only the last year. In May 2010, a pet shop for exotic animals (Spiderzone, Czech Republic) offered no less than seven live Socotran endemics simultaneously, of which vertebrates appeared as newly acquired 'products' (reptiles *Chamaeleo monachus* and *Haemodracon riebeckii,* centipede *Scolopendra balfouri* and arachnids *Bessia* sp., *Hersilia wraniki, Hottentotta socotrensis* and *Monocentropus balfouri*). Besides collection for trade, the overcollection for scientific research of some endemics with small populations may actually be an additional threat.

Prices may drop as the market saturates and as rarity declines with ex-situ breeding, yet the above examples illustrate a currently active collecting, exporting and international trade in endemic Socotran species. International collectors act mainly under the umbrella of tourism, smuggling out specimens for trade and - in case of live specimens - breeding them outside. With the now increased international traffic and tourism, the opportunities for such activity have increased. In 2005, airport authorities in Socotra had collected, over a few months, a total of 70 kg of seashells and coral fragments from tourists, and much more material escapes regular customs. This illegal practice creates on the island a damaging belief of people coming to 'steal' from the island and it has established a new system of giving bribes to local islanders for collection. The export of traditional medicinal products, resins and honey, is legal on Socotra, yet some of these are resold elsewhere for higher prices. For example, dragon's blood resin can be found for sale at $7.5 per ounce and *Boswellia dioscorides* frankincense at $5.5 from the US (September 2010, Ebay). The wildlife trade in mainland Yemen is a well-known phenomenon, linked with poverty and ignorance (STANTON 2009), but the island trade is different. Socotran species do not appear on the Yemeni market (STANTON, pers. comm.) but move directly through international channels; that is, it is comparably more organized, commercial and orchestrated from outside. The market value is largely determined by the exotic "Socotra" label. The fact that it happens relatively frequently also illustrates that the number of visitors and the resulting mining of biodiversity is beyond the capacity of local authorities to control.

The above sadly illustrates that a substantial market value in Socotra's biodiversity exists. With hundreds of specimens of a wide range of Socotran endemics being sold, this international trade has a considerable commercial value, of which Yemen receives no share. Socotran communities do not benefit, instead they stand by and observe the gradual mining of their local environment, or they turn a blind eye in exchange for tourism-derived revenues. Visitors, sadly, are increasingly regarded as collectors whose purpose is to remove rather than to observe the natural environment, reinforcing the view that outsiders come only to "take" from the island. Popular media reports on the island in turn attract more tourists, developers and collectors and are seen a first step in a future wave of impacts. The money resulting from such biodiversity-mining is not used to contribute to species conservation or to the preservation of local knowledge and expertise, and its depletion does not lead any increase in local standards of living (EVANS-ILLIDGE 2006).

Protection against such practices is limited. Endemic Socotran plants and birds have a conservation status, but no IUCN Red List assessments exist for reptiles or invertebrates, except for dragonflies and freshwater crabs. Assessing and assigning IUCN categories provides a tool for registering threatened species on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). For plants, only the three endemic *Aloe* species, a few species of *Euphorbia* and two orchid species are currently listed on CITES, despite 148 Socotran species categorized as threatened (MILLER & MORRIS 2004: 40). Among the animals that are currently exported, only *Chamaeleo monachus* – like most chameleons, a popular group for trade (CARPENTER et al. 2004) – is listed in CITES. None of the Socotran reptiles has so far had an IUCN Red List assessment. However international categorization of conservation value does not protect these species if local capacities are too limited to cope with this new Socotran 'gold rush', enhanced by the media. Therefore, increased media attention currently acts counterproductively on Socotran biodiversity. The value of Socotran plants, whose traditional uses are well known (MILLER & MORRIS 2004), is also understood by pharmaceutical markets. The number of studies on antimicrobial, antiviral and anti-cancer properties of Socotran plants is increasing (MOTHANA et al. 2006; 2009). Equitable benefit sharing and protection of the local biodiversity's genetic resources - major objectives of the Convention of Biological Diversity to help counter biopiracy - are urgently needed in Socotra where biodiversity has been traditionally used (EVANS-ILLIDGE 2006). Uncontrolled trade through unsustainable collection carries enormous risks for the long-term viability of natural populations through increased mortality rates and an increase in exploitation in order to meet export demands (such as in Madagascar; RASELIMANANA 2003). However, for every specimen collected for trade, hundreds more are at risk of direct loss through larger impacts that are not as visible.

Habitat fragmentation – roads

Road development in Socotra is of major concern to biologists (MILLER & MORRIS 2004, CHRISTIE 2005, CHEUNG & DEVANTIER 2006, BIRDLIFE INTERNATIONAL 2008, IUCN 2008, UNEP/WCMC 2008a, BANFIELD et al. 2009, VAN DAMME 2009). Since 2001, over 900 km of asphalt roads have been constructed on the island, without any consideration of environmental sensitivities or their long-term impacts (Figs 5A-E). Detwah Lagoon was saved from destruction by road building (ZANDRI 2006). Since 2007, it has been the first Ramsar Site in Yemen. Other places, such as the valuable archaeological site at Eriosh, were not as fortunate (VAN DAMME & DE GEEST 2006). Roads play an important role in this with many visitors having clear opinions about the developments such as the statement by GLANDER (2009) "*Almost the entire island is torn into patches by extravagantly designed roads, some of them ending nowhere*" (Figs 5A-B). Other tourists post photographs on the internet of road developments, entitled "*Socotra as it should not be*" (MARCHAT 2008), illustrating international public disapproval. In 2008, after most of the road works had been completed, a decree was approved for road management on Socotra in an ecologically sound way (IUCN 2008, UNEP/WCMC 2008a). Impacts will become clearer within a few years, but the new road network is already of such an extent that negative effects on the environment, especially in the narrow coastal regions that border the interior (Fig. 5E), are inevitable.

In general, road construction is one of the most destructive forms of habitat fragmentation on islands, facilitating extinction. It contributes to habitat isolation of terrestrial species, subdividing populations on either side of a new barrier thus limiting gene flow and increasing the chances of extinction. Roads result in significant loss of biodiversity due to (1) restricted movement of populations; (2) increased mortality; (3) habitat fragmentation; (4) edge effects, such as spoiling (dumping of excess soil from road digs on slopes or in the sea); (5) increased chances of invasion by exotic species and (6) increased human access to sensitive areas, with (7) increase of waste and chemicals along the roads (persistent pollutants; heavy metals such as lead) and (8) a depletion of local resources (FINDLAY & BOURDAGES 2000). In addition, roads lead to an increased alteration and use of habitats by humans (TROMBULAK & FRISSELL 2000). Road works on Socotra have a clear effect through spoiling –excess soil is thrown aside, sometimes covering complete hillsides, and is washed into sea, clouding coral reefs. Effects on vegetation, soil erosion and marine ecosystems in Socotra are inevitable (BANFIELD et al. 2009). A further devastating result is the cutting of hydrological connections to the sea in several of the major khors on the north coast, leading to massive fish mortality (BANFIELD et al. 2007; R. PORTER pers. comm.).These lagoons eventually become putrid mosquito-breeding centres. Traditionally, work-parties were set up specifically to clear out the khors of the northern coast whenever they became blocked or in any way damaged – another example of lost local expertise (in this case, khor management) (M. MORRIS pers. comm.). Overall, the extensive road development on Socotra can be considered as one of the strongest violations of insular biodiversity today.

Negative impacts on endemic species caused by habitat fragmentation may not be immediately visible but come with a lag effect (see TILMAN et al. 1994). The effects of road building on local animal and plant populations extend well beyond the actual road place (TROMBULAK & FRISSELL 2000). We will witness the extent of the current damage to Socotra's biodiversity in a few decades, not now. Even so, many extinctions may go unnoted because our current understanding of the total diversity, especially of the terrestrial invertebrates, is still incomplete. Several species in coastal areas have limited ranges or may harbor important biodiversity. For example, In the Hallah area along the northeast coast (Fig. 3A), about 50% of the endemic reptiles occur; reptile populations may suffer habitat destruction here, in particular those animals with patchy distribution, such as the monotypic endemic genus *Ditypophis* (F. Pella, unpubl.). The coastal stretch in the northeast is mostly less than 2 km wide, and road effects may easily affect 1-10% of the area and create new barriers. Terrestrial molluscs, which have extremely high endemism yet limited ranges in Socotra (Neubert 2005, 2009), are also known to be sensitive to habitat fragmentation caused by road works. The effect of habitat fragmentation by roads and their adverse effects to terrestrial molluscs has been studied in Europe using species adapted to arid conditions (e.g. *Helicella itala*), and a forest dwelling species (*Arianta arbustorum*) (Baur & Baur 1990, Wirth et al. 1999). These studies prove that both paved and unpaved roads wider than 3 m act as a real dispersal barrier to snails, and gene flow is seriously reduced. Smaller unpaved tracks do not affect mollusc populations. Both studies used quite large snail species, and the effects will be more dramatic if smaller species are concerned (Neubert, pers. comm.). Also plants with small areas of occupancy may be affected. The endangered plant *Erythroseris amabilis* (previously *Prenanthes*), is restricted to the Ma'alah escarpment in the West of Socotra, an area also threatened by road building.

As a result of environmental concerns about the impacts of road-building on the Socotran environment, clear guidelines to minimize environmental impacts were developed in 2008. IUCN, in its evaluation of Socotra as a World Heritage (WH) site, recommended that future road building should be located outside the core zone consistent with the Zoning Plan, be at smaller scale than existing road building and with reduction of spoil, be subject to environmental impact assessment (EIA), follow existing tracks where possible and involve EPA in decision-making (IUCN 2008). Unfortunately, not much road-building remains to be completed on Socotra, except for a short stretch in the southeast end of the island to connect the final sections of the Socotran Ring Road (near Matiyaf, see below). Nevertheless, there are still areas where plans for roads remain but building has not yet begun. Some are in extremely sensitive environmental areas, or in areas of high aesthetic value where levelling and widening has already been carried out, but without tarmac having (as yet) been laid, as in Erher on the northeastern coast. It is still possible, based on existing recommendations, to minimize the negative impacts of future roads, whilst providing local populations with a practical and safe road network proportionate to their needs.

Habitat degradation: Grazing, soil erosion and the importance of traditional land use

The people of Socotra traditionally raise cattle, sheep and goats, primarily for milk, with goats being the dominant group (Morris 2002). No exact data have been published on the size of livestock populations, yet numbers may have reached the maximum sustainable level (Fig. 5F). Changes in land use and the resulting effects are among the most important threats to Socotra's biota, through grazing and water use (Miller & Morris 2004). The breakdown of traditional livestock management threatens the local environment through: (1) unmanaged and uncontrolled breeding, (2) increases in livestock numbers due to supplementary feeding and young males being raised to adulthood (see below); (3) less control of livestock spatially and temporally; (4) human migration and settlements and (5) the collapse of seasonal transhumance (Morris 2002, Miller & Morris 2004). The devastating impacts of goats on island environments are well known, and have led to eradication programmes worldwide (Coblentz 1978, Campbell & Donlan 2005). Socotra's terrestrial ecosystems likely evolved in the absence of large herbivores, yet the current human-mediated landscape is shaped by the century-old impacts of the indigenous population and their livestock, including goats. The Socotran goats (Fig. 5F) were present at least 800 years ago (CHEUNG & DEVANTIER 2006), and their presence may well date back to the arrival of the first settlers.

It is not the grazing itself, but changes in traditional patterns of livestock management that pose an immediate and real threat to biodiversity on Socotra. Overgrazing is considered the most important cause of desertification in arid regions and causes shifts in the balance of relative species abundances (MILTON et al. 1994, DYKSTERHUIS 1949). Excessive grazing pressure results in land degradation through soil erosion, a process that recently accelerated in Socotra. Protection of soils is vital to the island's terrestrial ecosystems. "*Biodiversity is, of course, the most important argument for protecting the unique floral and faunal richness of the island but what would terrestrial biodiversity be without soils?*" (PIETSCH & MORRIS 2010).

In arid ecosystems, the erosion of cultural practices enhances soil erosion (Figs 6A-B). Where traditional nomadic pastoralism can be maintained on a sufficiently large spatial scale and when resources are given enough time to be replenished, negative density-dependent effects of grazing on plant biodiversity and therefore negative effects on the habitats are less pronounced or even absent (SINCLAIR & FRYXELL 1985, WARD 2009). This traditional rotation system and the spatial and temporal scale for grazing has changed Socotra, with higher concentrations of livestock being maintained on smaller areas for a prolonged period of time (MORRIS 2002).

The Homhil area of Socotra can be seen as example. Like many other parts of the eastern limestone plateau, the Homhil Protected Area shows clear signs of overgrazing. From the late 1960s onwards, people moved down from the escarpments above Homhil to live permanently on the valley floor (PIETSCH & MORRIS 2010). This has increased local grazing pressure in an area which was previously only exploited after rainfall and when people and animals were in lower numbers. A decline in the traditional seasonal transhumance of livestock between upland and lowland grazing has resulted in increasing numbers of animals spending more time around permanent settlements in the valley floor (PIETSCH & MORRIS 2010). Land degradation in the form of soil erosion is now very obvious in this area, a direct consequence of unsustainable land use caused by the breakdown of traditional pastoralism and the overstocking of livestock. Within three years of monitoring, 40 m^3 of soil was lost in a single gully head (PIETSCH & MORRIS 2010). The above example shows the importance of local knowledge in Socotran land management and how vital the traditional skills of pastoral transhumance are. Soil erosion, a reduction in plant biodiversity and the dominance of *Asphodelus fistulosus* (Asparagaceae) can be regarded as clear signs of overgrazing and degraded grasslands in such areas (MILLER & MORRIS 2004). The concentration of grazing around water points (*piosphere effect;* WARD 2009), whose number has greatly increased on Socotra since the 1980s due to the construction of additional man-made water catchments or *karifs*, and the sinking of many new wells have increased the number of overgrazed areas (MORRIS 2002). Tons of fertile soil may disappear yearly with water runoff on Socotra. In Shibehon Plateau, speleologists of the Socotra Karst Project found in 2003 meters of soil deposited inside main galleries in the Ghiniba Cave that were absent during a visit in 2001. This cave functions as a major sinkhole for wadi systems in the area (DE GEEST, pers. comm.). Evidence of vegetation loss, increased surface run-off and soil erosion, caused by overgrazing, can also be seen in several other areas in Socotra including the Sirahon limestone plateau (Figs 6A-B) and the southern coastal plain in Qa'arah.

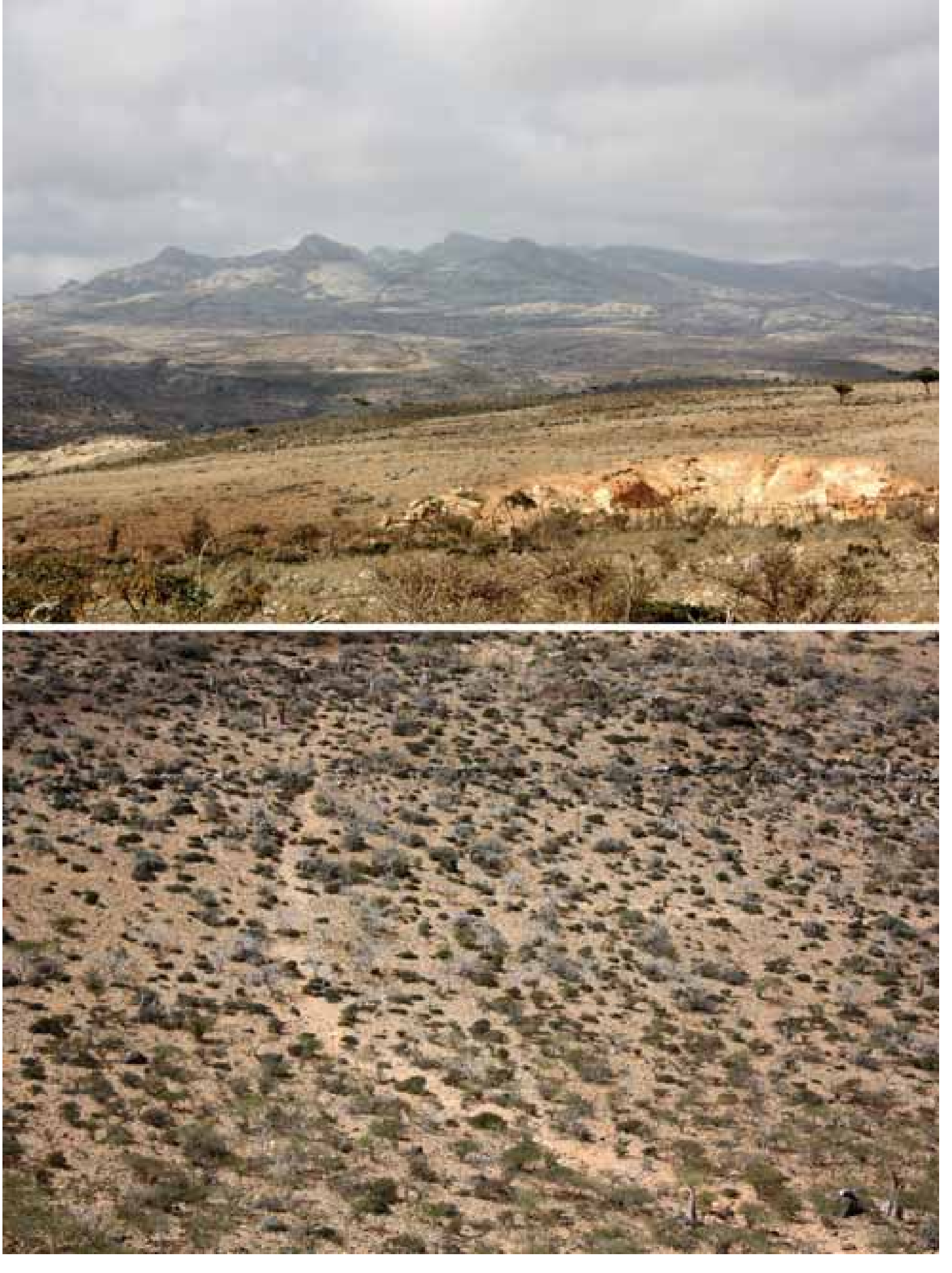

Fig. 1. A (top). Socotra's current landscape is human- mediated, a result of centuries of land use, yet harbors a rich biodiversity with high levels of endemism. The island consists for the largest part of karstic limestone plateaus, reaching up to 1000 m as in the Shebehon/Diksam Plateau, shown here (March, 2010). B (below). Socotran landscape, limestone plateau above Wadi Kilisan, South East of the island (March, 2010). Photos by KVD.

Fig. 2. A (top). *Rhyothemis semihyalina* (Odonata), not recorded on Socotra since 1953 (RISERVATO et al. 2010), is probably locally extinct. Drawing from MCLACHLAN (1903). B (below). Pollution through waste and biocides may pose a threat to Socotran freshwater fauna. Waste accumulation in Khor Qalansiyah, Qalansiyah Municipality, Socotra (March, 2010). Photo by KVD.

Fig. 3. Tourism on Socotra. A (top). The Island '*Paradise Effect'* – tourist impression of Socotra: unspoiled beaches, blue-green seas, the perfect destination for an escape (Hallah Area, March, 2010). B (middle). Tourism on Socotra at Detwah Lagoon (March, 2010). C (below). Damage to calcite crystals along the designated walking path in Hoq Cave, Socotra, by visitors. The cave now receives hundreds of tourists yearly. It is home to several endemic species, one of which only occurs in a single pool inside. Hoq Cave, Socotra (March, 2010). Photos by KVD.

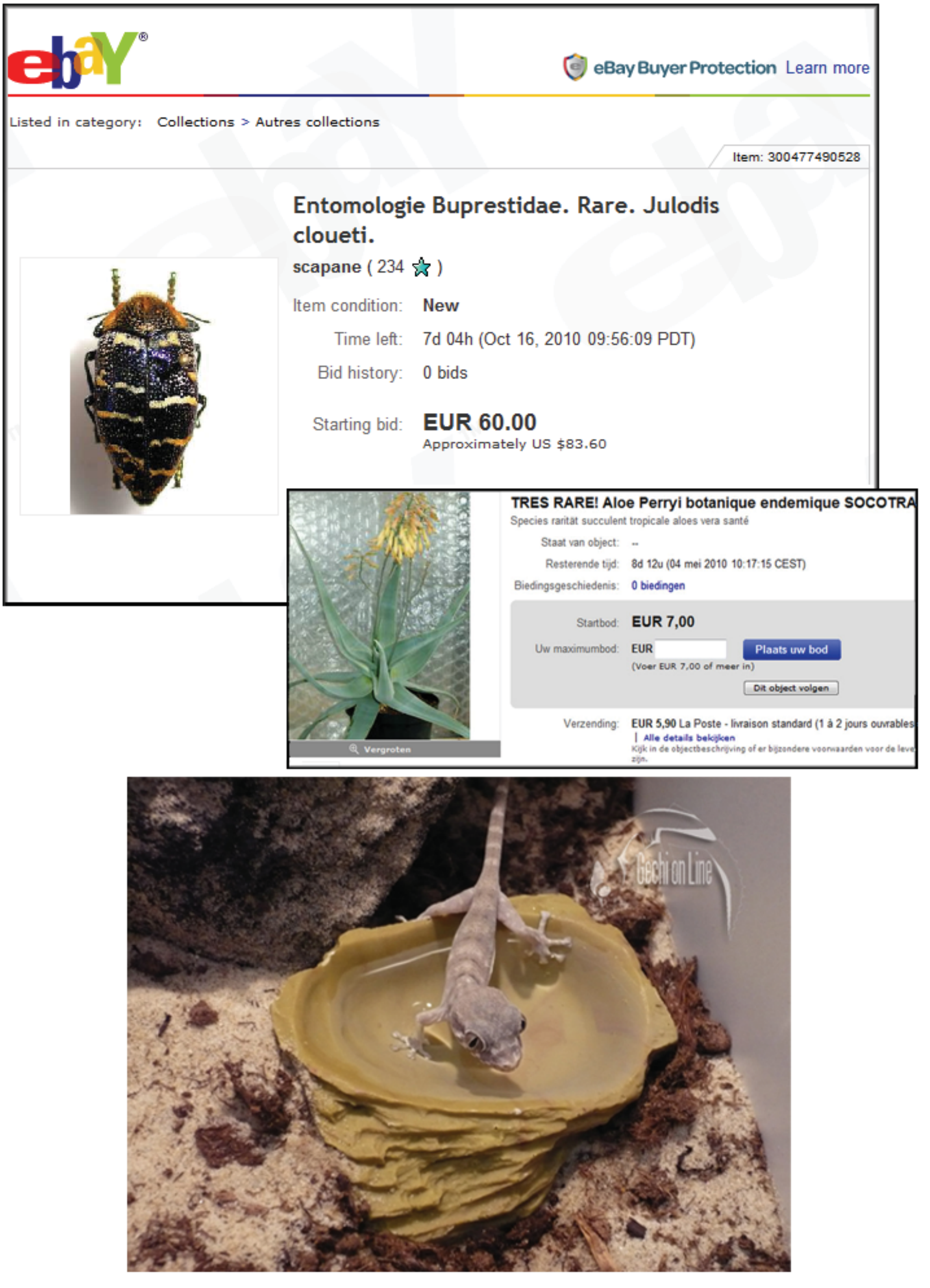

Fig. 4. International collection and trade of Socotran endemics. A (top). The endemic buprestid beetle *Julodis clouei* sold online on Ebay (October, 2010). B (middle). Trade of Socotran endemic plants is mainly aimed at succulent collectors; *Aloe perryi*, listed in CITES, sold on Ebay (May, 2010). C (bottom). The endemic gecko *Haemodracon riebeckii* shown in a terrarium and discussed on a gecko collector site (March, 2010).

Fig. 5. Habitat fragmentation and degradation through infrastructure development and grazing pressure on Socotra. A (top, left). Diksam Road, crossing the island from north to west, cutting through *Dracaena* stands (March, 2010); B (top, right). Development in the Hadiboh plain, view towards west, showing the Hadiboh road which extends along the northern coast; date palm cultivation is visible in the foreground (Suq) (March, 2010); C (middle, left). Roads effect vegetation through spoil (left corner of image) (Diksam Road, March, 2010). D (middle, right). Dune at Hawlaf, from which sand is dug used as stabilizer for roads (March, 2010); E (bottom, left). The wide roads on Socotra take in a significant portion of the narrow coastal stretch, especially in the southeastern part of the island (new road to Matiyaf, March, 2010). F (bottom, right). Goats have been part of the Socotran culture for centuries and have had a major influence on the landscape; recent changes in breeding control and transhumance skills through loss of tradition have resulted in population increases, with visible effects on terrestrial habitats (Socotran Plateau, 2007). Photos by KVD (Figs 5A-E) and LB (Fig. 5F).

Fig. 6. Impacts of overgrazing on the Socotran habitats. A (top). The seemingly lush green vegetation shown here is actually a botanically impoverished area with clear signs of overgrazing and habitat degradation on Sirahon Plateau, Socotra (Sirahon, 2008); B (below, left). Soil erosion at Sirahon Plateau, Socotra (Sirahon, 2008); C (below, right). Fenced areas show a clear contrast between non-grazed (left) and grazed (right) areas (Hadiboh Plain, March 2010). Photos by LB (Figs 6A-B) and KVD (Fig. 6C).

Fig. 7. Impacts of overgrazing on Socotran habitats. A (top). Umbrella-shaped trees on Socotra capture moisture and provide beneficial cover for smaller herbs to germinate underneath (green circle under tree is not darker because of shade but because of small herbs) (Homhil, 2007); B (below, left). *Cadaba insularis* growing within the protection of the spiny *Lycium sokotranum*; outside the protective cover, leaves have been eaten by goats (Di Hamari, 2008); C (below, right). *Dracaena cinnabari* replanted seedling in Diksam, Socotra (March 2010). Without constant watering or shelter, seedlings of *Dracaena cinnabari* have low chances of survival. Photos by LB (Figs 7A-B) and KVD (Fig. 7C).

Fig. 8. Exotic species, wood collection and clearing on Socotra. A (top). Local agriculture, stimulated by NGO's, is a major current pathway of exotic plants on Socotra; in many islands in the world, major invasives are garden escapes (homegardens at Suq; March 2010); B (middle, left). *Argemone mexicana,* an invasive that has been present in Socotra for over a century, thrives in degraded or disturbed areas; seeds are easily transported (Detwah; March, 2010); C (middle, right). Clearing of shrubland (right in image) and collection of stones (left in image) for building in the hills around Hadiboh (March, 2010); D (below, left). Wood bundles sold for fuel (along road to Diksam; March, 2010); E (below, right). One of the last trees of *Avicennia marina* in the northern coastal plain (Shaheb; March, 2010). Photos by KVD.

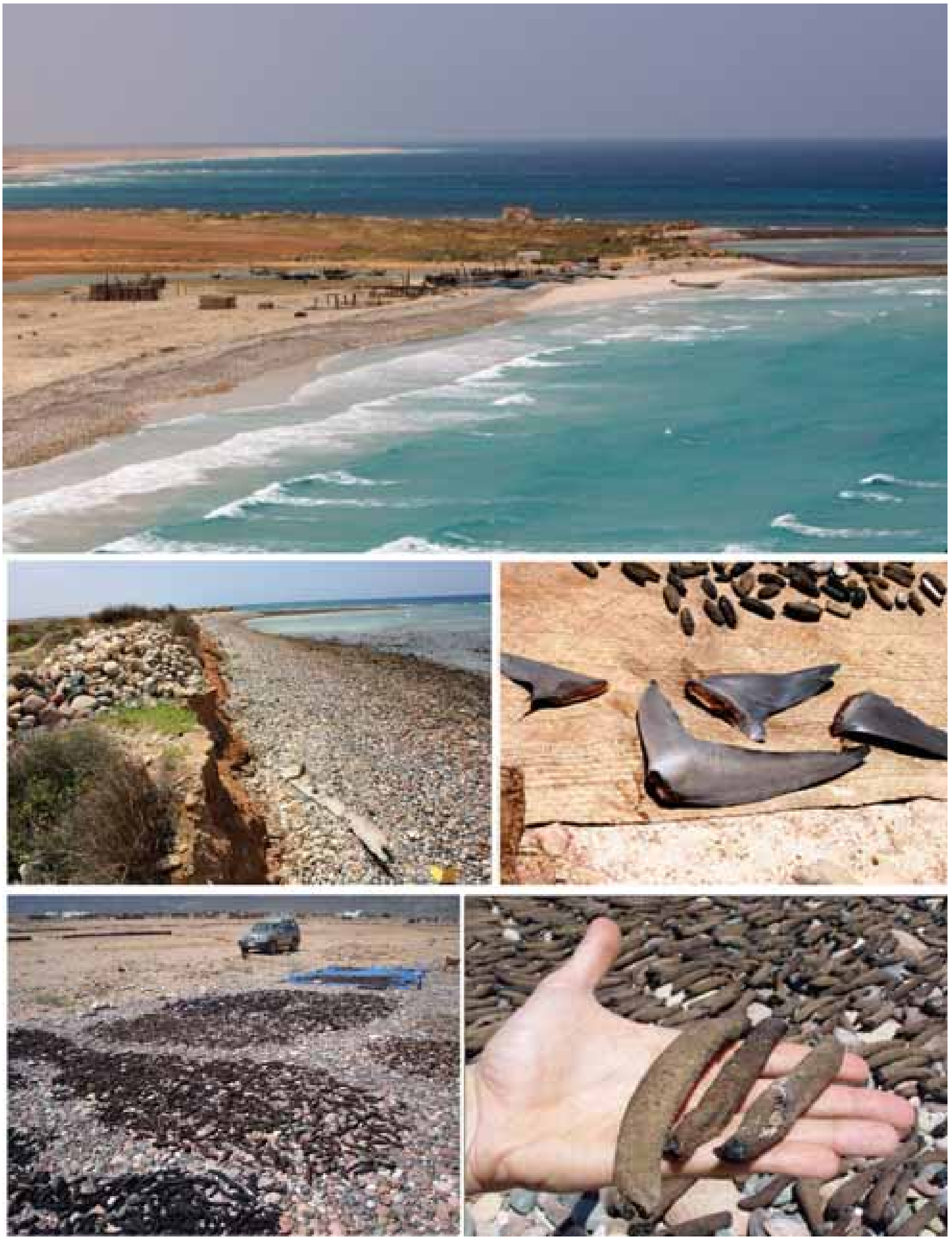

Fig. 9. A (top). Beach erosion at Qadhub, with the outer wall of the mosque remaining and with rapid deterioration of land (Qadhub, March, 2010); B (middle, left). Idem, detail (Qadhub, March, 2010). C (middle, right). Collection of shark fin for sale (Hadiboh area; April, 2006); D (below, left). Collection and drying of sea cucumbers for sale (Hadiboh area, April, 2006); E (below, right). Idem, close-up. Photos by KVD (Figs 9A-B) and Andrea BELLUCIO (Figs 9C-E).

Fig. 10. Climate Change and Socotra. A (top). Fog in the Haggeher Mountains is vital to the island's biodiversity and the provision of water for its inhabitants. Future changes in climate (increased aridification) will have severe effects on Socotran ecosystems (Haggeher Mountains; March, 2010); B (below). Many populations of the Socotran flagship species, *Dracaena cinnabari* suffer from overmaturity, lack of regeneration, due to either grazing, climate change or a combination; exploitation of its resin may form an additional threat (near Firmihin, March, 2010). Photos by KVD.

Fig. 11. A (top, left). Rubbish collection at Matiyaf, SE Socotra; the village has a designated area for collection (Matiyaf, March 2010). B-C (top, right). Recycling facility at Hadiboh (September, 2010). D (below). Lagoon at Matiyaf, SE Socotra (Matiyaf, March 2010). Photos by KVD (Figs 11A, D) and Max KASPAREK (Figs 11B-C).

Fig. 12. Adeeb's Nursery (A, top) and its owner (B, below left). Plants and seedlings of Socotran endemics (C) are grown in this local initiative, receiving wide attention and support; C (below, right) shows a young *Adenium obesum* ssp. *socotranum* (Adeeb's Nursery, Hadiboh Area; September, 2010). Photographs by Max Kasparek.

The suppression of palatable grasses and herbs through grazing may also allow more water to percolate into the subsoil, stimulating the growth of unpalatable species and leading to bush encroachment – the mass recruitment of cohorts of shrubs of similar age (WARD 2009) (Fig. 1B). The dominance of mainly unpalatable or poisonous plant species such as *Tephrosia apollinea* and *Senna* species in areas of dense human population can be considered a sign of habitat degradation through overgrazing. This phenomenon is particularly obvious in degraded *Croton socotranus* shrublands (MILLER & MORRIS 2004: 613) that are widespread in the northern coastal plain.

A major cause for the expansion in the livestock population is the breakdown of traditional practices, particularly the loss of seasonal and managed breeding over the last two decades (MORRIS 2002). Historically, goat populations on Socotra may have fluctuated with climatic changes, yet numbers have recently increased. Traditionally, breeding was managed to maximize the births during or after rains when rangeland was most productive; young males were mostly killed within the first few weeks of their life, a practice now declining, as more animals are raised for meat rather than milk, resulting in uncontrolled livestock population increase (MORRIS 2002). The low ratio of breeding males to females, the control of births and the practice of seasonal transhumance no longer follow traditional custom, partly as a result of the drop in demand for butter-oil, events such as the extreme drought of 1999, new employment opportunities and an increased demand for meat on the island (MORRIS 2002). Also economic factors, such as an increased reliance on tourism, the emergence of a cash economy and the migration of many local inhabitants from the interior to coastal areas, play an important role in the breakdown of pastoralism (ELIE 2008) and hence changes in grazing impacts.

The gradual loss of vegetative cover by goat overgrazing may cause a steady decline in whole ecosystems and affects invertebrates, for example, through soil erosion (such as in the Galápagos islands; DESENDER et al. 1999). Furthermore, plants rely on micro-climates provided by existing vegetation for germination and establishment. Several of Socotra's endemic and flagship species, such as *Dracaena cinnabari* and *Cadaba insularis* suffer from lack of regeneration due to a decline in the quality of habitat (MILLER & MORRIS 2004). The lack of tree regeneration on Socotra, for example for *Dracaena* (Fig. 7C), is traced back to either grazing or climate, or a combination of both (MIES 2001, ADOLT & PAVLIS 2004, MILLER & MORRIS 2004, ATTORE et al. 2007, HABROVA et al. 2009, SCHOLTE & DE GEEST 2010). The loss of beneficial cover caused by grazing may also be an important factor (MILLER & MORRIS 2004). Smaller herbs can be found growing in a microclimate provided by the shelter of dense-canopy trees such as *Euphorbia arbuscula* (Fig. 7A). The beneficial effects of microclimates provided by shrub cover have recently been demonstrated in a similar semi-arid ecosystem in Chile (TRACOL et al. 2011). Existing vegetation also provides protection from grazing to other plants. Many seedlings and saplings emerge from the centre of dense shrubs, demonstrating the importance of vegetation cover to the regeneration of tree species. For example, the Critically Endangered endemic *Cadaba insularis* was recently found in a new location, hidden between the spiny branches of *Lycium sokotranum* (BANFIELD, unpubl.; see Fig. 7B). All the branches and leaves growing outside the protection of the *Lycium* had been eaten. Other plant species can also grow in the protective cover of *Lycium sokotranum* or *Cissus* species, such as *Dendrosycios socotranus* – in fact, without these shrubs, there would be little, if any, regeneration (MILLER & MORRIS 2004: 44): Within enclosures, differences in plant community structure can be easily observed between grazed and non-grazed areas (Fig. 6C). A reduction in plant matter caused by grazing directly but also a lack of nursery species directly reduces the habitat available to invertebrates.

Habitat degradation caused by overgrazing is considered a realistic threat to Socotran birds, some of which are included in the IUCN Red List, for example, the Socotra Cisticola, *Cisticola haesitatus* (Near Threatened), the Socotra Bunting, *Emberiza socotrana* (Vulnerable) and the Socotran Sunbird, *Nectarinia balfouri* (Least Concern) (Birdlife International 2008, 2009). Not only larger animals are affected. Recent studies in nutrient-poor grassland showed that overgrazing by livestock has negative effects on the species richness as well as on the abundance of terrestrial snails (Boschi & Baur 2007). It was shown that these effects are independent of the grazer species, but correlate mainly to the maximum stocking rate (number of livestock units per hectare) and grazing duration (number of grazing days per year). The continuation of traditional land management practices, which limit grazing duration and stocking rates, could slow down the increasing incidence of soil erosion and habitat degradation. However, with the rate of change in Socotran culture this may unfortunately be utopian. With further degradation of Socotran habitats, enhanced by loss of traditional knowledge, the extinction of terrestrial species becomes a more pressing issue.

Agriculture

Agriculture, although historically important (date cultivation), is expanding on Socotra. Activities are often aided by international development projects that aim to create a local market and provide greater dietary variation for local populations. This phenomenon is increasing in scale on Socotra through the spread of home gardens (Ceccolini 2002) (Fig. 8A). Although such initiatives provide an important food source for people at a family level and can offer an alternative to expensive imports, the currently expanding home garden projects (Fig. 8A) pose four risks to biodiversity: (1) change of water provision because of the need for continuous freshwater supplies; (2) direct pollution through the application of biocides on an increasing scale; (3) uncontrolled import of exotics, some with the potential of becoming invasive and/or the introduction of plant diseases (expanded on below); and (4) habitat fragmentation through the clearing of natural areas in order to create gardens. Use of fertilizers may currently be too restricted to cause eutrophication, but effects depend on scale. Urgent measures are needed to increase the awareness of the possible ecological effects of small and large-scale development projects of this kind, which may be as threatening to island biodiversity as habitat deterioration. Development efforts which do not take into consideration possible local environmental impacts are unsustainable. The need for permanent freshwater is an acute problem in Socotra and is increasing with the spread of home gardens. In times of shortage of water from major wadi-systems or catchments, phreatic water tables may be exploited and altered, with the possible risk of sea water infiltration in coastal areas and disturbance of the Ghyben-Herzberg waterlens. If not planned and executed within an ecologically sound framework, development projects to improve nutrition and provide a wider variety of fodder and fuel may in fact impact negatively on ecosystems and therefore increase poverty in the long term. For example, 56% of the world's worst invasive plants are garden escapes, with devastating economic effects on islands as a result (Lowe et al. 2000), discussed in the next section.

Introduction and reintroduction of species

Wherever people colonize they spread exotic organisms, many of which become pests (Towns et al. 2006). Of all human-induced effects on islands, exotic species are considered to be the worst threat to biodiversity, surpassing habitat loss as the main cause of ecological degradation and extinctions in insular ecosystems (GROOMBRIDGE 1992, VITOUSEK et al. 1997, CLOUT & VEITCH 2002). Their effects are described as immense, insidious and usually irreversible (IUCN 2000). Impacts reach beyond biodiversity; exotics may increase poverty through the dangers they pose for local resources and human health. Effects of alien species are nearly always negative (GOODENOUGH 2010). Islands are more invaded than continental areas (ELTON 1958) because they are less resistant to invasion and more easily disturbed, therefore the potential for invasion may be greater (LONSDALE 1999). An increase in the number of human visitors increases the number of accidental introductions as well as the spread of exotics (LONSDALE 1999). Introduced species may predate, compete or bring in new pathogens that may cause extinctions in native organisms (VITOUSEK et al. 1997, FRITTS & RODDA 1998, PURVIS et al. 2000a, BLACKBURN et al. 2004, WIKELSKI et al. 2004, MANGLA et al. 2008). In plants, competition with invasives may not be directly linked to extinction of indigenous species (SAX & GAINES 2008), yet the destruction by invasive trees on native ecosystems has devastating effects (e.g. in the Galápagos, JÄGER et al. 2009). Healthy ecosystems with large indigenous diversity are less prone to be affected by invasives, and their biodiversity acts as a barrier (NAEEM et al. 2000, KENNEDY et al. 2002). To minimize further extinctions or ecological changes on islands, the most important priority is to reduce the risk of new invasions. Whereas extinction of local species is irreversible, invasion itself can be reversed. Fighting invasives is therefore a major goal in the CBD (CLOUT & VEITCH 2009), which has been integrated into Yemen's NSAPs (National Strategy and Action Plans). The problem has been hitherto largely ignored on Socotra and literature on the subject is scarce, yet the island has its share of exotics.

About 87 exotic plant species have been identified on Socotra, of which 80% have been introduced since 2000, 40% have been identified as having the potential to become invasive and 61% were intentionally introduced by a single NGO, as crops, fodder or ornamental plants (SENAN et al. 2010). In reality, this number is likely to be higher; for example, CECCOLINI (2002) mentions the use of *Cordia sinensis* in home gardens on Socotra, which was not noted by SENAN et al. (2010). Other species that have been imported as fodder or ornamental plants, may have escaped wider surveys. Despite the presence of these exotics and the possible pressures they might exert on the environment, the vast majority of the 87 exotics are (i) found only within home gardens at present, (ii) require active cultivation and (iii) are not naturalized. Therefore, reflecting these as 10% of the total flora (SENAN et al. 2010) is somewhat misleading and the figure is not comparable to situations in other islands in the world. However, it leaves no doubt that the increase of introductions and exotics pose a direct threat to Socotran biodiversity – specialists agree that exotics are a reason of concern (BANFIELD et al. 2010).

Among the exotics, two species of *Opuntia* (the prickly pear) were introduced in 2004 as ornamental plants (SENAN et al. 2010). These species have high invasive potential and should be eradicated before it is too late. *Opuntia* is known to devastate ecosystems worldwide and is a widespread noxious weed on mainland Yemen (ZIMMERMAN & CUEN 2004). *Prosopis juliflora* is a known problem on the adjacent Arabian and African mainlands. This species arrived on Socotra accidentally and a small population was quickly eradicated (MILLER & MORRIS 2004), however it was recently rediscovered in a home garden (SENAN et al. 2010). Active management is being carried out on *Nicotiana glauca*, which appeared on a roadside of the limestone plateau Diksam. The plants have already survived several management attempts but efforts must continue to prevent further spread of this dangerous invasive. Although it is illegal to import seedlings or to cultivate qat on Socotra, bundles of *Catha edulis* are imported for consumption, risking the introduction of plant pathogens and animals from the mainland; in addition, trials for qat cultivation have recently occurred on the island. Several exotic plant species have been well established on Socotra for a long time, such as *Argemone mexicana, Calotropis procera, Leucaena leucocephala, Nicotania glauca* and to lesser extent, *Parkinsonia aculeata* (Miller & Morris 2004, Klein 2005, Senan et al. 2010). According to Senan et al. (2010), three of these species are now naturalized. These existing invasives pose real threats. The mimosoid tree *Leucaena leucocephala* for example, recorded on Socotra since 2003 (Klein 2005, Senan et al. 2010), is among the 100 worst invasives in the world and extremely hard to eradicate once naturalized; it may render disturbed land completely unusable (Lowe et al. 2000). Its current occurrence in Socotra is very low and has not been detected in the wild as of yet. The leguminose *Parkinsonia aculeata* was introduced to Socotra for use as shade and as an ornamental plant (Ceccolini 2002). This South American plant has become a major and expensive problem in other areas in the world such as Australia (Humphries et al. 1991). Other organisms, such as exotic insects or micro-organisms, may hitchhike along, with the cultivated plant material increasingly imported from the mainland.

As well as the potentially dangerous species mentioned above, several exotic plant species that were present at the time of the first botanical surveys in the 1880s have become naturalized on Socotra, mentioned above. The most notable are *Argemone mexicana* and *Calotropis procera* (Miller & Morris 2004). *A. mexicana* dominates in some heavily disturbed areas such as Detwah Camp site in the west of Socotra and Qadhub on the north coast (Fig. 8B). The species is also occasionally seen in wetter areas and near wadis, for example, along the track to Adho di Melho in the Haggeher Mountains, a popular route for hiking, and in Wadi Kilisan in the southeast of the island. As stated previously, increase in human movement around the island coupled with further habitat degradation could facilitate the spread of this species. *Calotropis procera* is also concentrated in overgrazed and heavily disturbed areas such as Habido itself; however occasional trees can also be seen elsewhere. Although the spread of these species could be controlled, eradication is likely impossible given the potential size of the seed bank. Other naturalized species include the small herbs *Ageratum conyzoides* and *Bidens* species (Miller & Morris 2004). Extremely widespread and occasionally dominant, these smaller herbs are less conspicuous and able to live in mixed assemblages with native species. Nevertheless, they may have caused changes to the original environment of which we are not aware.

More research is needed to establish exactly how many species are now naturalized and their precise distribution, though it seems that the number of naturalized plants comprises less than 10% of the ca. 88 exotic plant species, and they mainly are restricted to disturbed areas. In comparison, out of ca. 600 introduced species in the Galápagos in 2002, where agriculture is more intensive and therefore introductions more likely, 45% may be naturalized, comprising only 4% of the archipelago's area yet disproportionately affecting vulnerable areas (Soria et al. 2002). Currently, 748 introduced plant species occur in the Galápagos, exceeding the number of native species, while the total number of exotics (plants and animals) in the early 1990s in the Galápagos was just 112 species (Gosliner 2009).

Without adequate control and aimed efforts, an increase can be expected in the number of introductions and naturalizations of exotic species in Socotra. A rise in the ratio of naturalized introduced plants to total introduced plants is inevitable (Sax & Gaines 2008). The high current diversity in some areas, such as the Haggeher Mountains, effectively acts as biodiversity barrier against invasives spreading to protected areas. Not all exotics have severe ecological effects – some are more likely to invade than others, depending on the species' biology, climatic conditions and health of local ecosystems. Exotic species that may potentially affect complete ecosystems have been termed *transformers* (RICHARDSON et al. 2000). Some transformers have made it to the island and should be monitored closely. There is a need to prioritize action for Socotran invasives, sharpen legislation and capacity, even the adequate monitoring and control of development projects that actively introduce exotic species without consideration of ecological consequences. Such short-term, local scale practices for the purpose of development may in fact have large scale effects and increase poverty in the long term, through a potential loss of the benefits of local natural resources and ecosystem services.

Transport and reintroductions of natural populations should be considered just as threatening to indigenous populations as exotic species from outside the island. Human activities on islands alter natural dispersal mechanisms and increase genetic migration on islands by eliminating ecological and geographical barriers (FRANCISCO-ORTEGA et al. 2000). CECCOLINI (2002) notes that active exchange of germplasm on Socotra is ongoing and is receiving increased interest. The process, enhanced by facilitated means of transport and higher accessibility to formerly isolated regions (e.g., roads; Figs 5A-E), plant introductions (e.g. gardens and restoration projects; Figs 7C, 8A) and habitat changes, leads to a reduction of genetic variability in populations. Hybridization between allopatric endemic species, or even between endemic and introduced congeners, threatens the survival of rare species through “genetic erosion”. The process is well studied in the Canary Islands, where different degrees of genetic erosion have been observed in plants (FRANCISCO-ORTEGA et al. 2000). When provenance of genetic material is uncertain and restoration is actively carried out, genetic erosion is very likely. Populations on Socotra may have been separated for millennia, some perhaps even millions of years, maintaining a genetic diversity and local adaptation that is vital to a species’ natural resilience. Human-induced genetic migration reduces this natural diversity and increases species’ vulnerability to extinction when confronted with additional environmental changes (e.g. disease, climate change).

In addition to competition, habitat alteration and genetic erosion caused by species introductions, the risk of introducing new plant diseases is also increased. The introduction of diseases with exotics is an invisible yet major factor increasing island extinctions, not only in plants (ref. in FRANKHAM 1997). Every introduced plant, animal or amount of soil imported through the harbor and airport may carry bacteria or viruses that threaten human, animal and plant health on the island. Following introduced species, introduced diseases are now considered among the major causes of extinction of Guam’s heavily depleted native biota (FRITTS & RODDA 1998). MORRIS (2002) reported a new disease affecting aloes in the west of Socotra, unseen before by local people. The cause is unknown. Date palm plantations on the north coast have also been suffering from an as yet unidentified pest. An unknown disease is negatively affecting fruit yield and requires additional labor in an attempt to minimize impacts. The date palm has long been an important traditional cultivation plant on Socotra and the number of date palm gardens has enormously increased since the 1970s when the distribution of land-ownership was reorganized (MORRIS 2002). Currently there are only two suggestions of new plant diseases on Socotra, more may be expected in the future and risks should be minimized.

The effects of exotic animals on Socotran endemics have hitherto received no attention and notes are scattered in the literature. Population estimates or aimed studies are absent. What follows is the first review on animal exotics in Socotra. Several exotic species are present in addition to the livestock. In fact, all mammals on Socotra except for the insectivores are exotics: *Viverricula indica, Rattus rattus, Mus musculus* and *Felis catus* (WRANIK 1998, 2003). These species are known to have impacted indigenous species on insular ecosystems worldwide: three out of four are among the world's 100 worst invasives (cats, rats and mice; LOWE et al. 2000). Ship rats are associated with declines or extinctions of the largest number of indigenous vertebrate species on islands (e.g., birds) and a wide literature is available (TOWNS et al. 2006). As these species have been on Socotra for centuries, we do not know the impact they initially had on the native biodiversity and ecosystems. The exotics have likely arrived at new equilibria with the environment and interact mutually. For example, the Small Civet Cat (*Viverricula indica*), exploited for its musk glands, was noted by PURCHAS as abundant on Socotra as early as the 17th century (ca. 1608; KERR & EDIN 1811-1824). Considering that active visits from Indian traders go back to the 2nd to 4th centuries CE (STRAUCH 2006) and the fact that this species was also introduced by traders to Madagascar, civet cats may have been present even before this time. Removal of such "old" invasives that interact intimately with each other and with the environment may cause unforeseen chain reactions. For example, a reduction in cats may increase the numbers of rodents, a reduction of rodents may cause a predator to switch to native prey or the rodent's prey item to become overabundant (see BULL & COURCHAMP 2009). In comparison, the removal of goats from Sarigan Island (Micronesia) resulted in the sudden expansion of an invasive plant *Operculina ventricosa*; when released from grazing pressure, its spread had devastating effects on native flora (KESSLER 2002). Hence, ecosystem responses to species removals can have unpredicted effects and have to be understood in a wide ecosystem context (ZAVELATA et al. 2001). Prioritization and thorough study is important before the eradication of well-established invasives on Socotra can even be considered. With expansion of human populations, increased traffic/transport and growing settlements on the island, the dispersal and invasiveness of the exotics is facilitated. Populations may suddenly expand, putting pressure on prey species and competitors. For example, an explosion in rodent populations may locally affect reptiles and invertebrates in areas that were hitherto undisturbed.

Other vertebrate exotics are present on Socotra. In reptiles, the introduction of two species of *Hemidactylus* (*H. flaviviridis, H. homoeolepis*) is suggested as cause for the decline of endemic members of the genus in Hadiboh, by direct competition (JOGER 2000). In Socotra's freshwater ecosystems, the Arabian toothcarp *Aphanius dispar* is widespread. Although the island is well within distribution range of this fish and natural populations were present since the 1880s, alien specimens were introduced for biological malaria vector control in the 1990s; *A. dispar* is now the only fish in most active wadi systems on the island (Al-SAFADI 1998, WRANIK 1998, KRUPP et al. 2006).

Among invertebrates, not much is known of potential threats, yet introduced species are clearly present. Several isopod species are certain to be introductions and are now widespread. Some of these are recent introductions, such as *Xeroniscus angusticauda* and *Periscyphis vittatus,* which currently occur only in gardens and houses in Hadiboh (TAITI & FERRARA 2004). The freshwater mollusc from India, *Indoplanorbis exustus*, is considered to be an introduction and was most likely introduced to the lagoon in Hadiboh by sailors refilling water kegs (NEUBERT 2006). As *I. exustus* is a vector for *Schistosoma* and *Echinostoma* (BROWN 1994), the introduction of breeds of livestock that would carry these parasites might affect indigenous livestock. Luckily, ant species with destructive impacts on ecosystems are not present on Socotra yet according to recent surveys (COLLINGWOOD et al. 2004). Island ecosystems are particularly vulnerable to ants, such as the "fire ant" *Solenopsis invicta* and the Argentine ant *Linepithema humile,* which are among the worst invaders in the world; both have been reported from nearby in the Middle East and the latter from Yemen (COLLINGWOOD et al. 2004). The threat of ant invaders reaching the island is a real one with increased transport. Only an effective quarantine scheme can help protect against the introduction of such species, which are nearly impossible to eradicate once established (COLLINGWOOD et al. 2004).

From the above, we can estimate the total number of exotic species on Socotra, according to current knowledge, at roughly a minimum of 100 species (plants and animals) but this figure needs confirmation through further research. There are currently no quarantine or control systems in place on Socotra. With planned construction of a new harbor on the northern coast and extensive road networks, the number of pathways through which exotics may enter on Socotra will strongly increase. Considering the above for Socotra, that (1) intentional introduction of exotics occurs, many of which are uncontrolled or go unnoticed; (2) several top invasives are already present and the potential of others to become invasive is widely known; (3) there has been an increase in the number of visitors, transport networks, and other potential pathways and these will continue to increase in the future; and (4) habitats are under real threat of degradation, increasing the opportunities (and therefore, speed) for exotics to spread and to become naturalized.

Strategic planning including the collection of basic data, close monitoring and prioritization of the management of existing exotics, is urgent. More importantly, increased awareness, basic capacity building and a revision of the existing legislative tools should be put in place for Socotran invasive alien species (IAS); Yemen lacks an updated, enforced legal framework, and the local capacity and infrastructure to successfully tackle IAS on Socotra. The need for action on invasive species has been recognized as one of the priorities for preservation of Socotra as a World Heritage Site (IUCN 2008; UNEP/WCMC 2008a). Awareness of the severity of invasive species has grown in the last decade and has resulted in the active involvement of local conservation management and communities. This helps to prevent the introduction of potentially dangerous exotics which is of primary importance for invasive control, and is also the most cost-effective management strategy (CLOUT & VEITCH 2009).

Attempts in the past decade by individuals to introduce plants or animals for cultivation/ornament to the island have been controlled by local conservation management according to their capacity and knowledge. The introduction of orchids (C. CHEUNG & L. DEVANTIER, pers. comm.), rabbits (A. SULEIMAN & P. SCHOLTE, pers. comm.), citrus trees (A. MILLER & Abdul Rahman AL-ERYANI, pers. comm.), other breeds of livestock (Abdul Rahman AL-ERYANI, pers. comm.) and ornamental pigeons (M. MORRIS, pers. comm.) have been among the attempts. It shows there is an awareness about the dangers of the introduction of exotics and that local management may handle such issues effectively if the threats are well identified and reaction is swift. The Indian House Crow (*Corvus splendens*), a potentially invasive exotic threatening local biodiversity, that entered Socotra in the 1990s (four specimens in 1997; WRANIK 1998) and was successfully eradicated in 2009 (SULEIMAN et al. 2010). The GEF Small Grant Programme on Socotran invasive alien species funded eradication of the crow and awareness posters on the threats of exotic plant species were disseminated on the island. Continuous efforts are important and provide a basis for further invasive species management on Socotra, a major priority for future conservation.

Habitat fragmentation through unsustainable resource use – clearing and wood collection

When an area loses a large proportion of its original habitat and particularly when the remaining habitat is severely fragmented, it will eventually lose some of its species through what is called *ecological equilibration* – every amount of loss of habitat on an island is at the cost of population viability of one or more indigenous species (McArthur & Wilson 1967). This means that the protection of endemic hotspots may be insufficient to safeguard all species indefinitely (Myers et al. 2000). Habitat fragmentation in zones of 'general resource use' such as the Socotran plains or large shrublands in other areas should therefore be followed up closely. Fragmentation is actively happening on the island, due to wood collection for fuel and timber (Fig. 8D) and the clearing of vegetation for infrastructure (Fig. 8C).

The collection of wood for fodder, fuel or timber and the clearing of vegetation for housing of people and livestock (increased pen, fold and byre building as part of the current land-grab) have increased. Such changes are direct consequences of population movements and an increased construction of settlements on the island since the 1970s (Miller & Morris 2004). The phenomenon is most obvious in the Hadiboh plain, where *Croton* shrubland is receding and fragmenting as a result of urban expansion (Fig. 8C). As well as the direct loss of shrubland and the subsequent impact of this on associated species which rely on the larger shrubs (such as invertebrates), clearing has an additional impact through increased grazing pressure on the remaining vegetation. It may also increase the likelihood of future landslides on the hillsides around Hadiboh (Fig. 8C). Wood for fuel is also actively collected and sold on the eastern and central plateaus (Fig. 8D), especially *Croton socotranus*, *Zygocarpum* (syn. *Ormocarpum*) and *Arthrocarpum* (Morris 2002). With the increase of road networks and better access (Figs 5A-E), the amount of wood sold in some areas now seems on the increase as well. Until recently, a relatively sustainable practice was to collect only dead wood to use for fire and cooking (Morris 2002). Whereas removal of a large amount of potentially nourishing dead material may have an impact on an ecosystem, for example affecting shelter for terrestrial animals or providing nutrients, the practice left large parts of the existing shrubland relatively intact. As human populations increase and especially during times of bottled gas shortage, the need for fuel shifts from dead wood to cutting of live wood. This was seen as recently as 2008 when pirates hijacked a ship containing gas supplies for Socotra, meaning that a large population of the island's largest town (Hadiboh) had no alternative but to use wood as a source of fuel for cooking. Overharvesting of wood may also occur in times of drought (Morris 2002). The Critically Endangered endemic tree *Cadaba insularis*, for example, has become extremely rare on the island due to its use as fodder during extensive droughts in 1999 (Morris 2002, Miller & Morris 2004: 476). Currently, few trees remain on the island. Several tree species, such as *Maerua angolensis* var. *socotrana* and *Grewia* species, are likely to suffer from indiscriminate cutting for timber with increased development of the island and breakdown of traditional practices regulating the use of live wood (Miller & Morris 2004). As well as the threat to individual species, complete vegetation types may be destroyed by wood collection. The cutting of *Avicennia marina* for timber and fodder, perhaps in combination with changes in the water table, have caused a decline of mangrove woodlands in Socotra (Miller & Morris 2004). Mangroves on the northern coast, such as at Ghubbah, which still contained trees in 1989, were almost completely destroyed by cutting in 1990; other mangrove stands have completely disappeared in the last century, near Qadhub on the northern coast and Qalansiyah in the west (Morris 2002, Miller & Morris 2004). In the northern coastal plain, almost all but a few mangrove trees are now gone (Fig. 8E) and the remaining specimens are threatened by infrastructure development. The decline of mangroves is a worldwide phenomenon, combined with a permanent loss of species associated with these habitats; mangrove stands also offer important protection against coastal erosion (Alongi 2002). That this specific habitat harbors important biodiversity in Socotra, was illustrated as recently as 1999 when a new endemic gecko species was discovered in a mangrove in the southwest, only recorded from the type locality (*Pristurus obsti;* see ROESSLER & WRANIK 1999, 2004). If this mangrove had been destroyed to the extent of that of the northern coast, this population, hitherto the only reported one, would have been strongly affected by habitat loss and the species may have been lost altogether. Despite the above, import of timber facilitated by improved access to the island has also increased. This may mean that wood collection for building in particular may be decreasing, but also that more foreign material is brought in (increasing risk of exotics).

Besides local use, several Socotran plants have been historically exploited as products. The extraction of resin and other plant products such as aloe sap seems at present not to have a major impact (MILLER & MORRIS 2004). However, if the global market demand were to increase (see under trade) or the populations to encounter additional stress from another threat, exploitation may weaken existing populations, such as the flagship species *Dracaena cinnabari* and endemic *Boswellia* species from which resin is actively extracted (MILLER & MORRIS 2004).

Unsustainable resource use – marine environment

A discussion of impacts on the marine environment of Socotra is beyond the scope of this work. As a major component of the livelihoods of local people and of the island's biodiversity riches, marine ecosystems are very important on Socotra. Socotra harbors rich marine communities and coral reefs bordering the island and have been recognized an important part of the UNESCO World Heritage designation. The marine habitats of the archipelago are highly varied, of an exceptional condition and of high regional significance in terms of biodiversity, biogeography and endemism and have been merited international status (KEMP 1998, ZAJONZ et al. 2000, KLAUS et al. 2003, DEVANTIER et al. 2004, CHEUNG & DEVANTIER 2006). With a breakdown of traditional practices, threats to the marine environments have increased as well, resulting in overfishing whereas before, timing and place of fishing were regulated by traditional laws and were on lower scale (MORRIS 2002). The problem has increased through international demand for Socotran sea products and illegal fishing by industrial trawlers (CHEUNG & DEVANTIER 2006 and references therein). Control of protected sites depends on local capacity and needs enforcement – recent (2006) killings of sea-turtles from protected areas and the ongoing collection of sea cucumbers collected from coral reefs (Figs 9D-E) or of shark fins (Fig. 9C), are examples of ongoing unsustainable resource uses of the marine ecosystems. The Environmental Protection Agency in Socotra has attempted to improve regulations for sea cucumber (Fig. 9E) collection (CHEUNG & DEVANTIER 2006: 328), yet activities in marine overfishing remain hard to control. Impacts of modern development on the marine environment are part of separate projects by marine experts studying Socotra. The few examples will not be further expanded here, yet illustrate that the same underlying threats discussed above for terrestrial ecosystems such as habitat degradation, unsustainable resource use, breakdown of traditional practices etc., find their parallel expression in Socotran marine ecosystems.

Natural factors – climate change and shore erosion

Natural catastrophic effects are severe, affecting all ecosystems regardless. Climate change, a driving non-selective catastrophic extinction event, may deliver a final *coup de grace* to susceptible island populations, already weakened by human-mediated impacts such as habitat fragmentation, habitat degradation or exotic species (FRANKHAM 1997, PURVIS et al. 2000a). Impacts of climate-induced changes are expected to be more severe on the world's island biotas, because insular endemics are (1) poorly equipped against range shifts as a result of climate change and (2) more prone to shifts in ecosystems due to relatively low genetic diversity (FORDHAM & BROOK 2010). On Socotra, the impact of climate change is considered to be a major threat to ecosystems in the long-term as a result of gradual aridification, for which evidence is indirect (e.g. woodland decline; MILLER & MORRIS 2004: 43-44).

Current understanding of Socotran climate fluctuations is insufficient for exact predictions (SCHOLTE & DE GEEST 2010), although aridification is almost certain to affect the island's indigenous biota. The flagship species *Dracaena cinnabari* is an example. Socotra's Dragon's Blood Tree (Fig. 10B) is a species in decline, a species characterized by overmaturity and fragmentation in most areas (MILLER & MORRIS 2004, ADOLT & PAVLIS 2006, ATTORRE et al. 2007). Predicted climate change suggests a possible loss of 45% of the total predicted suitable habitat (not actual habitat) for *D. cinnabari* by 2080, according to climate and habitat modeling (ATTORRE et al. 2007). *Dracaena* may serve as an example for other Socotran endemics. A decline in key species that characterize the vegetation would have a major impact on the ecology of Socotra (MILLER & MORRIS 2004). Although many of the plant species are xerophytic and therefore able to naturally withstand extreme droughts, further reductions of populations would still have a severe effect (MILLER & MORRIS 2004). The island went through wetter and drier cycles during the Holocene, as evidenced from (i) palaeoclimatic data using speleothems (FLEITMANN et al. 2004, DE GEEST et al. 2006), (ii) archaeological data (e.g., former drainage systems), in historical times, (iii) through oral tradition in combination with botanical observations, noting contraction of distribution patterns (MILLER & MORRIS 2004). Human impacts increase during times of drought due to an additional stress on natural resources and population movements. Climate events in the past, like the severe drought of 1999, affected the island's traditional land use, breeding patterns and transhumance skills; consequences of this climatic event are still felt today (MORRIS 2002; see above under grazing). Herders from the west and centre of the island moved to grasslands in the Haggeher mountains, which were soon grazed out and the shrubs and trees exploited for extra foliage to feed livestock (MORRIS 2002). In the future, such events may be repeated and prolonged, each time with predictable, additional impacts on the local environment. Most of the permanent water supply on the island depends on orographic rainfall and fog from the higher regions (MILLER & MORRIS 2004) (Fig. 10A), which is collected in wadis flowing to the coasts; therefore changes in water regimes on Socotra's plateaus and mountains, will strongly affect all life on the island. In the spring of 2010, the main town of Hadiboh was unexpectedly – and fortunately only for a short time – in freshwater deficit (Abdul Rahman AL-ERYANI, pers. comm.). Most water in the city originates from the mountains' permanent supplies, yet additional phreatic sources are actively used. Future changes in climate may affect existing water provisions and freshwater ecosystems, but also the island's *wet refugia*, important centres of radiation, driving the more sensitive species to extinction (Fig. 10A). In analogy with *Dracaena cinnabari*, many other plant species are found only within the wet refugia across the island (MILLER & MORRIS 2004). These are mainly high altitude zones which benefit from monsoon fog, low cloud and drizzle. Anecdotal evidence suggests that the extent and duration of this atmospheric moisture has decreased even within living memory (MILLER & MORRIS 2004). The available habitat for species confined to the wet refugia is potentially shrinking due to aridification (Fig. 10A). Although this means that dry-adapted species may in the future have a greater potential range, endemics and endangered species are found disproportionately within wet refugia (BANFIELD 2006, BANFIELD & MILLER, unpubl.). Therefore any further aridification could threaten a large number of endemic species through fragmentation, range retraction and potentially drive species to extinction (Fig. 10B). *Begonia samhaensis* on Samha is a good example. The existing populations are limited to a few hundred specimens, 95% of which restricted to an area of 50 m², situated in a zone of constant mist at 50-60 m altitude; local droughts may easily drive the species to extinction (HUGHES et al. 2003).

In marine ecosystems such as the coral reefs that border the island, climate change is one of the major factors expected to have a large-scale effect. Coral reefs are widely affected by climatic events (SOKOLOW 2009) which has an impact on fisheries, a major source of income for Socotra's indigenous population. Thorough research on predicted effects of climate change on Socotra is necessary for a protection of the island's ecosystem services.

Natural processes occur on the island that may affect both marine and terrestrial ecosystems. No studies have been published on shore erosion in Socotra yet the phenomenon is clearly present and reported here for the first time (Fig. 9A-B). Beach erosion may have a series of causes, such as human-mediated effects, climate change or catastrophic events (e.g. FRENCH & BURNINGHAM 2009). As the beach sand is lost forever, hydraulics are affected, structures at the shoreline become unprotected and are damaged by direct wave impact. For example, at the old village of Qadhub on the northeastern coast, beach erosion is very evident (Fig. 9A). A flooding event in 1972 damaged the mosque (completed in 1861; SULEIMAN, pers. comm.) which was intact prior to this and altered local beach dynamics that led to the accelerated beach erosion visible today (Figs 9A-B). Other places on Socotra are undergoing similar coastal changes, some attributed to natural phenomena such as the 2004 tsunami (e.g. Mahferhin; UNEP 2005). Climate change is a major factor affecting shore erosion, for example through sea level fluctuations or changes in wave dynamics (ZHANG et al. 2004) and should also be taken into account when considering coastal processes on Socotra. Human-mediated changes may increase the existing problem, through the collection of coral and stones for building and liming (MORRIS 2002, AL-ERYANI & ZANDRI 2006) which change beach dynamics, or larger-scale developments that alter morphology of the shoreline, such as channels for a large harbor which is planned for construction on the northern coast. Also the decline of mangroves and increased building, evident on the north coast of Socotra, play an important role in modifying beach dynamics.

A glimpse of the future – Socotra *vs* Galápagos

Due to its remarkable biodiversity and endemism, Socotra has been given the name 'the Galápagos of the Indian Ocean' (SOHLMAN 2004). Parallels with the Galápagos may help conservation planning in Socotra (ZANDRI & DIGHT 2006). Both archipelagoes differ significantly in size, age and natural history, yet parallels can be made (Fig. 13). In the Galápagos, Darwin visited in 1835, the time of the first biodiversity surveys; the archipelago was declared a national park in 1959, tourism started immediately after in the 1960s and the Galápagos was designated a UNESCO WH site in 1978 (STEVENSON 2001, UNEP/WCMC 2008b) (Fig. 13). Events happened in parallel on Socotra, but 30-45 years later: first biodiversity surveys in the 1880s by BALFOUR and SCHWEINFURTH, the Socotra Zoning Plan in 2000, the immediate subsequent start of tourism (2000) and the designation as a World Heritage Site in 2008 (Fig. 13). Perhaps Socotran ecosystems could now be considered as having at least, a similar state of health of those in the Galápagos at the time of nomination as world heritage site 30 years ago. Threats on the Galápagos may be of a comparatively larger scale and impacts may have been relatively more severe. In overexploitation of marine resources such as shark fins and sea cucumbers, the Galápagos also has faced similar problems (ZANDRI & DIGHT (2006). If we consider the present-day condition in the Galápagos, we might catch a glimpse of Socotra's future, or better, what could happen if trends and threats continue in parallel.

The total number of 112 exotics in the Galápagos in 1990 rose to 1,321 introduced species, including 748 plants, in 2009 (Fig. 13) (GOSLINER 2009; see also under exotics section). These numbers have increased despite targeted efforts such as a quarantine and inspection systems established in 1994 (STEVENSON 2001), and have been linked to the increase in tourism and immigration (UNEP/WCMC 2008b). Ultimately, and largely for this reason, the Galápagos were listed in 2007 as one of the UNESCO World Heritage Sites In Danger (but removed again in 2010, despite protests from conservationists). The motivation for the listing as World Heritage Site In Danger, was stated as follows: '*due to… ever-increasing commercial pressure of tourism which has encouraged an uncontrolled invasion by mainland immigrants and of exotic flora and fauna'* (UNEP/WCMC 2008b). Tourism started in the 1960s, with ca. 3,000 tourists in 1969 (UNEP/WCMC 2008b) to a current total of 100,000-130,000 visitors yearly (GOSLINER 2009, WATKINS & CRUZ 2007, ZANDRI & DIGHT 2006). Some extinctions in the Galápagos can be directly attributed to introduced diseases as a result of exotics and habitat loss. The Galápagos has lost one subspecies of Darwin's Finch (Darwin's large ground finch, *Geospiza magnirostris* ssp. *magnirostris*) and several bird populations are extinct, others threatened or on the verge of extinction (DVORAK et al. 2004, GRANT et al. 2005, GOSLINER 2009). At least three subspecies of the Galápagos giant tortoise are considered extinct in the wild, not reported for 100 years (GOSLINER 2009). In terrestrial molluscs, COPPOIS (1995) noted that about one half, and possibly even two-thirds of the Galapagos' bulimulid species may now be extinct. Bulimulids, which underwent local radiations on the Galápagos, were major victims of human colonization, and suffered severely from habitat destruction and introduced predators (ants and rats) or competitors (COPPOIS 1995). Recent reports confirm that about half of these terrestrial mollusc species have not been seen in the wild over the past 25 years or so (C. PARENT, pers. comm.). A major difference with Socotra is that introduction of livestock in the Galápagos only occurred in the 19th century, whereas century-old introductions have established new equilibria on Socotra.

If we replace 'Galápagos' with 'Socotra' in the former paragraph and add roughly 20-30 years to the dates, the need for timely conservation efforts becomes clear. Without targeted conservation action, Socotra risks a similar fate. Could this mean that, by 2030, we may reach a sharp increase of the number of exotics and face imminent extinction of species? Socotra now has about 100 exotic species (plants and animals; this study), paralleling the situation in the Galápagos 20 years ago, and measures for control have yet to start. The number of tourists on Socotra is now similar to the situation of the Galápagos about 40 years ago, when the possible impacts of the rising trend in visitors on the islands' ecosystems, were not realized fully yet; as the trend in Socotra is steeply rising (SCHOLTE et al., in press), impacts will rise in parallel. Socotra has lost none of its endemic birds, reptiles or terrestrial molluscs over the course of a century (this study). In fact, revisions of population estimates of Socotran birds reveal quite healthy numbers (PORTER & KIRWAN 2010, PORTER & SULEIMAN in prep.). Nevertheless, an increase in habitat fragmentation, number of exotics and naturalized invasives, impacts of diseases resulting in increased extinction pressures on native biota are all very likely events. The Galápagos represent just one island comparison; Guam would show an even worse possible future scenario.

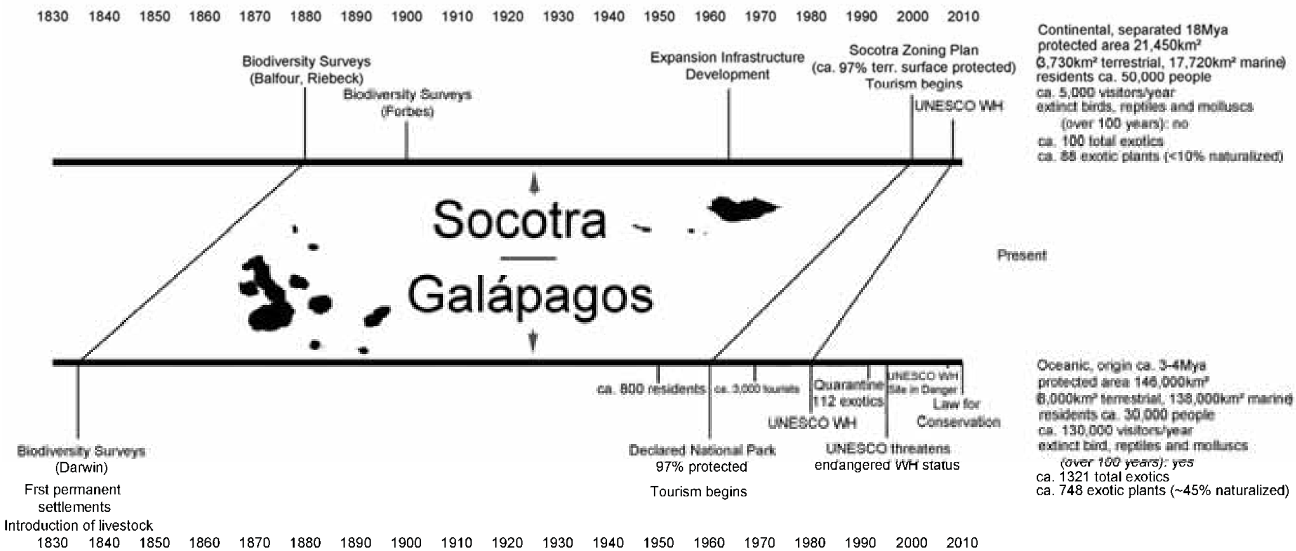

Fig. 13. Facts and timeline of events on Socotra, sometimes called 'the Galápagos of the Indian Ocean' compared to the real Galápagos. Connections between timelines connect similar events influencing current-day conservation on both archipelagoes: first biodiversity surveys, national protection, the start of tourism and international recognition as UNESCO World Heritage. Dates and facts of the Galápagos are based on STEVENSON (2001), GOSLINER (2009), ZANDRI & DIGHT (2006), UNEP/WCMC (2008b) and WATKINS & CRUZ (2007); for Socotra on CHEUNG & DEVANTIER (2006), ZANDRI & DIGHT (2006) and updated rough estimates mentioned in this study – these should be seen as numbers for comparative means rather than absolute data. See text for further explanation. The line in the centre of the figure is the 100 km scale bar for both map insets, Socotra right and the Galápagos left (both to scale).

Examples of local initiatives for conservation

Rubbish collection

The above impacts do not affect all areas and ecosystems on the island and are most severe in areas of main infrastructure development/population expansion. With increased access and further breakdown of traditional land management, more areas are likely to be affected in the future. Matiyaf, a small coastal village in the southwest of the island, was isolated and only reachable by boat until recently. The inhabitants of Matiyaf have a designated place for depositing rubbish in the village and all comply (Fig. 11A). Pollution is not seen, and the lagoon (Fig. 11D) resembles the Qalansiyah lagoon (Fig. 2B) a decade ago. For the first time a road has opened up a connection to Matiyaf (Fig. 5E) which is certain to bring change. Hopefully, the attitude towards rubbish and its collection may help in keeping the village clean. Semi-private initiatives for rubbish recycling are also emerging for the largest town on the island, Hadiboh, where waste is an acute problem (Figs 11B-C). Matiyaf illustrates that local impacts can be minimized, as long as these are manageable and awareness is already present.

Ex situ conservation

A focus of ex situ plant conservation in particular has been Adeeb's nursery in Hadiboh (Fig. 12A). This began as a small garden for endemic trees, based on local initiative but originally financed by the Ministry of Agriculture, the Environmental Protection Authority, the Socotra Conservation Fund and the former UNDP project (the Socotra Conservation and Development Programme) at various periods (see also BOGGS 2006). The garden is run by Socotrans, Adeeb Abdullah (Fig. 12B) and his family and provides an opportunity for awareness, education, research and conservation. Since 2007, the Royal Botanic Garden of Edinburgh has been working closely with the family to expand the number of species collected and together they have developed an accessions, labeling and record-keeping system. All specimens are collected with GPS and logbooks are kept, so provenance can be assured if any of the material is used for future restoration projects. Knowing the provenance of specimens reduces the risks of genetic erosion in indigenous populations in the case of restoration. For specimens collected before detailed logbooks were kept, provenance could be traced by molecular methods if needed, in order to identify the area of origin. The number of endemics held has now grown from 38 species in 2007 to 117 (as live plants or seeds) today, totaling 37% of the island's endemic plant species (Fig. 12C). In addition, two of the three Critically Endangered endemics are held as well as 22% of the Endangered species and 35% of the Vulnerable plant species (BANFIELD, unpubl. data). This shows how local initiatives can be supported and developed in close partnership with Socotri people for the benefit of conservation. Similar grassroots initiatives have been created across the island by local people, for example in Qa'arah and Homhil.

Discussion

From the above, it is clear that (1) Socotra is changing. The island is under threat of real loss of biodiversity through extinction adding modern human interference to historical impacts. The ecosystems may be pushed beyond a threshold of survival. Within a historical context, the impacts of the last decade may be considered the most severe since the arrival of humans on the island; (2) These impacts are: infrastructure development, loss of traditional knowledge and land management expertise, pollution, exotic species, collection and trade in island biota, overgrazing, habitat fragmentation and degradation, all of which are exacerbated by tourism, encouraged by the 'paradise effect' of the island, which is enhanced by unrealistic media coverage and travel agencies; (3) The increased attraction of, and attention paid to, development has put additional pressures on the environment and has been partly responsible for increased visitor numbers, loss of traditional island expertise, direct habitat loss, with consequent effects on trade and introduction of exotic species. Reports on new plant diseases occur but no data exists. Several of the impacts reinforce or affect each other. Future extrinsic factors such as climate change are expected to have an additional negative effect on populations, with decline of key species as predicted result. (4) Conservation efforts should grow in parallel with increased development. International recognition for outstanding biodiversity have little use if not accompanied with the means to safeguard a global treasure. Several examples indicate that local capacity for conservation may need further expansion in order to tackle current and future threats.

The degradation of Socotra's unique culture and nature is an ongoing process. Considering the historical background, human-mediated changes to the environment are not new, yet clearly they are increasing. Continuing efforts are necessary, taking into account that: (1) Socotra is a relatively large island. Current impacts are dispersed across its surface and over different ecosystems. Areas with significant demographic expansion are likely to be affected more strongly than others. However, the majority of impacts occur in the more developed areas and any area of the island accessible to increased human activity currently faces one or more of the threats discussed above; (2) Socotra has lost none of its terrestrial endemic reptile, bird and mollusc species in the past century. As this period is considered one of increased extinction elsewhere (GROOMBRIDGE 1992), the situation in Socotra is highly remarkable in comparison to other islands in the world. It provides some breathing space and a timely chance to protect the current endemic diversity. (3) Traditional knowledge, which has played a major role in reducing impacts of habitat degradation and fragmentation, is declining but not lost. There is no generation gap yet within the indigenous people that have maintained the traditional conservation practices based on centuries of knowledge, and the new generations. Again, this is a unique situation – in many other places, the gap is more than one generation. Provided that the protection of ecosystems is considered by the islanders to be important for their survival and to offer them a reasonable standard of living, a link between past and future may be maintained. Growing economies such as tourism further reduce the already declining value of traditional practices and knowledge. In addition, young people also move from the interior to study in the two main secondary schools on the island (Hadiboh and Qalansiyah), whereas they formerly learned about the island by observing and doing in their home areas, increasing the traditional knowledge gap by actual distance (MORRIS, pers. comm.); (4) Human-mediated extinction often follows predictable patterns. We can and must use this knowledge to help prevent further extinctions today (BOYER 2008). It means that within the current setting, we can tap into a vast knowledge on island ecology and extinctions to put early warning systems for Socotra in place. This should allow better insights into how to take appropriate action against current threats. For example, only a small proportion of Socotra's exotic plant species are naturalized, yet we know further spread of exotics is an inevitable process - which means action is needed now, in order to avoid the same situation as in the Galápagos (Fig. 13).

It is absolutely vital to establish a framework for the protection Socotra's biodiversity – in capacity, manpower, legislation and decisions based on a consistent scientific basis. With threats increasing, efforts will have to increase in order to conserve Socotran biodiversity. Listing and evaluating species using IUCN standards is an important step. Plants and birds, on which the best data on Socotra is currently available, have been assessed using IUCN criteria. Freshwater fauna is covered. Dragonflies, of which there is only a single endemic (*Azuragrion granti*), and three species of freshwater crabs belonging to two endemic genera (*Socotrapotamon* and *Socotra*), have been given IUCN categories as well. This leaves us without conservation status for all remaining terrestrial fauna. None of the reptile species are listed, despite the fact that endemism is high. The endemic monotypic snake genera *Hemerophis* and *Ditypophis*, or the many endemic geckoes that reside in the genera *Hemidactylus* and *Pristurus*, urgently need to be assessed. The same can be said for terrestrial molluscs, which have very limited ranges and local radiations on Socotra (NEUBERT 2009) and for other invertebrate groups that may be indicative of change and for which data is becoming available. Distribution ranges of such endemics may be very small. When it comes to limited distribution ranges, IUCN criteria are not equally applicable to all taxonomic groups, nor are they consistent with the small ranges typical for island groups (MARTIN 2009). Therefore more appropriate measures of conservation assessment may be required. If two species have equally small areas of occupancy (a few km²) in a single locality and a road will be constructed through one area yet no changes are planned in the other locality, priority should be given to the species under imminent threat of direct mortality through habitat loss. Species with small populations, extremely vulnerable to habitat destruction, face imminent extinction in the absence of appropriate and timely conservation action - the obvious immediate goal for such species is to conserve habitat in their single areas of occurrence (‘*trigger species*’; RICKETTS et al. 2005). It may be therefore be useful in Socotra, in future assessments, to go a step further and indicate trigger species with priority for conservation, taking potential habitat loss into account. Protected areas should be buffered to include edge effects (WOODROFFE & GINSBERG 1998). A significant number of endemics at high taxonomic level on Socotra (e.g. in plants, see BANFIELD et al. in press) may have to receive a higher priority in future protection – ancient taxonomically isolated groups should hold a special importance in conservation terms, in that their extinction would cause a greater loss of unique genetic sequences and morphological diversity (CRONK 1992).

The current basic framework for Socotran conservation, the Socotra Zoning Plan (2000), focuses on those regions with highest diversity. These were originally drawn up, based on the best available data at the time, namely plants, for terrestrial ecosystems. Some of these regions are potentially being damaged due to the increased attraction as officially designated protected areas and tourism exploitation, in contrast to the original intentions of the Zoning Plan. Since 1999, new data have emerged giving a better insight into areas with high biodiversity for plants as well as animals. Some regions outside the protected areas tend to be disproportionately impacted. We are at risk of ignoring of future developments in ‘general resource use zones’, such as the coastal areas or the Hadiboh Plain. If current trends continue, habitat loss in coastal areas may continue at an increasing rate, yet these areas are important for the continuation of widespread populations. For example, recent surveys suggest that the Hallah Area on the NE coast contains about 50% of all reptile species on the island (F. PELLA, unpubl.). This area has already seen the construction of a stretch of the Socotra ring road which effectively cuts the narrow coastal plain in two.

Efforts for conservation may perhaps be best focused on areas of high human population densities and impacts, as well as on those with the best remaining natural habitat (DAVIES et al. 2006). However, biodiversity surveys in terrestrial areas still lack the basic population

Fig. 14. Socotran Skink, *Trachylepis socotrana* (Peters, 1882) (formerly *Mabuya*), one of Socotra's endemic reptiles. Can Socotran endemics survive the 21st century? Photograph: Max KASPAREK.

and distribution data which would allow a follow up, and these need to be carried out in a timely fashion. Botanical surveys by the Royal Botanical Gardens of Edinburgh have been systematic, allowing comparison with collections from the late 20st century and providing the basis for the current delineation of areas with important biodiversity. These surveys on Socotra provide the best comparable data for the follow-up of changes in habitat, relative species abundances and diversity, and for the interpretation of human-mediated impacts. Marine sections have been well studied and provide important tools for conservation. Birds are currently the best-studied terrestrial animal group on Socotra. All other terrestrial species lack readily available and reliable population and distribution data and even need basic taxonomic studies. Hence, we lack a very important scientific basis for estimating future terrestrial biodiversity loss on Socotra. This is partly because larger biodiversity surveys only started in the last decade, and were undertaken by a handful of researchers. Therefore, plant data aside, we have little data available to measure changes in the last decade (before and after forcing events). Considering that due to the time-lag, it may take at least a few decades before extinctions take place, there is still time to carry out extensive biodiversity estimates which will allow us to select indicator species and monitor future changes. On the other hand, knowing already the extent and nature of the impacts and the speed with which current changes take place, this gap in knowledge should not stop us from making decisions about the conservation and further protection of Socotra against introductions, waste/pollution, habitat fragmentation, and ongoing habitat-, genetic - and cultural erosion.

Future conservation efforts in Socotra should be approached by viewing the ecosystem as a whole, taking also basic species biology into consideration. It is the only way to try and avoid the breakdown of complete ecosystems and singular extinctions. Species depend strongly on the ecosystem – therefore, even when a species occurs in large resilient populations, it may still be vulnerable to extinction if species on which it depends do not share these traits (chains of extinction; PURVIS et al. 2000a). On Socotra this means that effects on seemingly unimportant groups like invertebrates may strongly influence shifts in other groups, e.g., through loss of pollinators or prey species. Habitat changes such as roads or pollution of freshwater ecosystems, which occur as shown above, cause unforeseen shifts. We have argued in previous sections that such local changes induce extinctions in insular ecosystems. There is no reason why Socotra would be any different.

The threats illustrated here are considered major factors posing a risk to Socotran biodiversity. Each of these should be part of separate, more elaborate studies. Selected examples have been given of trends that have affected also other island ecosystems worldwide and have just begun in Socotra – we know these impacts historically lead to extinction, especially in ecosystems that may be close to a threshold. The remarkable thing about this particular island is that it was in a relatively good state until recently, and was traditionally managed in a sustainable way, undoubtedly a factor that has aided the preservation of its bird, mollusc and reptile species in the last century. Large areas still exist with stable habitats and low human population and grazing densities. The largest impacts have occurred in the decades 1970-2010, with acceleration in the last decade. For its proper conservation, we should aim to respect and protect the balance formerly achieved by the island's true inhabitants, instead of focusing only on imposing modern rules of conservation and management.

In order to maintain the landscapes and ecosystems that have helped the Socotran biota to survive the last century, it is necessary to emphasize the importance of local expertise and knowledge, the traditions and systems for sustainable management which protected the island relatively well for so long. Disentangling culture from nature on an island has direct consequences on both, and modern development is a strong disruptive force. In time, loss of culture will further increase poverty through loss of healthy ecosystems. The preservation of the unique language of Socotra may prove as equally important and relevant for the protection of its ecosystems as species-oriented conservation efforts. The language describes the island in detail before current changes took place, and the attitudes towards the biodiversity and ecosystems which helped the islanders to manage their home successfully. The Socotri language keeps this alive, and perhaps through its unique insight into effective survival on the island, can also inspire hope for its future protection. No-one can be better conservationists of the island than the Socotrans were. While the science of conservation biology is only some 30 years old, their *in situ* conservation skills have been passed on for generations and go back centuries. For local inhabitants, conservation ensured survival – there is no better way of protection. Socotra's indigenous population contains a reservoir of priceless knowledge that is vital to the continued preservation of the island. The Socotran people are the only ones who have over time devised systems which have allowed them to handle successfully the unique environment with which they have evolved. We have much to learn from their skills, to ensure truly sustainable development and conservation on Socotra.

Finally, it is worth considering whether an island like Socotra, after such a long period of isolation, may successfully withstand the impact of modern development. The answer is simple – it cannot. The real risk remains that some of the charismatic Socotran species we cherish now will not survive to the next century (Fig. 14). For some, extinction may already have begun. The benefits of development and new industries come at the cost of losing much of its natural and cultural heritage and consequent loss of identity. To protect the unique biodiversity, there must be a balance between economic growth and conservation on Socotra (SOHLMAN 2004). Yet, an equilibrium between development and conservation may be as vulnerable as the Socotran ecosystems themselves. At present, the trend is clearly in favor of development, which will inevitably lead to ecosystem decline and ultimately, to the loss of Socotra's unique position as one of the most remarkable islands in the world. We hope that the current study may be useful for the much needed, continuous efforts in protection of the unique biota and culture of the largest island in the Arabian Region.

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References

ADOLT, R. & J. PAVLIS (2004): Age structure and growth of *Dracaena cinnabari* populations on Socotra. – Trees 18: 43-53.

AL-ERYANI, A. R. & E. ZANDRI (2006): Case Study 4. Coral Mining. In: C. CHEUNG & L. DEVANTIER (2006), Socotra – A Natural History of the Islands and their People. K. VAN DAMME (Ed.). p. 355. Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.

ALONGI, D.M. (2002): Present state and future of the world's mangrove forests. – Environmental Conservation 29: 331-349.

AL-SAFADI, M. M. (1998): Freshwater fishes of Soqotra Island, Yemen. In: H. J. DUMONT. (Ed.), Soqotra: Proceedings of the First International Symposium on Soqotra Island: Present & Future, p. 213-217. – United Nations Publications, New York.

ATTORRE, F., F. FRANCESCONI, N. TALEB, P. SCHOLTE, A. SAEED, M. ALFO, & F. BRUNO (2007): Will dragonblood survive the next period of climate change? Current and future potential distribution of *Dracaena cinnabari* (Socotra, Yemen). – Biological Conservation 138: 430-439.

BAHN, P. & J. R. FLENLEY (1992): Easter Island, Earth Island. – Thames and Hudson, London. 240 pp.

BALFOUR, I. B. (1888): The Botany of Sokotra. – Transactions of the Royal Society of Edinburgh 31: 1-446.

BALMFORD, A. (1996): Extinction filters and current resilience: the significance of past selection pressures for conservation biology. – Trends in Ecology and Evolution 11: 193-196.

BANFIELD, L. (2006): The biodiversity and conservation of the wet refugia of the Socotra Archipelago. – Unpubl. MSc Thesis, Royal Botanic Garden Edinburgh.

BANFIELD, L., K. VAN DAMME, D. PIETSCH, R. PORTER & A. MILLER (2009): Road Development on Soqotra. – Friends of Soqotra Newsletter (Tayf) 6: 6-9.

BANFIELD, L., A. MILLER, E. NEUBERT, R. PORTER, A.S. SENAN & K. VAN DAMME (2010): Invasive Species: the Dangers of Introducing Alien Animals and Plants on Soqotra. – Friends of Soqotra Newsletter (Tayf) 7: 10-15.

BANFIELD, L., K. VAN DAMME & A. MILLER (in press): Evolution and biogeography of the flora of the Socotra Archipelago (Yemen). In: D. BRAMWELL (Ed.), The evolution of island floras. – Cambridge University Press.

BAUM, T. (1997): The fascination of islands: A tourism perspective. In: D. G. LOCKHART & D. DRAKAKIS-SMITH (Eds), Island tourism: trends and prospects. – London and New York: Pinter, p. 21-35.

BAUR, A. & B. BAUR (1990): Are roads barriers to dispersal in the land snail *Arianta arbustorum*? – Canadian Journal of Zoology 68: 613-617.

BEYDOUN, Z. R. & H. R. BICHAN (1970): The geology of Socotra, Gulf of Aden. – Quarterly Journal of the Geological Society London 125: 413-446.

BIAGINI, E. & B. S. HOYLE (1999): Insularity and development: international perspectives on islands. – Island Studies Series, London, Pinter, 378 pp.

BIRDLIFE INTERNATIONAL (2008): Nominated World Heritage Site facing development threats. Birdlife News. – www.birdlife.org/news/news/2008/02/socotra.html.

BIRDLIFE INTERNATIONAL (2008-2009): *Nectarinia balfouri*. *Cisticola haesitatus*. *Emberiza socotrana.* In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.3. – www.iucnredlist.org.

BLACKBURN, T. M., P. CASSEY, R. P. DUNCAN, K. L. EVANS & K. J. GASTON (2004): Avian extinction and mammalian introductions on Oceanic islands. – Science 305: 1955-1958.

BOGGS, R. (2006): Case Study 7. Socotran nursery and botanical garden for rare and endemic plants. In: C. CHEUNG. & L. DEVANTIER (2006), Socotra – A Natural History of the Islands and their People. K. VAN DAMME (Ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong, 360 pp.

BOSCHI, C. &B. BAUR (2007): The effect of horse, cattle and sheep grazing on the diversity and abundance of land snails in nutrient-poor calcareous grasslands. – Basic and Applied Ecology 8: 55-65.

BOYER, A. G. (2008) Extinction patterns in the avifauna of the Hawaiian Islands. – Diversity and Distributions 14: 509-517.

BROWN, D. S. (1994): Freshwater snails of Africa and their medical importance. – London: Taylor & Francis, 608 pp.

BUCKLEY, R. (2009): Evaluating the net effects of ecotourism on the environment: a framework, first assessment and future research. – Journal of Sustainable Tourism 17: 643-672.

BULL, L. S. & F. COURCHAMP (2009): Management of interacting invasives: ecosystem approaches. p. 232-247. In: M. N. CLOUT & P. A. WILLIAMS (Eds), Invasives species management. – Oxford Biology, Techniques in Ecology & Conservation Series, Oxford University Press, UK.

CAMPBELL, K. & C. J. DONLAN (2005): Feral Goat Eradications on Islands. – Conservation Biology 19: 1362-1374.

CARPENTER, A. I., J. M. ROWCLIFFE & A. R. WATKINSON (2004): The dynamics of the global trade in chameleons. – Biological Conservation 120: 291-301.

CASSON, L. (1982): Periplus Maris Erythraei: Notes on the Text. – The Journal of Hellenic Studies 102: 204-206.

CASSON, L. (1989): The Periplus Maris Erythraei. Text with introduction, translation, and commentary by Lionel Casson. – Princeton University Press, Princeton, New Jersey (USA), 320 pp.

CBD (2010): Convention of Biological Diversity – www.cbd.int/2010.

CECCOLINI, L. (2002): The homegardens of Soqotra island, Yemen: an example of agroforestry approach to multiple land-use in an isolated location. – Agroforestry Systems 56: 107-115.

CERNY, V., L. PEREIRA, M. KUJANOVA, A. VAOIKOVA, M. HAJEK, M. MORRIS, & C. MULLIGAN (2009): Out of Arabia-The Settlement of Island Soqotra as Revealed by Mitochondrial and Y Chromosome Genetic Diversity. – American Journal of Physical Anthropology 138: 439-447.

CHEKE, A. & J. HUME (2008): Lost land of the Dodo: an ecological history of the Mascarene Islands. – T&AD Poyser, London, 464 pp.

CHEUNG, C. & L. DEVANTIER (2006): Socotra – A natural history of the islands and their people. In: K. VAN DAMME (Ed.), Odyssey Books and Guides, Airphoto International Ltd., Hong Kong, 408 pp.

CHIBA, S., I. OKOCHI, T. OHBAYASHI, D. MIURA, H. MORI, K. KIMURA & S. WADA (2009): Effects of habitat history and extinction selectivity on species-richness patterns of an island land snail fauna. – Journal of Biogeography 36: 1913-1922.

CHRISTIE, S. (2005): Socotra's Road to Ruin. – Geographical 77: 60-64.

CHRISTOPHE, A. (2005): Socotra – the lost island. – Cactus & Co. Libri, 64 pp.

CLOUT, C. R. & M. N. VEITCH (2002): Turning the tide: the eradication of invasive species. – Proceedings of the International Conference on Eradication of Island Invasives. Occasional Paper of the IUCN Species Survival Commission 27. IUCN SSC Invasive Specialist Group, IUCN, Gland (Switzerland) & Cambridge (UK), 414 pp.

COBLENTZ, B. E. (1978): The effects of feral goats (*Capra hircus*) on island ecosystems. – Biological Conservation 13: 279-286.

COLLINGWOOD, C. A., H. POHL, R. GÜSTEN, W. WRANIK & A. VAN HARTEN (2004): The ants (Insecta: Hymenoptera: Formicidae) of the Socotra Archipelago. – Fauna of Arabia: 20: 473-495.

COPPOIS, G. (1995): Threatened galapagos bulimulid land snails: an update. In: E. A. KAY (Ed.), The conservation of molluscs. – Proceedings of a Symposium held at the 9th International Malacological Congress, Edinburgh, Scotland, 1986. p. 8-11. – IUCN Publications, Gland (Switzerland).

CRONK, Q. C. B. (1992): Relict floras of Atlantic islands: patterns assessed. – Biological Journal of the Linnean Society 46: 91-103.

CRONK, Q. C. B. (1997): Islands: stability, diversity, conservation. – Biodiversity and Conservation 6: 477–493.

DA FONSECA, G. A. B., R. A. MITTERMEIER & C. G. MITTERMEIER (2006): Conservation of island biodiversity: Importance, challenges and opportunities. – Centre for Applied Biodiversity Science. A Conservation International Publication, 16 pp.

DAVEY, S. & M. SCHLOSSMAN (2007): Unforgettable islands to escape to before you die. – BBC Books, Ebury Press (United Kingdom), 256 pp.

DAVIES, R. G., C. D. L. ORME, V. OLSON, G. H. THOMAS, S. G. ROSS, T.-S. DING, P. C. RASMUSSEN, A. J. STATTERSFIELD, A. J. STATTERSFIELD, P. M. BENNETT, T. M. BLACKBURN, I. P. F. OWENS & K. J. GASTON (2006): Human impacts and the global distribution of extinction risk. – Proceedings of the Royal Society B 273: 2127-2133.

DE GEEST, P., E. KEPPENS, S. VERHEYDEN, H. CHENG & L. EDWARDS (2006): High-resolution Holocene speleothem records from Soqotra Island, Yemen as a tool for Indian Ocean climate reconstruction. – Karst Waters Institute Special Publication 10: Archives of Climate Change in Karst: 103-104.

DEIDUN, A. (2010): Challenges to the conservation of biodiversity on small islands: the case of the Maltese Islands. – International Journal of Arts and Sciences 3: 175-187.

DESENDER, K., L. BAERT, J.-P. MAELFAIT & P. VERDYCK (1999): Conservation on Volcan Alcedo (Galapagos): terrestrial invertebrates and the impact of introduced feral goats. – Biological Conservation 87: 303-310.

DEVANTIER, L., G. DE'ATH, R. KLAUS, S. AL-MOGHRABI, M. ABDULAZIZ, G.B. REINICKE & C. CHEUNG (2004): Reef-building corals and coral communities of the Socotra Archipelago, a zoogeographic 'crossroads' in the Arabian Sea. – Fauna of Arabia 20: 117-168.

DIAMOND, J.M. (1984): 'Normal' extinctions of isolated populations. p. 191-246. In: M. H. NITECKI (Ed.), Extinctions. – The University of Chicago Press, Chicago.

DUMONT, H. J. & W. SCHNEIDER (1998): Checklist of the dragonflies and damselflies of Soqotra Island (Insecta: Odonata). P. 219-231. In: H. J. DUMONT (Ed.), Soqotra: Proceedings of the First International Symposium on Soqotra Island: Present & Future. – United Nations Publications, New York.

DVORAK, M., H. VARGAS, B. FESSL & S. TEBBICH (2004): On the verge of extinction: a survey of the mangrove finch Cactospiza heliobates and its habitat on the Galápagos Islands. – Oryx 38: 171-179.

DYKSTERHUIS, E. J. (1949): Condition and management of range land based on quantitative ecology. – Journal of Range Management 2: 104-115.

ELIE, S. (2008): The waning of Soqotra's pastoral community: political incorporation as social transformation. – Human Organization 67: 335-345.

ELIE, S. (2009): State-Community Relations in Yemen: Soqotra's Historical Formation as a Sub-National Polity. – History and Anthropology 20: 363-393.

ELTON, C. S. (1958): The ecology of invasions by animals and plants. – Methuen, London, 181 pp.

EVANS-ILLIDGE, E. (2006): National Sovereignity, 'green mining' and the UN Convention of Biodiversity. p. 322-323. In: C. CHEUNG. & L. DEVANTIER (2006), Socotra – A natural history of the islands and their people. K. VAN DAMME (Ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.

EXTOXNET (1996): Temephos. Extension Toxicology Network Pesticide Information Profiles. Oregon State University. – http://extoxnet.orst.edu/pips/temephos.htm.

FINDLAY, C. S. & J. BOURDAGES (2000): Response time of wetland biodiversity to road construction on adjacent lands. – Conservation Biology 14: 86-94.

FLEITMANN, D., A. MATTER, S.J. BURNS, A. AL-SUBBARY & M.A. AL-AOWAH (2004):Geology and Quaternary climate history of Socotra. – Fauna of Arabia 20: 27-44.

FONSECA, C. R. (2009): The silent mass extinction of insect herbivores in biodiversity hotspots. – Conservation Biology 23: 1507-1515

FORBES, H. O. (1903) (Ed.): The natural history of Sokotra and Abd-el-Kuri. – Special Bulletin of the Liverpool Museums, Henry Young & Sons, London, 598 pp.

FORDHAM, D. A. & B. W. BROOK (2010): Why tropical island endemics are susceptible to global change. – Biodiversity and Conservation 19: 329-342.

FRANKHAM, R. (1997): Do island populations have less genetic variation than mainland populations? – Heredity 78: 311-327.

FRANCISCO-ORTEGA, J., A. SANTOS-GUERRA, S.-C. KIM & D. J. CRAWFORD (2000): Plant genetic diversity in the. Canary Islands: A conservation perspective. – American Journal of Botany 87: 909-919.

FRENCH, J. R. & H. BURNINGHAM (2009): Coastal geomorphology: trends and challenges. –Progress in Physical Geography 33: 117-129.

FRITTS, T. H. & G. H. RODDA (1998): The role of introduced species in the degradation of island ecosystems: A case history of Guam. – Annual Review of Ecology and Systematics 29: 113-140.

GERLACH, J. (2004): Giant Tortoises of the Indian Ocean. The genus *Dipsochelys* inhabiting the Seychelles Islands and the extinct giants of Madagascar and the Mascarenes. – Edition Chimaira, Frankfurt am Main, 207 pp.

GILLESPIE, R. G. & D. A. CLAGUE (2009): Encyclopedia of Islands. – University of California Press, Berkeley and Los Angeles, California, 1074 pp.

GLANDER, A. (2009): Soqotra revisited. – Yemen Times, 12.08.2009. www.yementimes.com/DefaultDET.aspx?i=1245&p=report&a=1.

GOODENOUGH, A. E. (2010): Are the ecological impacts of alien species misrepresented? A review of the “native good, alien bad” philosophy. – Community Ecology 11: 13-21.

GOSLINER, T. M. (2009): Galápagos Islands, Biology. p. 357-367. In: R. G. GILLESPIE & D.A. CLAGUE (Eds), Encyclopedia of Islands. – University of California Press, Berkeley and Los Angeles, California.

GÖSSLING, S. (2003): Tourism and development in tropical islands: Political ecology perspectives. p. 1–37. In: S. GÖSSLING (Ed.), Tourism and development in tropical islands: Political ecology perspectives. – Edward Elgar Publishing, UK, 297 pp.

GRANT, P. R., B. R. GRANT, K. PETREN & L. F. KELLER (2005): Extinction behind our backs: the possible fate of one of the Darwin’s finch species on Isla Floreana, Galápagos. – Biological Conservation 122: 499-503.

GROOM, N. (1981): Frankincense and myrrh: a study of the Arabian incense trade. – London: Longman, 285 pp.

GROOMBRIDGE, B. (1992): Global biodiversity: status of the earth’s living resources. A report compiled by the World Conservation Monitoring Centre. – Chapman & Hall, London, 585 pp.

GWYNNE, M. D. (1967): The possible origin of the dwarf cattle of Socotra. – The Geographical Journal 133: 39-42.

HABROVA, H., Z. CERMAK & J. PAVLIS (2009): Dragon’s blood tree – Threatened by overmaturity, not by extinction: Dynamics of a *Dracaena cinnabari* woodland in the mountains of Soqotra. – Biological Conservation 142: 772-778.

HUGHES, M., P. M. HOLLINGSWORTH & A. MILLER (2003): Population genetic structure in the endemic *Begonia* of the Socotra archipelago. – Biological Conservation 113: 277-284.

HUMPHRIES, S. E., R. H. GROVES, D. S. MITCHELL, G. M. HALLEGRAEFF & J. CLARK (1991): Plant Invasions: The Incidence of Environmental Weeds in Australia. – Australian National Parks and Wildlife Service, Canberra.188 pp.

IUCN (2000): Guidelines for the prevention of biodiversity loss due to biological invasion. IUCN – The World Conservation Union, Gland (Switzerland), 21 pp.

IUCN (2008): World Heritage Nomination – IUCN Technical Evaluation – Socotra Archipelago (Yemen). – IUCN Evaluation Report 1263, May 2008, 12 pp.

JÄGER, H., I. KOWARIK & A. TYE (2009): Destruction without extinction: long-term impacts of an invasive tree species on Galápagos highland vegetation. – Journal of Ecology 97: 1252-1263.

JOGER, U. (2000): The reptile fauna of the Soqotra Archipelago. In: G. RHEINWALD (Ed.), Isolated vertebrate communities in the tropics. – Bonn Zoological Monographs 46: 337-350.

KEMP, J. M. (1998): Zoogeography of the coral reef fishes of the Socotra Archipelago. –Journal of Biogeography 25: 919-933.

KENNEDY, T. A., S. NAEEM, K. M. HOWE, J. M. H. KNOPS, D. TILMAN & P. REICH (2002): Biodiversity as a barrier to ecological invasion. – Nature 417: 636-638.

KERR, R. S. & F. A. S. EDIN (1811-1824): General history and collection of voyages and travels, arranged in systematic order: forming a complete history of the origin and progress of navigation, discovery, and commerce, by sea and land, from the earliest ages to the present time. – Ramsay, Edinburgh, 18 vols.

KESSLER, C. C. (2002): Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands. p. 132-140. In: C. R. VEITCH & M. N. CLOUT (Eds), Turning the tide: the eradication of invasive species. Proceedings of the International Conference on Eradication of Island Invasives. – Occasional Paper of the IUCN Species Survival Commission 27. IUCN SSC Invasive Specialist Group, IUCN, Gland (Switzerland) and Cambridge (UK).

KLAUS, R., D. A. JONES, J. TURNER, N. SIMOES & D. VOUSDEN (2003): Integrated marine and coastal management: a strategy for the conservation and sustainable use of marine biological resources in the Socotra Archipelago, Yemen. – Journal of Arid Environments 54: 71-80.

KLEIN, N. (2005): The global integration of Socotra – Challenge and opportunity for conservation and development. Lessons Learned Report from Socotra Field Learning Site, Yemen. – IUCN WCPA World Conservation Union World Commission on Protected Areas: Ecosystems, Protected Areas and People Project.

KOSSMAT, F. (1907): Geologie der Inseln Sokotra, Semha und Abd El Kuri. – Denkschriften der Kaiserlichen Akademie der Wissenschaften Wien, mathematisch-naturwissenschaftliche Klasse 71: 1-62.

KRUPP, F., U. ZAJONZ & F. N. S. KHAMIS (2006): Socotra's freshwater and estuarine fishes. p. 136. In: C. CHEUNG. & L. DEVANTIER. Socotra: A natural history of the islands and their people (K. VAN DAMME, Ed.). – Odyssey Press, Hong Kong.

LEROY, S., P. GENTE, M. FOURNIER, E. D'ACREMONT, P. PATRIAT, M. O. BESLIER, N. BELLAHSEN, M. MAIA, A. BLAIS, J. PERROT, A. AL-KATHIRI, S. MERKOURIEV, J. M. FLEURY, P. Y. RUELLAN, C. LEPVRIER & P. HUCHON (2004): From rifting to spreading in the eastern Gulf of Aden: a geophysical survey of a young ocean basin from margin to margin. – Terra Nova 16: 185-192.

LODÉ, J. (2010): Succulent plants of Socotra. A Cactus adventures handbook. – Cactus Adventures Intl., Spain, 60 pp.

LONSDALE, W. M. (1999): Global patterns of plant invasions and the concept of invasibility. –Ecology 80: 1522-1536.

LORETZ, R. & F. MARTIN (2006): SWM Masterplan for Socotra, Yemen. – NSD-U Thesis, University of Applied Sciences Northwestern Switzerland, 23 pp.

LOWE, S. J., M. BROWNE, S. BOUDJELAS & M. DE POORTER (2000): 100 of the world's worst invasive alien species: A selection from the Global Invasive Species Database. – Auckland, New Zealand, IUCN/SSC Invasive Species Specialist Group (ISSG). 12 pp (available at www.issg.org; see also www.issg.org/database/species/search.asp?st=100ss).

MACLACHLAN, R. (1903): The Dragon-Flies of Sokotra. p. 398-403. In: H. O. FORBES (Ed.), The natural history of Sokotra and Abd-el-Kuri. – Special Bulletin of the Liverpool Museums. Henry Young & Sons, London. [Note: confusing reference. The Dragonfly section in FORBES (1903) is part of a section entitled: "*White Ants, Dragon-Flies, and Ant-Lions*" by H. O. FORBES,R. MCLACHLAN & W. F. KIRBY. On p. 396, the editor notes that "*Insecta: Neuroptera: Amphibiotica*" were written by R. MCLACHLAN (pp. 398-403), Pseudo-neuroptera by H.O. FORBES (p. 397) and Planipennia by W.F. KIRBY (p.404-405); hence the author of the Dragonfly section is only R. MCLACHLAN; plates of the dragonflies are on p. 406-409].

MALANSON, G. P. (2008). Extinction debt: origins, developments, and applications of a biogeographical trope. – Progress in Physical Geography 32: 277-291.

MANGLA, S., INDERJIT & R.M. CALLAWAY (2008): Exotic invasive plant accumulates native soil pathogens which inhibit native plants. – Journal of Ecology 96: 58-67.

MARCHAT, L. (2008): Socotra Island threatened. – www.socotra.tripod.com/danger-english.

MARTIN, J. L. (2009): Are the IUCN standard home-range thresholds for species a good indicator to prioritize conservation urgency in small islands? A case study in the Canary Islands (Spain). – Journal for Nature Conservation 17: 87-98.

MAYER, A.-N. (2009): Probleme touristischer Entwicklung auf der Insel Soqotra. Vom Missverständnis "Ökotourismus" zu nachhaltigem Tourismus. – Jemen Studien 19: 1-152.

MCARTHUR, R. H. & E. O. WILSON (1967): The theory of island biogeography. – Princeton, New Jersey, Princeton University Press, Maple Press Company, 203 pp.

MCKINNEY, M.L. (1997): Extinction vulnerability and selectivity: combining ecological and paleontological views. – Annual Review of Ecology and Systematics 28: 495-516.

MIES, B. A. (2001): Flora und Vegetationsökologie der Insel Soqotra. – Essener Ökologische Schriften 15: 1-270.

MILLER, A. & M. MORRIS (2004): Ethnoflora of the Soqotra Archipelago. – Royal Botanical Gardens of Edinburgh, Edinburgh, 759 pp.

MILTON, S. J., W. R. J. DEAN, M. A. DU PLESSIS & W. R. SIEGFRIED (1994): A conceptual model of arid rangeland degradation. – Bioscience 44: 70-76.

MINEAU, P. (2005): A review and analysis of study endpoints relevant to the assessment of "long term" pesticide toxicity in avian and mammalian wildlife. – Ecotoxicology 14: 775-799.

MORRIS, M. (2002): Manual of traditional land use in the Soqotra Archipelago. – GEF/YEM/96/G32. Royal Botanic Garden Edinburgh, unpubl. report, 540 pp.

MOTHANA, R. A. A., R. MENTEL, C. REISS & U. LINDEQUIST (2006): Phytochemical screening and antiviral activity of some medicinal plants from the Island Soqotra. – Phytotherapy Research 20: 298-302.

MOTHANA, R.A.A., U. LINDEQUIST, R. GRUENERT & P.J. BEDNARSKI (2009): Studies of the in vitro anticancer, antimicrobial and antioxidant potentials of selected Yemeni medicinal plants from the island. – BMC Complementary and Alternative Medicine 9:7.

MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. DA FONSECA & J. KENT (2000): Biodiversity hotspots for conservation priorities. – Nature 403: 853-858.

NAEEM, S., J. M. H. KNOPS, D. TILMAN, K. M. HOWE, T. KENNEDY & S. GALE (2000): Plant diversity increases resistance to invasion in the absence of covarying extrinsic factors. – Oikos 91: 97-108.

NEUBERT, E. (2005): The continental malacofauna of Arabia and adjacent areas, IV. Revision of the family Cerastidae in the Soqotran Archipelago, I: The genus *Passamaella* L. Pfeiffer 1877, with description of a new genus and species (Gastropoda: Pulmonata: Cerastidae). – Archiv für Molluskenkunde 134: 1-21.

NEUBERT, E. (2006): Land snails of the Socotra Archipelago. p. 125-127. In: C. CHEUNG & L. DEVANTIER (2006), Socotra – A Natural History of the Islands and their People (K. VAN DAMME, ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.

NEUBERT, E. (2009): The continental malacofauna of Arabia and adjacent areas: VI. Pomatiidae of Arabia, Socotra and Northeast Africa, with descriptions of new genera and species (Gastropoda: Caenogastropoda: Littorinoidea). – Fauna of Arabia 24: 47-127.

NMCP (2003): National Malaria Control Programme in Yemen Progress Report 2003. – WHO Country Reports. www.emro.who.int.

NOVACEK, M. (2009): Terra: our 100-million-year-old ecosystem and the threats that now put it at risk. – Farrar, Strauss & Giroux, NY, USA. 451 pp.

OLSON, S. L. & H. F. JAMES (1982): Fossil birds from the Hawaiian Islands: evidence for wholesale extinction by man before Western contact. – Science 217: 633-635.

OLSON, S. L. (1989): Extinction on islands: Man as a catastrophe. p. 50-53. In: D. WESTER & M. C. PEARL (Eds), Conservation for the twenty-first century. – P. Oxford University Press, Oxford.

PATIL, C., R. PAUL & M. MALKANNA (2008): Neuroendocrine regulation and pesticidal impact on the freshwater crab, *Barytelphusa guerini* (H. Milne Edwards). – Journal of Environmental Biology 29: 887-892.

PAULAY, G. (1994): Biodiversity on oceanic islands: its origin and extinction. – American Zoologist 34: 134-144.

PIETSCH, D. & M. MORRIS (2010): Modern and ancient knowledge of conserving soils in Socotra Island, Yemen. p. 374-386. In: P. ZDRULI et al. (Eds), Land degradation and desertification: Assessment, mitigation and remediation. – Springer Publishing, Dordrecht.

PIMM, S. L., G. J. RUSSELL, J. L. GITTLEMAN & T. M. BROOKS (1995): The future of biodiversity. – Science 269: 347-350.

PORTER, R. F. & A. S. SULEIMAN (in prep.) The population and distribution of the breeding birds of Socotra. – BirdLife International/SCDP.

PORTER, R. F. & F. STONE (1996): An introduction to Socotra and its birds. – Sandgrouse 17: 73-80.

PORTER, R. F. & G. M. KIRWAN (2010): Studies of Socotran birds VI. The taxonomic status of the Socotran Buzzard. – Bulletin of the British Ornithologists' Club, 130: 116-131.

PURVIS, A., J.L., GITTLEMAN, G. COWLISHAW & G.M. MACE (2000): Predicting extinction risk in declining species. – Proceedings of the Royal Society of London, B 267: 1947–1952.

PURVIS, A., P.-M. AGAPOW, J. L. GITTLEMAN & G. M. MACE (2000): Nonrandom extinction and the loss of evolutionary history. – Science 288: 328-330.

RASELIMANANA, A. P. (2003): Trade in reptiles and amphibians. p. 1564-1568. In: S. M. GOODMAN & J. P. BENSTEAD (Eds), The natural history of Madagascar. – The University of Chicago Press, Chicago & London.

RÉGNIER, C., B. FONTAINE & P. BOUCHET (2008): Not knowing, not recording, not listing: Numerous unnoticed mollusk extinctions. – Conservation Biology 23: 1214-1221.

RESH, V. H. & J. P. RESH (2009): Islands in popular culture. p. 761-765. In: R. G. GILLESPIE & D. A. CLAGUE (Eds), Encyclopedia of Islands. – University of California Press, Berkeley & Los Angeles (California).

RICHARDSON, D. M., P. PYSEK, M. REJMANEK, M. G. BARFOUR, F. D. PANETTA & C. J. WEST (2000): Naturalization and invasion of alien plants: Concepts and definitions. – Biodiversity and Distributions 6: 93-107.

RICKETTS, T. H., E. DINERSTEIN, T. BOUCHER, T. M. BROOKS, S. H. M. BUTCHART, M. HOFFMANN, J. F. LAMOREUX, J. MORRISON, M. PARR, J. D. PILGRIM, A. S. L. RODRIGUES, W. S. SECHREST, G. E. WALLACE, K. BERLIN, J. BIELBY, N. D. BURGESS, D. R. CHURCH, N. COX, D. KNOX, C. LOUCKS, G. W. LUCK, L. L. MASTER, R. MOORE, R. NAIDOO, R. RIDGELY, G. E. SCHATZ, G. SHIRE, H. STRAND, W. WETTENGEL & E. WIKRAMANAYAKE (2005): Pinpointing and preventing imminent extinctions. – Proceedings of the National Academy of Sciences 102: 18497–18501.

RISERVATO, E., C. GRIECO, F. PELLA, R. SINDACO, F. PUPIN, A.S. SULEIMAN & M. FASOLA (2010): A contribution to the knowledge of the odonatofauna of the Socotra Archipelago (Yemen). – Zoology in the Middle East 50: 101-106.

ROESSLER, H. & W. WRANIK (1999): Beiträge zur Herpetologie der Republik Jemen. 5. Drei neue Gecko-Arten vom Sokotra-Archipel (Reptilia: Sauria: Gekkonidae). – Zoologische Abhandlungen des Staatlichen Museums für Tierkunde Dresden 21: 113-132.

ROESSLER, H. & W. WRANIK (2004): A key and annotated checklist to the reptiles of the Socotra Archipelago. – Fauna of Arabia 20: 505-534.

ROYLE, S.A. (2001): A geography of islands: small island insularity. – Routledge: London. 239 pp.

SAX, D. F. & S. D. GAINES (2008): Species invasions and extinction: The future of native biodiversity on islands. – Proceedings of the National Academy of Sciences 105: 11490-11497.
SCHOLTE, P. & P. DE GEEST (2010): The climate of Socotra Island (Yemen): a first-time assessment of the timing of the monsoon wind reversal and its influence on precipitation and vegetation patterns. – Journal of Arid Environments 74: 1507-1515.
SCHOLTE, P., A. OKAISHI & A. SAED SULEIMAN (in press). When conservation precedes development: experience with conservation during the opening up of Socotra, the Island of the Dragon's Blood (Yemen). – Oryx, *in press.*
SEDOV, A. V., V. V. NAUMKIN, Y. A. VINOGRADOV, V. A. ZHUKOV, E. M. VINOGRADOVA, E. A. KURKINA & A. V. SARABJEV (2009): Preliminary report of the Russian Interdisciplinary Mission to the Republic of Yemen submitted to the general organization of antiquities and museums (G.O.A.M.). – Moscow, 19 pp.
SENAN A. S., R. K SOMASHEKAR F. ATTORRE, N. TALEB & F. BRUNO (2010): Exotic species of Socotra Island, Yemen: a first contribution. – Annali di Botanica (Roma), 2010: 85-97.
SINCLAIR, A. R. E. & J. M. FRYXELL (1985): The Sahel of Africa: Ecology of a Disaster. – Canadian Journal of Zoology 63: 987-94.
SOHLMAN, E. (2004): A bid to save the 'Galápagos of the Indian Ocean'. – Science 303: 1753.
SOKOLOW, S. (2009): Effects of a changing climate on the dynamics of coral infectious disease: a review of the evidence. – Diseases of Aquatic Organisms 87: 5-18.
SORIA, M. C., M. R. GARDENER & A. TYE (2009): Eradication of potentially invasive plants with limited distributions in the Galapagos Islands. P. 287-292. In: C. R. VEITCH & M. N. CLOUT (Eds), Turning the tide: the eradication of invasive species. Proceedings of the International Conference on Eradication of Island Invasives. – Occasional Paper of the IUCN Species Survival Commission 27. IUCN SSC Invasive Specialist Group, IUCN, Gland (Switzerland) & Cambridge (United Kingdom).
STANTON, D. (2009): Opportunistic wildlife trade in Yemen. – Wildlife Middle East 4: 7.
STEVENSON, M. J. (2001): Galapagos Islands: Managing introduced species in an endangered ecosystem. – Yale School of Forestry & Environmental Studies Bulletin 105: 83-100.
STRAUCH, I. (2006): Socotra – the western-most outpost of ancient Indian scripts. P. 231. In: C. CHEUNG & L. DEVANTIER (2006), Socotra – a natural history of the islands and their people. (K. VAN DAMME, ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.
SULEIMAN, A. S., G. G. MEIER & P. J. HAVERSON (2010): Confirmed eradication of the House Crow from Socotra Island, Republic of Yemen. – Wildlife Middle East 4: 4.
TAITI, S. & I. CHECCUCCI (2009): New species and records of terrestrial Isopoda (Crustacea, Onscidea) from Socotra Island, Yemen. – Zookeys 31: 73-103.
TAITI, S. & F. FERRARA (2004): The terrestrial Isopoda (Crustacea: Oniscidea) of the Socotra Archipelago. – Fauna of Arabia 20: 211-325.
THIEME, M. L., R. ABELL, M. L. J. STIASSNY, P. SKELTON, N. BURGESS, B. LEHNER, E. DINERSTEIN, D. OLSON, G. TEUGELS & A. KAMDEM-TOHAN (2005): Freshwater ecoregions of Africa and Madagascar. A conservation assessment. WWF Ecoregion Assessment. – Island Press, 483 pp.
TILMAN, D., R. M. MAY, C. L. LEHMAN & M. A. NOWAK (1994): Habitat destruction and the extinction debt. – Nature 371: 65-66.
TOWNS, D. R., I. A. E. ATKINSON & C. H. DAUGHERTY (2006): Have the harmful effects of introduced rats on islands been exaggerated. – Biological Invasions 8: 863-891.
TRACOL, Y., J. R. GUTIÉRREZ & F. A. SQUEO (2011): Plant Area Index and microclimate underneath shrub species from a Chilean semiarid community. – Journal of Arid Environments 75: 1-6.
TRIANTIS, K. A., P. A. V. BORGES, R. J. LADLE, J. HORTAL, P. CARDOSO, C. GASPAR, F. DINIS, E. MENDONCA, L. M. A. SILVEIRA, R. GABRIEL, C. MELO, A. M. C. SANTOS, I. R. AMORIM, S. P. RIBEIRO, A. R. M. SERRANO, J. A. QUARTAU & P. J. WHITTAKER (2010): Extinction debt on oceanic islands. – Ecography 33: 285-294.
TROMBULAK, S. C. & C. A. FRISSELL (2000): Review of ecological effects of roads on terrestrial and aquatic communities. – Conservation Biology 14: 18-30.

UNEP (2005): After the tsunami: rapid environmental assessment. – Report produced by the UNEP Division of Communications and Public Information. UNEP Publications, 145 pp.

UNEP/WCMC (2008a): Socotra Archipelago, Yemen. UNESCO Fact Sheet. World Heritage Sites – Protected Areas and World Heritage. United Nations Environment Programme & World Conservation Monitoring Centre, 11 pp. www.unep-wcmc.org/sites/wh/pdf/Socotra%20revised.pdf.

UNEP/WCMC (2008b): Galápagos Islands National Park and Marine Reserve Ecuador. UNESCO Fact Sheet World Heritage Sites – Protected Areas and World Heritage. United Nations Environment Programme & World Conservation Monitoring Centre, 15 pp. www.unep-wcmc.org/sites/wh/pdf/Galapagos.pdf.

VAN DAMME, K. & P. DE GEEST (2006): Case Study 2. Diksam Road and Eriosh's unique archaeology and biology. P. 350. In: C. CHEUNG & L. DEVANTIER, Socotra – a natural history of the islands and their people (K. VAN DAMME, ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.

VAN DAMME, K. (2009): Socotra Archipelago. P. 846-851. In: R. G. GILLESPIE & D.A. CLAGUE (Eds), Encyclopedia of Islands. – University of California Press, Berkeley & Los Angeles (California).

VAN DER DUIM, R. & J. CAALDERS (2002): Biodiversity and Tourism: Impacts and Interventions. – Annals of Tourism Research 29: 743-761.

VELLEND, M., K. VERHEYEN, H. JACQUEMYN, A. KOLB, H. VAN CALSTER, G. PETERKEN & M. HERMY (2006): Extinction debt of forest plants persist for more than a century following habitat fragmentation. – Ecology 87: 542-548.

VITOUSEK, P. M., C. M. D'ANTONIO, L. L. LOOPE, M. REJMANEK & R. WESTBROOKS (1997): Introduced species: a significant component of human-caused global change. – New Zealand Journal of Ecology 21: 1-16.

WARD, D. (2009): The Biology of Deserts. The Biology of Habitats Series. – Oxford University Press, New York, 339 pp.

WATKINS, G. & F. CRUZ (2007): Galápagos at aisk: A socioeconomic analysis of the situation in the archipelago. – Puerto Ayora (Ecuador), Charles Darwin Foundation, 19 pp.

WATTS, D. (1993): Long-term environmental influences on development in islands of the Lesser Antilles. – Scottish Geographical Magazine 109: 133-141.

WEEKS, L., M. MORRIS, B. MCCALL & K. AL-ZUBAIRY (2002): A recent archaeological survey on Soqotra. Report on the preliminary expedition season, January 5th–February 2nd 2001. – Arabic archaeology and epigraphy 13: 95-125.

WHITTAKER, R. (1998): Island biogeography. Ecology, evolution, and conservation. – Oxford University Press, New York, 285 pp.

WHO (2005): World Malaria Report 2005. WHO/HTM/MAL/2005.1102. World Health Organisation and Unicef, 294 pp.

WIKELSKI, M., J. FOUFOPOULOS, H. VARGAS & H. SNELL (2004): Galápagos birds and disease: invasion pathogens as threats for island species. – Ecology and Society 9: 5.

WIRTH, T., P. OGGIER & B. BAUR (1999): Effect of road on dispersal and genetic population structure in the land snail *Helicella itala*. – Zeitschrift für Ökologie und Naturschutz 8: 23-29.

WOODROFFE, R. & J. R. GINSBERG (1998): Edge effects and the extinction of populations inside protected areas. – Science 280: 2126-2128.

WRANIK, W. (1998): Faunistic notes on Soqotra Island. P. 135-198. In: H. J. DUMONT (Ed.), Soqotra: Proceedings of the First International Symposium on Soqotra Island: Present & Future. – United Nations Publications, New York.

WRANIK, W. (2003): Fauna of the Socotra Archipelago. Field Guide. – Universität Rostock (Germany), 542 pp.

ZAJONZ, U., M. KHALAF & F. KRUPP (2000): Costal fish assemblages of the Socotra Archipelago. p. 127-170. In: M. APEL & K. I. HARIRI (Eds), Conservation and sustainable use of biodiversity of the Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Progress Report of Phase III. – Senckenberg Research Institute, Frankfurt a.M.

ZANDRI, E. (2006): Case study 1. Hadiboh–Qalansiyah road and Ditwah Lagoon. p. 348-349. In: C. CHEUNG & L. DEVANTIER, Socotra – a natural history of the islands and their people (K. VAN DAMME, ed.). – Odyssey Books and Guides, Airphoto International Ltd., Hong Kong.

ZAVELATA, E.S., R.H. HOBBS & H.A. MOONEY (2001): Viewing invasive species removal in a whole-organism context. – Trends in Ecology and Evolution 16: 454-459.

ZHANG, K., B.C. DOUGLAS & S. P. LEATHERMAN (2004): Global Warming and Coastal Erosion. – Climate Change 64: 41-58.

ZIMMERMAN, H. G. & M. P. S. Y. CUEN (2004): Prickly pear, the other face of cactus pear. – Acta Horticulturae 728: 289-295.

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