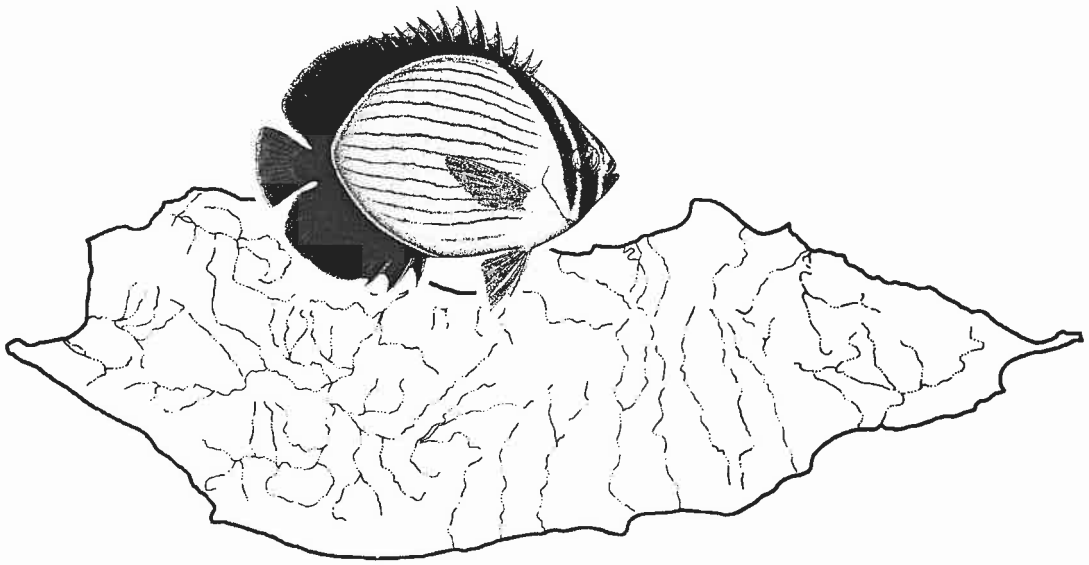
Conservation and Sustainable Use of Biodiversity of Socotra Archipelago

Marine Habitat, Biodiversity and Fisheries Surveys and Management



Final Overall Report Including Final Statement of Expenditures

submitted by

Senckenberg Research Institute and Natural History Museum, Frankfurt a.M.
Hariri & Associates: Environmental & Natural Resources Management Consultants, Sana'a
University of Jordan and Yarmouk University: Marine Science Station, Aqaba
Red Sea University: Faculty of Marine Sciences and Fisheries, Port Sudan

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YEM/96/G32 – Conservation and Sustainable Use of Biodiversity of Socotra Archipelago

Marine Habitat, Biodiversity and Fisheries Consultancy Services

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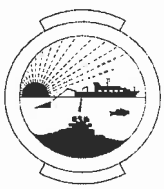

FINAL OVERALL REPORT INCLUDING FINAL STATEMENT OF EXPENDITURES

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Final Overall Report

Introduction

In December 1997, a contract was signed between the United Nations Office for Project Services (UNOPS) and the Senckenberg Research Institute (SRI) for the execution of "Marine Habitat, Biodiversity and Fisheries Surveys and Management", which formed a component of the GEF-funded project "Conservation and Sustainable Use of Biodiversity of Socotra Archipelago". The SRI executed the project component together with three partners: Hariri & Associates, Environmental and Natural Resources Management Consultants, Sana'a, Yemen; University of Jordan and Yarmouk University, Marine Science Station, Aqaba, Jordan; and the Red Sea University, Faculty of Marine Sciences and Fisheries, Port Sudan, Sudan. The date for the completion of the surveys had been estimated at 31 July 2000. However, there were considerable delays for reasons which are beyond the control of the SRI and its partners. These reasons include:

- A security incident in the Socotra Archipelago and a subsequent ban for international project personnel to travel to the area delayed the inception of the project by about one year.
- Because of the resulting change in schedule, some of the project personnel were no longer available and replacements had to be identified. Advice by a European Government to its nationals not to travel to Yemen resulted in the loss of project personnel. It proved particularly difficult and time-consuming to replace the project's international fisheries biologist.
- One of the SRI's assumptions, when submitting its technical proposal, had been the availability of a research vessel as working platform throughout the duration of the project. Contrary to the original plans, the project after its inception decided against the procurement of a research vessel, requiring the short-term hiring of boats. This resulted in less than ideal work conditions for most of the time and hence in further delays.
- Baseline information on habitats and biodiversity available during the formulation phase of the project was very fragmentary. The patchy distribution of marine habitats across the Archipelago and a much richer biodiversity than expected resulted in a much more complex task. This made data analyses more time-consuming than expected.

The following reports have been submitted (see Appendix for details):

• Inception Report	December 1997
• Final Report First Phase	August 1999
• Final Report Second Phase (including Training Manuals)	February 2000
• Progress Report Third Phase	September 2000
• Final Report Third Phase (including Fisheries Management Plan and Biotope Manual)	July 2002

In the following, a summary of project achievements as documented in these reports is given.

Marine Habitat, Biodiversity and Fisheries Surveys and Management – Summary of Achievements

This summary follows the sequence of Annex II of the contract.

1 Habitat Classification by Remote Sensing and Ground-Truth Surveys

Information on the distribution and spatial extent of marine habitats and communities is a fundamental requirement for conservation management of coastal ecosystems. Prior to the project, there was very little information available on the distribution of species and benthic communities around Socotra Archipelago. Their regional and global significance was insufficiently known. Not only is this information important for ecosystem management, but also for the protection of both individually threatened species and overall biodiversity through the conservation of the heterogeneity of habitats. Surveys were conducted to define a marine biotopes classification scheme and to map the extent of these biotopes to be used in the preparation of an integrated coastal management plan (KLAUS et al. 2002 a).

Marine environmental assessment is often confronted with insufficient baseline knowledge of widely distributed and often inaccessible critical marine habitats. Remote sensing is a valuable method of surveying and mapping extensive coastal and marine habitats. Hence, surveys were supported by marine satellite image processing, and a geographical information system (GIS) was designed to integrate the spatial data for the Socotra Archipelago. The GIS was created using MapInfo Professional and Vertical Mapper. Data layers were created or acquired and digitised from various historical and recent sources. Three archive satellite scenes were used: one Landsat 5 Thematic Mapper and two SPOT scenes. Image processing included atmospheric and geometric correction, and unsupervised classification. The enhancements applied to the image allowed for the identification of key coastal environmental features, such as coral reefs and seagrass beds, and hence for selection of localities to be investigated during the ground-truth surveys. A series of maps from satellite imagery was produced to illustrate marine biotopes for purposes of future ecological assessment, conservation management and sustainable development of the archipelago (KLAUS 1999).

As a next step, a ground-truth survey of the coastal and shallow subtidal zone was conducted. During this survey, the range of marine habitats and biotic assemblages around the archipelago was described. The survey utilised the unsupervised classification of the Landsat satellite images to identify different types of habitats and species communities. Littoral and subtidal rapid site assessments were conducted within pre-selected subsections of coast identifiable on the image, which appeared heterogeneous at the locality scale (10 km) and homogenous at the site scale (100 m). Assessments included recording of main physical attributes of the habitats and the key species present. Measurements of distribution and abundance used a semi-quantitative scale over approximately 100 m² areas. Each habitat type and community were documented by underwater and/or land photography. Surveys were also made of the positions of topographical features to ensure georeferencing of the imagery. An initial biotope classification incorporating seven littoral biotope complexes (coastal wadis, sand beach, rock platforms, cobble beaches, undercut cliffs, salt marshes, mangrove stands) and 25 subtidal biotopes (grouped into four major biotopes as clean mobile sand, seagrass, rock, and coral) was developed from the habitat and community descriptions. A photographic database of biotopes was assembled. The positions of 164 surveyed sites at which these biotopes were observed were used to conduct a supervised classification of the Landsat image. A series of 91 maps of the marine biotopes around the islands of Socotra, Darsa and Samha was produced. These biotope classifications formed the basis for the habitat, biodiversity and fisheries surveys (TURNER et al. 1999).

Biotopes are the smallest geographical units of the biosphere that can be delimited by convenient boundaries and are defined as the physical habitat together with its distinctive assemblage of conspicuous species. The biotope classification scheme developed for Socotra using multi-

variate statistical analysis of the survey data is hierarchical and identified six marine habitat groups, which subdivide into 23 biotope groups and 60 biotopes. The classification scheme is applicable across the different levels of the hierarchy, dependent on the appropriate spatial scale and the user's level of interest or technical ability. It is traceable from survey site level upwards and therefore can be extended to incorporate biotopes from different localities within a realm, a region or across ocean scales. Full details on the biotope classification were included in a separate document "Sublittoral and Littoral Biotope Manual for the Socotra Archipelago" (KLAUS et al. 2002 b).

2 Multidisciplinary Habitat and Biodiversity Surveys

Following the remote sensing and ground-truth surveys, detailed habitat and biodiversity surveys were conducted.

2.1 Intertidal Surveys

The initial intertidal rapid assessment survey covered 162 sites along the coastline of Socotra. Sites were surveyed at regular intervals, or where topography changed drastically. At each site the topography, ambient environmental parameters, abundance of flora and fauna and human impact were assessed and information was entered into a standardised "Site Information Sheet" and a "Key Species Presence-Absence Sheet". A classification of intertidal biotopes based on cluster analysis of the results of the rapid assessment showed a vast array of different types of beaches and coastal morphology. Almost every site sampled could be easily separated from the previous site based on a combination of factors. For each of the seven general biotope types (sand beaches, rock platforms, cobble beaches, mudflats, undercut cliffs, salt marshes and mangrove stands) a description was prepared, key species identified and data on distribution and frequency of occurrence collected.

Highest biodiversity was observed on rock platforms and cobble beaches, where numerous microhabitats (e.g. tide pools) enhance diversity of the biota. In general, these biotopes were in good condition and do not face immediate threats. Tar pollution was only observed at nine of 162 sites, and was concentrated almost exclusively on the north-east coast. Overall extent of contamination was generally low. There was no evidence of shore collecting of animals – apparently local people do not consume oysters or mussels.

Sand beaches are typically low in species diversity due to the mobility of the sediment, but close to Ras Qadamah large sabelliform reefs form a very diverse microhabitat. These reefs, however, have been partially destroyed to obtain bait.

The extent of mudflats, salt marshes and mangroves is limited on Socotra and mainly restricted to the khawr areas (estuaries). Even though these biotopes have a low species diversity, they are of high ecological and resource value as they have high primary production and thus host large numbers of individuals. These habitats face the most severe threats, since they are typically close to human settlements and already show certain signs of eutrophication (SIMÕES & JONES 2000).

In the "Sublittoral and Littoral Biotope Manual for the Socotra Archipelago" (KLAUS et al. 2000 b), intertidal biotopes throughout the island group are described in terms of the physical habitat, community types and characteristic species. The biotope descriptions are accompanied by photographs and maps of the defining sites.

2.1.1 Study of the Mangrove Ecosystems of Socotra

Prior to the GEF project, knowledge about the extent and distribution of mangroves in the Socotra Archipelago was very limited. During the surveys it became evident that mangroves are rare and of limited ecological importance. Only a single species, the black mangrove (*Avicennia*

marina), occurs in the archipelago. Some mangroves are practically terrestrial, making their classification and relation to the sea more difficult. Mangrove areas tend to cluster with mudflats.

The present condition of the Khawr Girmah mangrove area, both the seaside and the landward stands, is of concern. Most trees died recently. The rapid destruction of these habitats may have profound impacts on coastal morphology. The causes for the high mortality are not yet understood. Changes in the flow of freshwater to Khawr Girmah and irregular openings to the sea may have created adverse conditions for the mangroves resulting in their death. All other mangrove stands show signs of environmental stress, the one at Khawr Shu'ub probably being the best preserved one. Although it is only a fringing mangrove, one to two trees wide, it borders a lagoon and has some fauna associated with the pneumatophores and stems. The mangrove at Nit is by far the largest in extent of tree cover, but it is very poor in terms of marine life, as it is completely dry. Although the admiralty chart reports large areas of mangrove in the western part of the Nit Plain, the present survey found only few trees in this area, buried in fine sand and without pneumatophores. There is no tidal effect due to the dune system separating the mangrove stand from the sea. Khawr Shu'ub on the south-west coast, the most important area of live mangrove trees, is in direct contact with seawater, with a typical mangrove-associated biotic community, although at low abundance levels. The mangrove area is limited to trees fringing the margins of the khawr.

A proposed mangrove reforestation programme should focus on the north coast khawrs (especially Khawr Girmah) and the Nit Plain. It requires active participation of the local communities and should be preceded by a detailed study of the actual environmental conditions present at potential mangrove sites. Since tree growth rates are expected to be low and mortality high, the initial nursery capacity has to be high and capable of maintaining trees of different ages to enable restocking over several years (SIMÕES & JONES 2000).

2.2 Subtidal Surveys

A subtidal rapid assessment of about 400 sites around all islands of the archipelago was conducted in 1999 to estimate the extent of habitats and to identify target areas and indicator sites of special interest (i.e. high biodiversity, coral cover, structural complexity) for more intensive surveys. The data collected during these assessments were used to select sites for the biodiversity surveys (APEL 2000 a). Additionally, results of the ground-truth surveys (TURNER et al. 1999) and several other sublittoral surveys (e.g. DEVANTIER 2000, 2002; ZAJONZ et al. 2000; KLAUS et al. 2002 a, 2002 b) were used to compile an inventory of subtidal habitats and biota. To map the subtidal biotopes using supervised classification, the Landsat 7 ETM+ satellite images were subset to exclude the area beyond 5 km offshore, where the water is deeper than is mappable using visible multispectral remote sensing images. The images were further processed to correct for depth variation. The total area mapped was 2691 km². Of this mapped area, the class "open water > 20 m" occupied 2015 km² (75 %), whereas the total mapped area of sublittoral biotopes covered 677 km² (25 %).

Around Socotra Island, the habitat groups within the mappable depth range included the following categories, in order of abundance: bedrock (304 km², 45 %), corals (256 km², 38 %), sediments (65 km², 10 %), large rock boulders (36 km², 5 %), cobbles (14 km², 2 %) and small rock boulders (1 km², 0.2 %). The area of coral habitats incorporates the extensive areas of relict or fossil reef on the south coast as well as coral communities typical of the north and east coast (KLAUS et al. 2002 a). As is the case for intertidal areas, full details on the biotope classification are included in a separate document "Sublittoral and Littoral Biotope Manual for the Socotra Archipelago", where biotopes are described in terms of the physical habitat, community types and characteristic species (KLAUS et al. 2002 b).

The development of a biotope classification scheme, mapping these resources and their integration, together with other spatially referenced data such as the results of taxonomic surveys and monitoring data using the GIS, provides a valuable tool and basis for zoning and integrated coastal management (KLAUS et al. 2002 a).

2.3 Key Species and Biodiversity Surveys

Besides the assessment of habitats and species communities, key taxa were studied in more detail and biodiversity inventories produced for selected plant and animal groups.

2.3.1 Seaweed and Seagrass Biodiversity Survey

A study on the diversity and distribution of marine benthic macroalgae and seagrasses of Socotra resulted in a record of approximately 260 species. Intertidal seaweed communities were rare around the island, and were restricted to small patches on rock platforms or cliffs. Subtidal seaweed beds were common in several areas on the north and south coasts. In shallow subtidal biotopes, dense seaweed communities rich in species were found at Rhiy Di Qatanan (south-western tip) and at several locations along the western side of the Nojid (south coast). At greater depths (between 10 and 15 m) species-rich seaweed communities, mixed with hard and soft corals, occur in the central Nojid. Socotra shows a marked difference in macroalgal species richness between its north and south coast. The algal assemblages of the north coast are dominated by taxa which are characteristic for East Africa. The vegetation structure along the south coast is similar to that of other upwelling areas in the Arabian Sea and shows an interesting number of species with a disjunctive distribution pattern. Seagrass beds, which are much less abundant than seaweeds, occur in Qalansiyah Lagoon and at several sites along the Nojid coast. Three species of seagrass have been identified (LELIAERT 2000, SCHILS 2002).

2.3.2 Marine Invertebrates

Until recently, the marine invertebrate fauna of Socotra Archipelago was virtually unexplored. In the framework of the project, first comprehensive biodiversity studies on key taxa, such as corals, molluscs, polychaetes and crustaceans were conducted, resulting in a significant increase of the number of species recorded (e.g. from 67 to 240 for scleractinian corals, from 100 to more than 300 for crustaceans and from none to more than 150 for bryozoans).

The Socotra Archipelago supports a high scleractinian coral diversity of about 240 species in 56 genera and 14 families, including several undescribed species and new distribution records for 115 species and 15 genera. The communities are composed of species with wide Indo-West Pacific distributions, species from the Indian Ocean and species with restricted distributions within Arabia, including several taxa which had so far been regarded as Arabian Sea and Red Sea endemics. This community composition is consistent with larval replenishment from both local and external sources, the latter mediated via long-distance larval dispersal. Some corals were ripe for spawning from spring to early summer, which is consistent with spawning periodicity in most other Indo-Pacific areas. Coral communities of the archipelago are important 'stepping stones' connecting populations in the above regions.

Individual coral communities are characterised by low to high coral diversity (13-81 species of Scleractinia, average 44 species) and cover (< 1 to > 75 %, average 22 %). Most coral communities are small (1-5 ha) and developed on the north coasts, where coral cover and diversity are higher than in macroalgae-dominated south coast locations. Sites on the outer islands were, on average, more diverse than the ones on Socotra. Six major benthic community types are structured by 16 intergrading assemblages, ranging from monotypic stands of massive, submassive, branching and tabular corals, through diverse mixed assemblages of stony and soft corals, to macroalgae-dominated assemblages with sparse corals.

Some corals attain great size and are centuries old, although there is little recent biogenic reef accretion. Corals around the islands were affected to greater or lesser degree by the 1998 global bleaching event, like most other reef areas of the Indian Ocean. Several sites along the north-eastern coast of Socotra Island experienced major coral mortality, with near total loss of live coral cover (> 70 % dead coral cover) and shifts in community structure, with loss of most shallow-water acroporids, large massive corals and soft corals. Sizes of the dead corals at worst affected sites suggest that complete recovery will take decades to a century, provided environmental conditions remain suitable, whereas other sites, notably on the outer islands, remained in a near-pristine state. These communities also support other reef-associated species of high conservation value and/or economic importance (DEVANTIER 2000, 2002).

A total of 26 transect surveys were carried out to study abundance and distribution patterns of soft corals (Octocorallia, Alcyonacea). Distribution patterns of soft corals differed between the northern and southern coasts of Socotra. Colonies at locations along the northern coast were generally small, probably representing recent recruitment following the 1998 bleaching event. Soft coral assemblages along the south coast appeared to be less affected. Differences in abundance and species diversity were also noted between Socotra and the outer island locations, with highest values recorded at Abd al-Kuri and Samha (REINICKE et al. 2000).

Polychaetes (bristle worms) are among the most common invertebrates of marine habitats, playing an important role in marine food chains. A total of 19 families has been recorded from the Socotra Archipelago, with Eunicidae and Nereididae being the most common ones. Once identified to species level, many new records for the Arabian Seas area are to be expected (WEHE 2002).

Diversity of decapod Crustacea of the Socotra Archipelago is very high. More than 300 species were recorded, including 15-20 species apparently new to science. Anomuran diversity is particularly high, and species numbers exceed those known from the Red Sea and other well-studied areas of the Western Indian Ocean. Among intertidal habitats, rock platforms and cobble beaches on the north coast support the most diverse decapod assemblages. Intertidal soft sediments are poor in numbers of species. Intertidal ocypodid and sesarmine crabs are underrepresented, with several genera missing and others being represented by only a small portion of what is usually found in other parts of the Western Indian Ocean. Subtidally, the most diverse decapod assemblages were observed along the north coast, where the lack of pronounced upwelling and lower fluctuations of environmental parameters result in more extensive development of coral communities and support a higher species diversity. Zoogeographically, the decapods of Socotra show strong links to the Gulf of Aden and the Red Sea. Several species known from south and east Africa have their northern distributional limit at Socotra. The decapod fauna of Socotra represents a unique assemblage of species at the transition between the Arabian and the eastern African regions (APEL 2000 b).

A total of about 130 species of intertidal molluscs has so far been recorded from Socotra. Nine species account for more than 50 % of the individuals and 21 species for more than 75 %. All but one of the widely distributed species occur on rocky shores. Sites at the northern coast reveal significantly higher mollusc diversity than sites at the southern coast (JANSSEN 2000).

2.3.3 Fishes

A fish species inventory was compiled, species richness, diversity, abundance, distribution and composition of fish assemblages assessed, indicator species for monitoring identified, and conservation needs assessed. About 730 fish species in 110 families were recorded. Gamma diversity is highest at Socotra Island and Sabuniya, where 422 species have been recorded, followed by 279 species at Abd al-Kuri and Kal Farun and 236 species at Samha and Darsa. About 36 % of the fish species have a wide distributional range throughout the archipelago. Alpha diversity and abundances are highest at Abd al-Kuri and Kal Farun, closely followed by Samha and Darsa, and lowest at Socotra Island. Species richness decreases from west to east, and fish assemblages at northern coasts are usually more diverse than those occurring to the south. Though small in area,

the outer islands host a large proportion of the archipelago's fish biodiversity. The ten most frequently recorded species account for 71 % of the individuals. The most diverse families are Labridae (73 species) and Pomacentridae (44 species). The most common species is *Chromis flavaxilla*, followed by *Pomacentrus caeruleus*. At 34 sites, semi-quantitative surveys were conducted by line transect censuses. They yielded, on average, 71 species and 1200 individuals per transect of 1250 m^3 water body. Five main community types were identified and divided into up to 14 subtypes. The community types are characterised by diversity indices and by their characteristic species. Fish species composition differs in various parts of the archipelago. Abd al-Kuri has the highest number of East African species. Fish population sizes at sites of high biodiversity near this island are rather small and assemblages are particularly sensitive to disturbance. Although nearshore fish populations throughout the archipelago are presently in healthy condition, it is expected that degradation of their sparsely connected habitats will make it difficult for certain species to maintain their populations (ZAJONZ et al. 2000, ZAJONZ & KHALAF 2002).

2.3.4 Sea Turtles

Four species of marine turtles have been reported from the waters surrounding the Socotra Archipelago. Turtle nesting took place primarily on the main island of Socotra, with only scattered nesting on Abd al-Kuri and Samha. No nesting occurred on Darsa, Kal Farun or Sabuniya. The stretch from Ghubbah to Ras Qadamah was the main nesting beach during the pre-monsoon period on Socotra, with most nesting (about 90 %) occurring 2.5 km on either side of Ras Abelhen. Nesting averaged approximately two turtles per night over 5 km of beach. Nesting on all other beaches was diffuse (< 1-2 turtles per night). It is unlikely that nesting lasts longer than three months, translating to a nesting population of about 50-100 females. Although remains of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) were identified on the beaches, only the loggerhead turtle (*Caretta caretta*) was found nesting at any of the beaches. It is possible that the green turtles and hawksbill turtles nest at earlier or later dates, or are simply non-nesting residents. The use of turtle meat and eggs by local people was evident. Turtles were brought to the market in Hadibo daily, captured from places as far distant as Ghubbah. Eggs were similarly collected, particularly on the southern coast. No turtle or egg collection was evident at Shu'ub, though occasional slaughtering of adult females was reported to occur. No major nesting was detected at Qalansiyah. Options for conservation will require the participation of the Socotri people. They should include a Nature Sanctuary between Ghubbah and Ras Qadamah extending 1-2 nm into the sea, educational programmes to discourage turtle meat consumption, and a 'turtle-safe' certification programme to curb harvests and demand (SA'AD & PILCHER 1999, PILCHER & SAAD 2000).

2.3.5 Seabirds

Fishermen at major coastal settlements of Socotra were interviewed in order to gather initial information on seabirds, using a questionnaire. Based on the results, a survey of breeding seabirds covering all islands and islets of the Socotra Archipelago established that at least eight species of seabirds frequently breed within the archipelago. Although the timing and the logistics of the survey, as well as the inaccessibility of most breeding colonies, prevented the team to make accurate population estimates, the survey revealed that the archipelago is of regional and international importance for breeding masked boobies (*Sula dactylatra*) and brown boobies (*S. leucogaster*), Persian shearwater (*Puffinus persicus*), red-billed tropicbird (*Phaeton aethereus*), sooty gull (*Larus hemprichii*), bridled tern (*Sterna anaethetus*), Saunders's tern (*S. saundersi*) and common noddy (*Anous stolidus*). Substantial information provided by local shepherds suggests that a ninth species, Jouanin's petrel, may breed during the winter monsoon in large numbers on some inland cliffs in the Shu'ub area on Socotra Island. Prime conservation areas for breeding seabirds include the limestone islets Kal Farun and Sabuniya and the uninhabited island of Darsa. The proper conservation and management of these sites as protected areas should be given high priority. The

remainder of the breeding sites are mostly situated on high, steep and inaccessible coastal cliffs, which are generally safe and naturally protected from disturbance by people and from predation by the widespread rats. Many of these cliffs are located in areas of outstanding natural beauty which deserve the status of Nature Sanctuary as good and often intact representatives of the unique coastal ecosystems of the Socotra Archipelago (HAIDARA & SYMENS 1999, AL-SAGHIER et al. 2000).

3 Target Areas and Indicator Sites

As a result of remote sensing, ground-truth surveys and initial detailed habitat and biodiversity surveys, areas of biodiversity significance, ecosystems representative of the archipelago, areas under present or perceived future threats, sites of special conservation significance in terms of representativeness, unusual community structures, the presence of rare and/or endemic species and replenishment were identified. In mid 1999, project and resident marine team members held a workshop to discuss the significance of these target areas and indicator sites and to develop a draft zoning plan. A zoning scheme suitable for Socotra Archipelago was drafted and agreed upon, based on the IUCN system. It recognises three categories in order of increasing protection and management. Definitions, objectives and selection criteria for each of the three categories within the Socotra Archipelago were developed. Biological and socio-economic survey results were analysed and incorporated into the zoning plan. Coastal and marine areas throughout the archipelago were identified and mapped according to their sensitivity, and a guide identifying activities which should be permissible in the various zones of the MPA was drafted (KRUPP & KLAUS 2000).

The mapped biotopes were entered as a layer into the GIS, and these data, together with recommendations from taxonomic experts, were used to identify and map the zoning plan for the coastal and marine areas of the Socotra Archipelago. Thereafter, the zoning process involved iterative consultation and negotiation with a wide range of stakeholders, including the community leaders within the proximity of the proposed areas. The final zoning plan for the islands, covering an area of 17,180 km² of coastal land and sea, contains the entire island group within a Resource Use Reserve (15,216.13 km², 88.57 %), within which are National Parks (1,759.00 km², 10.24 %) containing 27 highly protected Nature Sanctuaries (204.78 km², 1.19 %). The size of the Nature Sanctuaries ranges between 0.27 km² to over 45 km². A total of five out of the 27 Nature Sanctuaries were proposed by local communities. The boundaries of each Nature Sanctuary were agreed and mapped with participation of members of the local community. The biotope maps were integrated with the proposed zoning plan using GIS. The area and percentage cover of different biotopes within the Nature Sanctuaries in water less than 20 m deep was assessed. Overall, the average portion of each biotope protected within the Nature Sanctuaries is 20.2 % (KLAUS et al. 2002 a).

An integrated database system to facilitate future use of data collected during the present surveys as a baseline for monitoring and more detailed studies was designed to allow storage and retrieval of data collected during the surveys. The database is programmed as an MS Access application and allows storage of ambient environmental parameters, general site and bio-inventory (species presence/absence) data for intertidal and subtidal surveys, line intercept and fish transect data and biological collection data. Tools for data analysis are included and can be used for monitoring and for future biodiversity studies (APEL et al. 2000).

A long-term monitoring programme was established around the Socotra islands with the objective to assess present status and future trends in selected intertidal and subtidal communities, essential in efficient management of the Marine Protected Areas (MPAs) around the islands. Following initial quantitative surveys of 26 sites on Socotra Island and the outer islands, 11 permanent monitoring sites were established using the Global Coral Reef Monitoring Network line transect protocol in 2000, mostly within Nature Sanctuary zones.

Some sites were composed of large monospecific stands of corals, others support more diverse communities (about 50 hard coral species) and some were dominated by macroalgae with sparse corals. In 1999, the averages of overall cover around the islands were 28 % for living hard corals, 8 % for dead corals, 10 % for soft corals and 25 % for algae. In 2000, there was little overall change in cover of most species, with averages for hard corals of 28 %, for dead corals of 16 %, for soft corals of 8 % and for algae of 27 %, although there were significant shifts in cover at individual sites. Between 1999 and 2000, changes in the coral communities included coral death following flood run-off during the intense rains of December 1999, contributing to the significant overall increase in cover of dead corals from 8 % to 16 %. Other changes included clear coral recovery, evident in growth of surviving corals and recruitment of juveniles, at several sites impacted by bleaching in 1998 (DEVANTIER 2000, DEVANTIER et al. 2002).

Based on the bio-inventory and community surveys of inshore fishes, a fish monitoring programme was developed and implemented. A suite of indicators and additional descriptive parameters were defined and standard monitoring procedures established. The fish communities of the Nature Sanctuary zones were outlined and recommendations for a sustainable management of the fish resources prepared (ZAJONZ & SAEED 2002).

A monitoring programme of 11 selected intertidal sites around the coast of Socotra was implemented in April 2000. The programme was designed with the aim of enabling local personnel to conduct basic intertidal monitoring using qualitative and semi-quantitative sampling methods. Sand beach, rock platform, undercut cliff, cobble and mudflat sites were sampled using a relative abundance scale and the presence or absence of key species to assess human impacts. The skills acquired during the programme give local personnel the ability and opportunity to continue intertidal sampling on a long-term basis (WEST & APEL 2002).

The islands are important as monitoring sites at national, regional and global scales, being situated in a key location for assessing effects of climate change and other impacts. With increasing pressures from expanding fisheries and tourism, and the completion of the GEF-UNDP project, there is an urgent need for continued support for monitoring, management and protection of the Marine Protected Areas, if these communities are not to go the way of other unique marine ecosystems now being rapidly depleted.

4 Ecotourism Areas

Marine ecotourism means responsible travel to natural coastal and marine areas that conserves the environment and sustains the welfare of local communities. By avoiding mass developments that, in many parts of the world, have exploited coral reefs and other critical biotopes for short-term financial gain, ecotourists can influence future developments to be environmentally responsible. Beaches and seascapes of outstanding scenic beauty, well-developed coral reefs with high fish species diversity and areas where rare and/or conspicuous species, such as manta rays or marine mammals, occur are of particular interest to ecotourism. These are also areas of high environmental sensitivity. They have been identified throughout the archipelago (KLAUS et al. 2002 a, 2002 b; DEVANTIER 2002, ZAJONZ & KHALAF 2002). The Socotra group of islands has a clear potential for the development of marine-based ecotourism, though with regard to numbers of visitors the carrying capacity at most sites is rather low.

5 Biodiversity Training

Throughout the project, Yemeni nationals from Socotra and the mainland received formal and on-the-job training in basic marine biology, marine conservation, species identification, sampling and collection management and monitoring. A formal training course on intertidal and subtidal survey and monitoring methods was held in February/March 1999. A curriculum for this course has been developed and a training manual compiled in Arabic (Final Report Second Phase,

Appendix III). The course was mainly conducted in Arabic. Trainees were introduced to key species and species identification, biological sampling and laboratory methods as well as basic methodology of intertidal and subtidal survey and monitoring. Besides theoretical lectures held at the marine laboratory, the course included several excursions to sites in the vicinity of Hadibo for practical training. Additionally, trainees participated in survey activities and received on-the-job training (APEL & ZAJONZ 2000).

6 Inventory of Fishing Activities

Fisheries community structure, traditional conservation systems, potential conflicts and fisheries production as a basis for introducing resource management were studied by a team of Yemeni fisheries specialists. In March 1998, a survey of the status of the Socotran fisheries sector was undertaken. Information was collected primarily by means of in-depth interviews with local artisanal fishermen and other members of the community. Fishermen and their families represent a substantial part (more than 40 %) of the total population on the island, and the fishery forms an important social and economic activity, which is increasing due to a shortage of alternative job opportunities. There are problems associated with inadequate infrastructure, high costs of fishing materials compared to those on the mainland, processing, storage, marketing and distribution. On-shore facilities for processing, freezing and storing of fish products are inadequate or non-existent (HARIRI & YUSIF 1999).

Discussions with the Socotran fishermen in April to June 1999, coupled with fisheries development projects led by investors from the mainland, triggered sufficient enthusiasm among the local fishermen to initiate the establishment of fishermen's co-operative societies. By October 1999, eight preparatory committees had begun work. The project team from Hariri & Associates, along with representatives from the Socotra offices of the Ministry of Social Affairs and the Ministry of Legal Affairs, made several visits to different locations to explain the legal basis for the formation of these fishermen's co-operative societies. The project team recommended the formation of only four to five such societies within the archipelago (YUSUF & KASSEM 2000).

7 Stock Assessment, Management and Monitoring

The main targets of artisanal fishermen are sharks, followed by pelagic finfish and then demersal species. No reliable statistical data are available. Stock assessment at landing sites is unreliable, because it is common practice among Socotri fishermen to sell their catches straight from the fishing boats to vendors' boats at sea, without landing them. No fisheries research vessel for experimental stock assessment was available (see above) and hiring such a vessel was far beyond the project budget. Stock estimates of key resources (lobsters, sharks and demersal fishes) were conducted and reef fish stocks were assessed along underwater transect lines (see above). It was agreed that experimental stock assessment as a one-time exercise is of very limited value and it is unlikely that funds for regular stock assessments will become available. However, during stakeholder consultations it became obvious that there was an urgent need for a Fisheries Management Plan for the Socotra Archipelago and emphasis was placed on the development of such a plan.

There is very little historical or biological data on the lobster fishery of Socotra, but the fishery appears relatively healthy with good catch rates and large individuals being caught. Until recently, agreements between local communities and a limited market served to keep fishing effort at a low level. It is, however, obvious that effort is increasing and will increase further in the near future. Consequently, various strategies were proposed to allow development of the fishery in a sustainable manner. Most of the fishing communities practice self-restraint in the areas fished, the period when fishing is allowed, what gear can be used and at what size lobsters can be taken. Formalisation of these practices along with awareness programmes seem, in the absence of

clear data, to be the best means of managing the rock lobster fishery. Lobster species found in the landings of Socotran fishermen were *Panulirus homarus, P. versicolor, P. penicillatus* and *P. longipes*. The most abundant species is *P. homarus*, accounting for about 60 % of the catch. Maximum sustainable yield is estimated at about 230 mt whole lobsters annually. At the present level of productivity, the number of local boats in the lobster fishery should not exceed 300 and the season be limited to 90 days (ESSEEN & KHANBASH 1999, KHANBASH 2000).

Throughout the archipelago, sharks are abundant and are fished with longlines and gill nets. The annual production of sharks is estimated at about 7300 tons, and average catch per unit effort at 54 kg per boat and day. Fishing boats go for shark fishing on about 160 days per year. The predominant species are *Carcharhinus albimarginatus, C. sorrah* and *Sphyrna lewini*. During the monsoon season, all fishing ceases due to the high wind speeds and wave swells. Fishermen in Di Lisheh on Socotra Island continue fishing in more sheltered fishing areas. During this period, pelagic fishes tend to migrate offshore while the demersal species move to deeper waters. The months October and November witness the highest productivity, with an increase in plankton biomass after the monsoon. Fishing effort is limited by the lack of marketing paths for all products except for dried shark fins and limited amounts of dried shark meat. Lack of fisheries services, in terms of availability of fishing gear and of maintenance workshops for outboard engines and boats, hampers an increase in fishing effort (SAEED 2000).

In recent years, production of demersal fishes increased, reaching a maximum of about 2660 mt in 1999 with an effort of 249 kg per boat and day for a fishing period of 120-140 days. Artisanal fishermen in the Socotra Archipelago catch about 120 demersal fish species belonging to 18 families. Five families that are found in commercial abundance dominate the catches. These families include groupers, emperors, trevally, snappers and sweetlips. There are 16 species of groupers, but only 11 are considered important. These include *Cephalopholis aurantia, C. miniata, Epinephelus areolatus, E. chlorostigma, E. flavocaeruleus, E. multinotatus, E. poecilonotus, E. radiatus, E. tukula, E. undulosus* and *Variola louti*. Groupers represent 23 % of the catch. Emperors occur in 11 species, of which four are caught commercially. These are *Lethrinus mahsena, L. lentjan, L. nebulosus* and *L. olivaceus*. Emperors represent 36 % of the catch. Of the 23 species of trevally only four are frequently caught in commercial quantities: *Carangoides chrysophrys, Caranx sexfasciatus, Gnathanodon speciosus* and *Seriola rivoliana*. They represent 7 % of the catch. There are 17 species of snappers, 10 of which are important commercially: *Aphareus furca, Lutjanus bohar, L. fulviflamma, L. gibbus, L. lutjanus, L. malabaricus, L. rivulatus, L. russellii, L. sanguineus* and *L. sebae*. They represent 27 % of the catch. Of the 10 species of sweetlips present, four are caught in commercial quantities: *Diagramma pictum, Plectorhinchus flavomaculatus, P. pictus* and *P. schotaf*. Sweetlips represent 7 % of the catch. In terms of production, the main fishing period for demersal fishes in the Socotra Archipelago is October to December (MOHSEN 2002).

A draft Fisheries Management Plan (FMP) has been prepared in 2000. It is the first document of its type for the fisheries resources of Yemen and contains information gained from a number of sources, including existing documentation and interviews held with officials, fishermen and officers of the newly established fishermen's co-operative societies. It was intended to promote discussion on possible options for improved fisheries management. The FMP, which should eventually become a formal arrangement between the fishery management authority, the Ministry of Fish Wealth, and other interested parties, contains management objectives for all the constituent artisanal fisheries in Socotra Archipelago. It serves as a reference and information source for the management authorities and all interest groups. It summarises the current state of knowledge on the resources, the environment and the fisheries, and reflects the decisions and actions either agreed upon or indicated during the course of consultations between the interest groups. Resources that are currently under-utilised but could in the future form the basis of sustainable and economically viable fisheries are also covered, e.g. deep-water snappers and small shoaling pelagic species. The FMP is presented in two parts: Part I provides a fisheries overview and management options for each target species group. It is based on a standard format for fisheries management plans developed by FAO as a component of the Code of Conduct for Respon-

sible Fishing. Part II details a fisheries data collection programme for monitoring purposes, with formats for recording fishery and resource data (NICHOLS 2001).

Workshops were held in Sana'a and Socotra to review the draft FMP. Key stakeholders from the Socotran fisheries sector participated. The management plan was discussed in detail, with particular emphasis on the creation of a vessel registration scheme, the formation of a Fisheries Management Committee for Socotra and the collection of fisheries data for assessment and monitoring. The draft plan was endorsed by the workshops, though it was agreed that the fisheries data collection forms should be simplified. New versions of the forms were prepared. Training in the use of data collection forms was delivered. Possible avenues for sustainable funding of the plan were explored (ESSEEN & AL-SAQAF 2002).

Implementation of the FMP should start as soon as possible and its success will depend on a close co-operation between the Ministry of Fish Wealth, which is the lead agency, the Ministry of Tourism and Environment and other key stakeholders. The steps to be taken towards successful implementation were identified and the impact of recent institutional changes analysed, emphasising the need to harmonise relevant legislation (HARIRI 2002).

8 Legal Aspects

The present and proposed future fisheries legislation of the Republic of Yemen was reviewed, with special regard to the situation in the Socotra Archipelago. The legal framework was analysed in the larger context of fisheries management. Traditional fisheries management practices, official fisheries regulations and management before the unification of the former Yemen Arab Republic and the People's Democratic Republic of Yemen in 1990 were reviewed. A detailed overview of the fisheries legislation after 1990 was provided, followed by a brief review of the institutional framework relevant to the sector. The current legal framework for fisheries is weak. A proposed new law and by-laws developed in 1993 and a draft law drawn up in 1997 that proposed greater regulation of shrimp and rock lobster fisheries has the potential of strengthening the legal framework. Recommendations for an improved fisheries management to be achieved on short-, medium and long-term basis were presented (HARIRI & SHOTAH 1999).

9 Community-based Fisheries Organisation and Management

YUSUF & KASSEM (2000) describe efforts made to assist rural fishing communities to organise themselves into coherent co-operative societies. In October 1999, discussions were held with fishermen on the role and responsibilities of fisheries co-operatives. The work complements the survey of co-operatives undertaken by HARIRI & YUSIF (1999). Significant effort was expended on public awareness campaigns to explain the benefits of co-operative societies, how these should be established and operated under Law No. 39 of 1998 and the lessons to be learned from the failure of the Socotra Fishermen's Cooperative in the early 1990s. The problems facing the artisanal fishermen and the steps required in order to establish co-operatives in line with Law No. 39 of 1998 were laid out. The responsibility of local communities in the management and enforcement of the regulatory measures proposed for each zone is described in the Zoning Plan (KRUPP & KLAUS 2000).

10 Fisheries Training

The fisheries training programme covered a wide range of topics, such as fisheries data collection, stock estimates, environmentally friendly fish handling, processing and marketing, maintenance of fishing boats and gear, surveillance, control, management and monitoring. Both formal and on-the-job training were delivered to fishermen and environmental extension officers. A training

manual and guidelines in Arabic were prepared and distributed (Final Report Second Phase, Appendices IV and V).

Environmental extension officers were trained in: assessment of present fisheries production; main concepts of stock assessment, fisheries surveillance and control; collection of data for lobster and shark stock assessment; fisheries management; integrated coastal management. Fishermen were trained in: fish handling methods; fish preservation and transportation on ice; freezing of fish and fisheries products; fish salting; methods of preparing smoked fish; fish marketing; GRP fishing boat repair and maintenance; maintenance of fishing gear; maintenance and repair of outboard engines; sustainable use of coastal and marine resources. Training methods included lectures, demonstrations, handouts, interactive group discussions and practical work. A total of 11 environmental extension officers and 417 fishermen were trained. During community discussions, members of the fishing community at large participated (HARIRI 2000).

Appendix: List of Reports submitted by the SRI and its partners

Final Report First Phase (1999)

KRUPP, F. & HARIRI, K.I. (eds) 1999. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Report of Phase I.* 212 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.

ESSEEN, M. & KHANBASH, M.S. 1999. The rock lobster fishery of Socotra – current status and management options. Pp. 181-190.

HAIDARA, S.H. & SYMENS, P. 1999. Seabird questionnaire. Pp. 195-198.

HARIRI, K.I. & SHOTAH, J. 1999. Review of fisheries legislation in Yemen. Pp. 141-160.

HARIRI, K.I. & YUSIF, M.D. 1999. Fishing communities and status of the fisheries sector in the Socotra Archipelago. Pp. 161-179.

KLAUS, R. 1999. Summary of the marine satellite image processing and Geographical Information Systems. Pp. 9-31.

SA'AD, M.A. & PILCHER, N.A. 1999. Marine turtle questionnaire. Pp. 191-194.

TURNER, J.R., KLAUS, R., SIMÕES, N. & JONES, D.A. 1999. Littoral and sublittoral ground-truthing survey of the Socotra Archipelago. Pp. 33-139.

Final Report Second Phase (2000)

HARIRI, K.I. & KRUPP, F. (eds) 2000. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Report of Phase II.* 2 vols. 176 pp + 284 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.

AL-SAGHIER, O., ALSUHAIBANY, A. & SYMENS, P. 2000. The status of breeding seabirds. Pp. 97-104.

APEL, M. & ZAJONZ, U. 2000. Intertidal and subtidal survey and monitoring methods. Pp. 129-132.

Hariri & Associates 2000. Fisheries Training Programme. Pp. 133-135.

KHANBASH, M. 2000. Preliminary survey of rock lobster catches. Pp. 113-121.

KRUPP, F. & KLAUS, R. 2000. Contributions to a zoning plan for coastal and marine areas of Socotra. Pp. 137-149.

PILCHER, N. & SAAD, M.A. 2000. Sea turtle survey. Pp. 83-95.

SAEED, S.S. 2000. Preliminary survey on the status of shark stocks in Socotra. Pp. 123-128.

SIMÕES, N. & JONES, D. 2000. Intertidal and coastal lagoons ecology survey. Pp. 11-82.

YUSUF, M.D. & KASSEM, F.N.E. 2000. Establishment of fishermen's cooperative societies. Pp. 105-112.

Progress Report Third Phase (2000)

APEL, M. & HARIRI, K.I. (eds) 2000. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Progress Report of Phase III.* 191 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.

APEL, M. 2000 a. Subtidal rapid assessment and selection of survey sites. Pp. 9-12.

APEL, M. 2000 b. Survey of the decapod Crustacea of Socotra. Pp. 107-125.

APEL, M., ZAJONZ, U. & LAIS, M. 2000. "Socotra Biodiversity and Monitoring Database" – an integrated database for survey and monitoring data. Pp. 171-175.

DEVANTIER, L.M. 2000. Coral communities of the Socotra Archipelago. Pp. 49-80.

JANSSEN, R. 2000. Report on intertidal molluscs from Socotra Island. Pp. 97-105.

LELIAERT, F. 2000. Marine benthic macroalgae and seagrasses of the Socotra Archipelago. Pp. 13-48.

REINICKE, G.B., AL-MOGHRABI, S. & DEVANTIER, L.M. 2000. Soft corals of the Socotra Archipelago. Pp. 81-95.

ZAJONZ, U., KHALAF, M. & KRUPP, F. 2000. Coastal fish assemblages of the Socotra Archipelago. Pp. 127-170.

Final Report Third Phase (2002)

APEL, M. HARIRI, K.I. & KRUPP, F. (eds) 2002. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Final Report of Phase III*: 485 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.

DEVANTIER, L.M. 2002. Corals and coral communities of the Socotra Island Group. Pp. 169-206.

DEVANTIER, L.M., REINICKE, G.B. AL-MOGHRABI, S. & ABDULAZIZ, M. 2002. Monitoring coral communities around the Socotra islands. Pp. 207-235.

ESSEEN, M. & AL-SAQAF, H. 2002. Review of the Fisheries Management Plan for the Socotra Island Group. Pp. 437-479.

HARIRI, K.H. 2002. Notes on the implementation of the Fisheries Management Plan for the Socotra Island Group. Pp. 481-485

KADAGIES, N. & SCHOLZ, J. 2002. Preliminary notes on Bryozoa from the Socotra Archipelago collected in spring 2000. Pp. 395-397.

KLAUS, R., TURNER, J.R. & WEST, F. 2002 a. The marine biotopes of the Socotra Island Group. Pp. 11-167.

MOHSEN, S. 2002. A preliminary survey of the status of demersal fish species in the Socotra Archipelago. Pp. 399-409.

NICHOLS, P.V. 2002. Report on fisheries surveys and management activities during autumn 2000. Pp. 411-436.

SCHILS, T. 2002. Macroalgal assemblages of the Socotra Archipelago. Pp. 383-389.

WEHE, T. 2002. Polychaete worms of the Socotra Archipelago – Preliminary report on the survey period 29 March – 29 April 2000. Pp. 391-393.

WEST, F. & APEL, M. 2002. Intertidal monitoring for human impacts. Pp. 339-381.

ZAJONZ, U. & KHALAF, M. 2002. Inshore fishes of the Socotra Archipelago: diversity and community structure. Pp. 237-296.

ZAJONZ. U. & SAEED, F.N. 2002. Inshore fish monitoring programme for the Socotra Archipelago. Pp. 297-337.

Fisheries Management Plan

NICHOLS, P.V. 2001. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Fisheries Management Plan for the Socotra Island Group*. 130 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.

Biotope Manual

KLAUS, R., TURNER, J. & WEST, F. 2002 b. *Conservation and Sustainable Use of Biodiversity of Socotra Archipelago. Marine Habitat, Biodiversity and Fisheries Surveys and Management. Sublittoral and littoral biotope manual for the Socotra Archipelago*. 221 pp. Senckenberg Research Institute; Frankfurt a.M., Germany.