REPORT 1: BRUTON, MN

IFC/GEF Vilanculos Coastal Wildlife Sanctuary Project

Biodiversity Management Plan: Sub-Activity 'Marine Systems'

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Preamble: If you were to design a place with maximum diversity, choose a location on the tropical east coast of Africa, add a peninsula, a large bay, tidal sand flats, an estuarine lagoon, sea grass beds, freshwater lakes, extensive mangrove swamps and reed swamps, throw in coral and rocky reefs, idyllic sandy beaches, forested dunes and a wide tidal range, and then sprinkle it with over 400 species of fishes, including the elusive sea horses and mudskippers, thousands of rare and unusual invertebrates, nesting turtles, millions of jellyfish, the enigmatic dugong, giant manta rays and whales offshore. Improve the mix by adding items of cultural diversity, including traditional fisherfolk and life styles, Arabian dhows, expert boat builders, an historic lighthouse, ancient middens, a dark past but a bright future, thatched camps under satin skies, and the night-time drum beat of Africa.

What do you have? *The Vilanculos Coastal Wildlife Sanctuary in Inhambane province, Mozambique.*

1. Holistic analysis of marine, estuarine and lagoonal systems

Introduction: The Vilanculos Coastal Wildlife Sanctuary (VCWS) comprises a series of interlinked marine, coastal, estuarine, lagoonal, terrestrial and freshwater systems that, in combination, form one of the most diverse and interesting biodiversity hotspots on the east coast of Africa. Furthermore, the area has a rich and interesting cultural history that combines elements of Africa, Asia and Europe. The biological and cultural diversity of the place need to be considered together in order to appreciate its real value.

This report deals primarily with the marine and coastal subsystems, including the offshore marine environment, coral reefs, inshore rocky reefs, sandy beaches, estuarine lagoon, San Sebastian Bay and its tidal sand flats and sea grass meadows, and the mangrove swamps, reed swamps and other shoreline habitat types found in the Sanctuary. This is a vast array of habitat types with probably thousands of different species, many of which are poorly known. The relatively low energy sand flats are a dominating feature of the Sanctuary and play host to a wide variety of marine animals, some of commercial value. Distinct patches of sea grass occur in the tidal flats. These meadows stabilize

the shifting sand communities and provide habitat for a host of marine animals, including the dugong *Dugong dugon*. Extensive mangrove swamps occur along some shores of the Bay and along the coasts of the elongate, north-south extending estuarine inlet near the marine coast.

The VCWS is washed by the southward flowing Mozambique Current with velocities of up to 2 m/sec (Dutton, 1990). The temperature of the seawater ranges from 23°C in winter to 27°C in summer. The average tidal amplitude is about 3 m during normal spring tides, reaching 4.39 m during equinox tides. The tidal flats between the San Sebastian Peninsula and Bangue Island experience strong currents, especially at high spring tides. These currents transport vast quantities of sand and silt, as well as the larval forms of many marine animals. There is therefore extensive interchange of organic and inorganic material between the sea and the lagoon.

Although the environmental importance of the coastal plain of Mozambique is appreciated internationally, it has been relatively poorly studied for a variety of reasons, including its remoteness, the presence of tropical diseases, the extended civil war, the relatively poorly developed transport infrastructure, and the lack of a strongly developed research infrastructure in Mozambique. Very few scientific papers have been published in the international, peer-reviewed literature on the ecology of his part of Mozambique, although a fair number of informal, unpublished reports are available.

Inhaca Island, on the eastward edge of Delagoa Bay in southern Mozambique, is probably the best-studied part of the Mozambican coastal and marine environment (McNae & Kalk, 1962, 1969; Kalk, 1995, and references contained therein). Research was initiated there in 1911 by staff of the Museu Alvaro de Castro in (then) Lourenco Marques, and subsequently the Instituto de Investigacao Cientifica de Mocambique (from 1955) and the University of Witwatersrand in South Africa (from the mid-1930s). Fortunately, the marine and coastal environments of Inhaca Island are similar to those in the VCWS and extrapolations can be made, with a reasonable amount of certainty, from one to the other.

Tilney (1969) and Dutton (1990) carried out extremely valuable early surveys and quantitative research in the Bazaruto archipelago, which is invaluable today.

The author spent seven years based at a field research station on the shores of Lake Sibaya in Maputaland, northern Zululand, where he studied aspects of the ecology of the freshwater, marine, estuarine and terrestrial environments (Bruton, 1979; . The ecology of Maputaland, which is also situated on the sandy coastal plain that extends from Somalia through Kenya, Tanzania and Mozambique into the north-east corner of KwaZulu-Natal, is very similar to that of the VCWS. The extensive literature on the Maputaland coastal plain (Allanson et al., 1974; Bruton, 1980a & b; Bruton & Cooper, 1980; Bruton & Haacke, 1980; Bruton & Kok, 1980; Bruton et al., 1980, and references contained therein) is therefore also of relevance to this study.

It nevertheless needs to be recognized that this study was conducted on the basis of less than two weeks in the field and with access to a very restricted literature. Furthermore, the range of animals and ecosystems that had to be covered was huge – whereas some consultants were concerned with only one class of animals, the author had to deal with over 39 classes of highly diverse, and often poorly known, animals placed in 13 phyla. Marine animals are also more difficult to survey, not only because they are under water, but also because many of them are small, cryptic, subterranean, nocturnal and/or elusive. Under these circumstances, it is impossible to give full justice to the diverse and complex biota of the VCWS, and to the complex environmental problems involved in their management.

Ideally, several years, preferably decades, of intensive research by a team of specialists, comprising taxonomists, biologists, ethologists, ecologists, life-history specialists and eco-physiologists, would be required to even begin to understand the ecology of this interesting and complex part of tropical Africa. During the survey we only had time to document the major marine and coastal habitats, with little time to examine individual species. In addition, it was impractical to make large specimen collections from the marine and coastal environments due to the variety of gear that would be required and the severe time constraints. The amount of taxonomic research that could be carried out was therefore very limited.

This report should therefore be regarded as a very preliminary account that hopefully encourages more in-depth research and review in future.

Present levels of exploitation: The extent of exploitation of marine and coastal resources in the VCWS is not known but useful comparable figures are available for the Bazaruto archipelago to the immediate north. Dutton (1990) reports that about 1500 people from 60 artisanal fishing communities in the Bazaruto archipelago commercialized over 1500 tonnes of dried marine products during 1989/90. The consumers of this fisheries yield were mainly Mozambicans residing in Vilanculos, Inhassaro and inland areas of the mainland. *Mapalo* sand oysters *Pinctada imbricata* have been a staple food in the diet of the local people for centuries (as evidenced by the extensive *mapalo* middens adjacent to their villages). Turtles and turtle eggs are harvested, but not on a sustainable basis although the eggs could possibly be used sustainably if the adult turtle population is protected. A well-organized semi-commercial fishery from Inhassaro, Vilanculos and the Bazaruto islands exported 4 610 tonnes of frozen fish, 42 tonnes of crayfish, 7 165 tonnes of dried fish, 500 tonnes of dried squid and 39 tonnes of dried sea cucumber in 1989/90 (Dutton, 1990).

It is clear from the above figures that the artisanal and semi-commercial fisheries of the Bazaruto archipelago, and, from our preliminary observations, the Vilanculos Coastal Wildlife Sanctuary (VCWS), provide considerable social and economic benefits to the Tsonga people of the region. Artisanal fisheries are clearly a valid and substantial form of resource use in the Bazaruto/VCWS area and cannot be replaced or phased out in favour of tourism. Tourism development should therefore take place as a complementary activity to traditional methods of resource use in the Sanctuary.

Review of the biotic diversity of the main marine and coastal ecosystems

Coral reefs and open sea: The main requirements for the building of a successful coral reef are found off the coast of the Sanctuary, i.e. consistently high sea temperatures (> 20°C), hard rocky substrata on which to build the coral reef, strong currents to wash away deposits of sand and to transport larvae and nutrients, and a water column relatively free of sediment from large rivers. The coral reefs off this coast are of mid-Holocene origin (about 7000 years old; Dutton, 1990) and are therefore fairly recent. The coral reefs off the Sanctuary and the Bazaruto archipelago are not true barrier reefs, as in the Great Barrier Reef of Australia, as they are not comprised solely of new coral built on old coral in a continuous reef formation. They should rather be classified as coral-encrusted rocky reefs, or patch reefs, similar to those found off the coast of northern Zululand but richer in coral species. They have an extremely rich attached invertebrate fauna and are inhabited by a wide variety of free-living cephalopods, other molluscs, crustaceans, fishes and other life forms. The reef that the author examined appeared to be scoured by strong currents; this is apparently typical of reefs in the area. True coral reefs are found further north in Mozambique.

Coral reefs are as dependent on light as are green plants on land as the cells of reef-building coral animals contain thousands of unicellular algae that contain photosynthetic chloroplasts. These algae must be exposed to light so that the corals will grow. The multitude of large pores (calyces) in the coral rock, which contain the coral polyps, allow for the penetration of light into the internal tissues of the coral in daylight. At night, polyps extend their tentacles to feed (Kalk, 1995). Corals can therefore not survive if they are covered with sand or submerged in turbid water.

The coral reefs of Inhaca Island are inhabited by over 100 species of animals that are associated with the living coral as commensals, lodgers or predators (Kalk, 1995) and a similar number of species can be expected to inhabit the coral reefs in the VCWS. Many additional species inhabit the dead coral bases. In addition, coral reefs are typically associated with sea meadows, reef flats, and open sandy habitats that are inhabited by further species. The overall community associated with a coral reef is one of the most diverse of any ecosystem in the world (Steene, 1990).

Coral-encrusted rocky reefs occur close to shore along the marine coast of the VCWS as well as well offshore opposite the entrance to the Bay and off the Bazaruto archipelago. The former reefs may be accessible to snorkel divers operating from the shore on calm days whereas the latter are only accessible to scuba divers operating from boats.

The coral reef surveyed by the author in the entrance to San Sebastian Bay is inhabited by the following species, based on direct observations or records from other studies of coral reefs in southern Mozambique:

Phylum Protozoa: *flagellates, ciliates*: Single-celled animals, together with the larval forms of multi-cellular animals (especially sponges, arthropods,

polychaetes, arrow worms and chordates), form the zooplankton that floats in midwater. The zooplankton typically feeds on the phytoplankton and forms the base of the food chain on a coral reef. All higher forms of life on a coral reef ultimately depend on the availability of phyto- and zooplankton.

Phylum Porifera: *sponges*: Sponges are primitive, sedentary animals that lack a mouth, digestive tract or any other conventional internal organ. Water and small food particles enter the sponge through numerous tiny pores and exit through large opens that are often raised like turrets. Sponges reproduce either by budding or by producing planktonic larvae. Sponges are conspicuous inhabitants of rocky and coral reefs. Solitary sponges are common on coral reefs in Mozambique, both on the live coral as well as on dead coral and reef rubble.

The cup sponge, *Ircinia* spp., forms a cup up to one metre across and is found on coral reefs in the Sanctuary, as is the crumpled sponge, *Axinella waltneri*.

Phylum Cnidaria: *hydroids, bluebottles, jellyfish, soft corals, sea fans, sea pens, sea anemones, zoanthids and hard corals*: Cnidarians all have a simple body structure which is sac-like with an outer skin and an inner gut lining. They have a mouth but no anus, and there are no specialized organs for respiration or excretion. Notwithstanding their simplicity, cnidarians are extremely successful and abundant in the marine environment (less so in freshwaters). They were among the earliest forms of multi-cellular animals to evolve on Earth, having arisen at least 650 million years ago). They uniquely possess highly specialized stinging cells (nematocysts). They are both solitary and colonial animals.

Many unidentified sea anemones were seen on the coral reef. The giant anemone, *Radianthus ritteri*, occurs on coral debris and coral reefs in the VCWS as well as abundantly in the tidal shallows and sea grass beds of the lagoon, estuary and Bay. The giant anemone is an important component of the biota of the VCWS, and should be regarded as a flagship species; they should be the subject of more detailed study.

Zoanthids, such as the columnar sandy zoanthid, *Palythoa nelliae*, are colonial animals that, like corals, depend on microscopic symbiotic algae (zooxanthellae) for most of their nutrients, although they also prey on small organisms. Zoanthids form continuous carpets on reefs in the Mozambique region. Another species, *Zoanthus natalensis*, lies on the sand between corals and its surface is encrusted with sand (Kalk, 1995).

Jellyfish are bell-shaped, gelatinous creatures and are extremely common in marine and lagoonal habitats in the VCWS. The root-mouthed jellyfish, *Rhizostoma* spp., the largest jellyfish known, is commonly seen floating about 2 m below the water surface in offshore and inshore marine environments of the VCWS. Captured specimens were found to have several ‘hitchhikers’, in the form of small crabs, under the bell. These giant jellyfish, which average 30 cm in diameter, are unusual in that they lack tentacles and feed only on microscopic prey which are sieved out of the water by the manubrium. They

often wash up on shore, where they are scavenged by plough shells, *Bullia* spp., and crabs.

The bluebottle or Portuguese man-of-war, *Physalia utriculus*, the raft hydroid, *Porpita pacifica*, and the by-the-wind sailor, *Velella* spp., which are all hydroids, were observed on the surface of the open sea off San Sebastian Bay. They are all driven along by the prevailing winds, and often strand on the shore.

Hard coral 'skeletons' belonging to the following genera were found on the reef and shoreline, and need to be studied further to determine the species present in the VCWS: *Acropora, Montipora, Porites, Favia, Meandrina, Pocillopora, Stylophora, Pavona, Platygyra, Leptoria* and *Dendrophyllia.* The following species were recognized: staghorn coral *Acropora irregularis* and plate coral *A. vasiformis.*

Phylum Ctenophora: *comb jellies*: These spherical, planktonic animals have rows of cilia along the sides of their bodies that are used for locomotion. They are carnivorous and feed on shrimp-like prey. Comb jellies, probably in the genus *Beroe*, were seen in the VCWS over the coral reef.

Phylum Platyhelminthes: *free-living flatworms*: Free-living flatworms were seen on the coral reef, but could not be identified. They are related to the parasitic flukes and tape worms, and feed on small crustaceans and molluscs.

Phylum Annelida: *segmented worms, bristle worms*: Bristleworms are among the commonest inhabitants of tropical rocky shores and coral reefs, and can be found under virtually every loose rock or colonial animal. The fireworm, *Eurythoe complanata*, and the beadworm, *Syllis* spp., were observed on the coral reef, and many more species are likely to be found in the VCWS in future. Unidentified tangleworms, feather-duster worms and coral-worms were seen on the rocky reefs. Bamboo worms, *Euclymene* spp., have been reported from Mozambican shores (Branch et al., 1994), but were not seen.

Phylum Arthropoda: *copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*: Arthropods have jointed limbs and a segmented body that is covered by a hard, jointed exoskeleton made of chitin. Because the exoskeleton cannot expand, arthropods periodically shed their exoskeletons (moulting) in order to grow. Arthropods include the insects and spiders, which are abundant on land but hardly represented in the sea, and the crustaceans, by far the most diverse group in the sea. Some crustaceans, such as crabs, are remarkably successful on land, in freshwaters and in the sea. Most crustaceans have several larval stages that are planktonic and are dispersed widely by currents before they metamorphose into adults.

Copepods undoubtedly occur in the VCWS, either as free-living forms in the plankton or benthos, or as parasites of fishes. The east coast rock lobster *Panulirus homarus* and the penicillate spiny lobster *P. penicillatus* were observed in crevices among rocks on the coral reef. The painted rock lobster *Panulirus versicolor* and the ornate spiny lobster *P. ornatus* occur along the

Mozambique coast (Branch et al., 1994) but were not seen. The cleaner shrimp *Stenopus hispidus* was recorded on the coral reef. Cracker shrimp *Alpheus crassimanus* probably also occur there but were not seen.

Phylum Brachiopoda: *lamp shells*: Lamp shells probably occur off the coast of the VCWS but were not recorded.

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squid*: Oysters were seen on the rocky coral reef, probably Cape pearl oyster *Pinctada capensis*. The giant clams *Tridacna squamosa* and *T. maxima* are spectacular inhabitants of the coral reefs and should be regarded as a flagship species. Giant clams filter invertebrates from the water column and also 'farm' microscopic algae that are housed in the brightly-coloured mantle lobes. They reach their southernmost limit of distribution in southern Mozambique/northern Zululand.

A Spanish dancer *Hexabranchus sanguineus* was observed over the coral reef. These spectacularly colourful nudibranchs are predators on the reef, and are a delight for divers to see. Their flamboyant colours warn potential predators of their unpleasant taste. Ridged nudibranchs, *Phyllidia* spp., may occur on the reef; they are dangerous as they produce toxic chemicals from their skin (Branch et al., 1994).

Phylum Echinodermata: *starfish, brittle stars, sea urchins, sea cucumbers, sea lilies, feather stars, sand dollars*: The echinoderms (five-rayed animals) are a flagship taxon for the VCWS due to their high diversity, abundance, importance in the food chain and importance to commercial and subsistence fishermen. Echinoderms are pentaradially symmetrical, a body form not found in any land animals. All five classes of echinoderms are present in the VCWS – starfishes, feather stars, brittle stars, sea urchins (including pansy shells) and sea cucumbers.

The beaded starfish *Pentaceraster mammillatus* is common on the coral reefs and sand flats between rocky reefs and is a great attraction to divers and underwater photographers. The crown-of-thorns starfish *Acanthaster planci*, which is a voracious coral predator and devastated corals on the Great Barrier Reef in Australia, has been recorded from the coast of northern Mozambique (Grindley, 1963) but has not as yet been recorded from Inhaca Island (Kalk, 1995) or elsewhere in southern Mozambique. The elegant feather star *Tropiometra carinata* was seen on the coral reef.

The needle urchin *Diadema setosum*, which has long, black, needlelike spines, inhabits crevices on coral and rocky reefs. The flower urchin *Toxopneustes pileolus*, which has lethally poisonous poison glands (Branch et al., 1994),was also seen. The spiny brittle star *Ophiocoma valenciae* and green brittle star *Ophiactis savigny* occur on the coral reef and debris; the latter often has six arms, as opposed to the five commonly found in echinoderms. Brittle stars are extremely common on the coral and rocky reefs and are by far the most mobile of the echinoderms; they are also very adept at hiding in crevices or under rocks when pursued.

14 Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*: The marine fishes known from the VCWS are detailed elsewhere in this report. The ichthyofauna of the Sanctuary and adjacent Bazaruto archipelago is extremely rich, with about 80% of all fish families in the world represented in the area. Dutton (1990) estimates the total species count of fishes in the area exceeds 2000; the present author concurs. Most fishes in the area are of Indo-Pacific origin and many have wide ranges in the Western Indian Ocean. This applies particularly to the highly migratory game fishes, including billfishes and large sharks. The recruitment of new stocks into the Sanctuary is therefore reasonably secure. There are very few endemic fish species or species with narrow ranges.

Fishes observed over the coral reef included:

Giant sandshark *Rhynchobatos djiddensis*, honeycomb moray eel *Gymnothorax favagineus*, floral moray eel *Echidna polyzona*, blackedged conger eel *Conger cinereus*, scorpionfish *Scorpaenopsis* spp., devil firefish *Pterois miles*, squirrelfish *Sargocentron* spp., soldiers *Myripristis* spp., bigeye *Priocanthus spp.*, cardinals *Apogon* spp., sea goldie *Anthias squammipinnis*, coral rockcod *Cephalopholis miniata*, yellowback fusilier *Caesio xanthonota*, stumpnose *Rhabdosargus* spp., moony *Monodactylus* spp., old woman *Pomacanthus rhomboides*, emperor angelfish *P. imperator*, jumping bean *Centropyge acanthops*, threespot angelfish *Apolemichthys trimaculatus*, semicircle angelfish *Pomacanthus semicirculatus*, swallowtail angelfish *Genicanthus caudovittatus*, threadfin butterflyfish *Chaetodon auriga*, pearly butterflyfish *C. madagaskariensis*, other *Chaetodon* species, wedgetail filefish *Paramonacanthus barnardi*, halfmoon triggerfish *Sufflamen chrysopterus*, whitespotted boxfish *Ostracion meleagris*, bluefin kingfish *Caranx melampygus*, golden kingfish *Gnathodon speciosus*, other *Caranx* species, spotted hawkfish *Cirrhitichthys oxycephalus*, freckled hawkfish *Paracirrhites forsteri*, sweepers *Pempheris* spp., sergeant major *Abudefduf vaigiensis*, blackbanded cardinal fish *Apogon cooki*, twobar clownfish *Amphiprion allardi*, chocolate dip *Chromis dimidiata*, blue pete *Pomacentrus caeruleus*, hogfish *Bodianus* spp., wrasse *Halichoeres* spp., tripletail wrasse *Cheilinus trilobatus*, cleaner wrasse *Labroides dimidiatus*, ember parrotfish *Scarus cyanescens*, fivesaddle parrotfish *S. scaber*, blue emperor fish *Lethrinus nebulosus*, flame goatfish *Mulloides vanicolensis*, powder-blue surgeonfish *Acanthurus dussumieri*, epaulette surgeon *A. nigricauda*, convict surgeon *A. triostegus*, other surgeons *Acanthurus* spp., clown triggerfish *Balistoides conspicillum*, whitespotted blaasop *Arothron hispidus*, fourbar porcupinefish *Lophodiodon calori*.

The swallowtail angelfish *Genicanthus caudovittatus*, which was observed in a shoal over the coral reef, has previously been recorded only as far south as Pinda (14°C) in Mozambique. A more thorough survey of the coral reefs off the VCWS will reveal many more fishes, probably in excess of 400 species.

Other significant fish species that are likely to occur over coral reefs in and around the VCWS could include:

Whitetip reef shark *Triaenodon obesus*, potato bass *Epinephelus tukula*, bluebanded snapper *Lutjanus kasmira*, firegoby *Nemateleotris magnifica*, spotted ragged-tooth shark *Eugomphodus taurus*, and many more. The stonefish *Synanceia verrucosa*, one of the most deadly fish in the world, probably also occurs on the coral and rocky reefs (as it does further south at Inhaca Island and in northern Zululand; pers. obs.). Kalk (1995) also reports that this species may lie half-buried in muddy sand between rocks near reefs. The stonefish discharges venom that may be lethal to humans within a few hours (Smith & Heemstra, 1986). For this reason it is essential that tourists (and researchers) should wear boots and gloves when venturing into these areas. The devil firefish *Pterois miles*, which also has venom in its spines, is found on the coral reef as well as in rocky pools and near substrates, such as jetties and logs, in the lagoon. Firefish are territorial and hunt crabs and small fishes. Firefish should not be handled as the venom may cause great pain although it is apparently not lethal to humans (Kalk, 1995).

Inflated and dried shortspine porcupinefish *Diodon liturosus* are sold in curio shops in Vilanculos, these would have originated from coral and rocky reef habitats offshore.

Game fish that occur in the open sea off the VCWS probably include the springer *Elops machnata*, eastern little tuna *Euthynnus affinis*, skipjack tuna *Katsuwonus pelamis*, king mackerel *Scomberomorus commerson*, queen mackerel *S. plurilineatus*, sailfish *Istiophorus platypterus*, barracuda *Sphyraena barracuda*, black marlin *Makaira nigricans*, blue marlin *M. indica*, striped bonito *Sarda orientalis* and garrupa *Epinephelus fasciatus*. Giant sandshark *Rhynchobatos djiddensis* are also considered to be game fish in Mozambique. Dutton (1990) gives a comprehensive list of principal marine fish species that are exploited in the Bazaruto archipelago, and the method of exploitation.

Dutton (1990) also reports that 100-120 billfish were landed around the Bazaruto archipelago annually in the 1980s out of a total recreational catch of about 250 billfish per annum for the whole of Mozambique.

The whale shark *Rhincodon typus* and the giant manta ray *Manta birostris* are conspicuous inhabitants of the marine offshore environment; 6 whale sharks, 9 dolphins, 3 dugongs and 11 manta rays were counted off the coast and over the lagoon of the VCWS during a 57 minute air flight in July 2002. The whale sharks are the largest of all fishes and reach a length of 12 m whereas the mantas achieve a disc width of 6.7 m. Both these giant fishes feed on plankton. Manta rays perform spectacular cartwheels at the water surface, or jump entirely out of the water, landing with a slap that is audible for kilometers around (Smith & Heemstra, 1986).

The interesting possibility exists that the coelacanth *Latimeria chalumnae* may occur off the coast of the VCWS. Coelacanths have been caught off South Africa, northern Mozambique (near Pebane), Comoros, Madagascar and Kenya (Bruton & Stobbs, 1991). Recently they have been seen by scuba divers off the coast of northern Zululand near Sodwana (H. Fricke, unpubl. obs.,

2002). The Sodwana coelacanths inhabit steep rocky canyons at depths of >100 m; whether such canyons occur off the Sanctuary and the Bazaruto archipelago is not known. The coelacanth, which is classified as 'endangered' in the Red Data Book and appears on Schedule I of CITES, is a flagship conservation species and has been nicknamed the 'panda of the sea' (Bruton & Stobbs, 1991).

The marine and coastal reptiles are investigated in a separate report, and a few comments will suffice here. Five species of marine turtles (known collectively as *xinholua* locally) occur off the Sanctuary, the green turtle *Chelonia mydas*, loggerhead turtle *Caretta caretta*, leatherback *Dermochelys coriacea*, hawksbill *Eretmochelys imbricata* and the olive ridley turtle *Lepidochelys olivacea*. According to Dutton (1990), the loggerhead, leatherback and hawksbill nest on beaches in the area, whereas the others probably only feed in the area. On this survey direct evidence was only found of the green turtle – 9 carapaces were found in the bushes near the fishing village on the north shore of the Sanctuary near Ponta Chiunzine. These specimens had been harvested some years previously. Dutton (1990) reported finding over 150 turtle carapaces on Bazaruto island, two thirds of which belonged to green turtles.

Yellow-bellied sea snake *Pelamis platurus* also occur off this coast. They spend their entire lives at sea and have potent venom.

Marine mammal species in and around the Sanctuary include the dugong *Dugong dugon*, four species of dolphins (common dolphin *Delphinus delphis*, spinner dolphin *Stenella longirostris*, hump-backed dolphin *Sousa plumbea* and bottlenosed dolphin *Tursiops truncatus*), the humpback whale *Megaptera novaeangliae*, and the Cape clawless otter *Aonyx capensis*. Other whale species, such as the sperm whale *Physeter macrocephalus* and the killer whale *Orcinus orca*, as well as the striped dolphin *Stenella coeruleoalba*, occur further offshore and are rarely seen.

The four dolphin species that frequent the Sanctuary are itinerant visitors from pelagic marine environments. The common dolphin *Delphinus delphis* often occurs in large schools and feeds on shoaling pelagic fishes. The bottlenosed dolphin *Tursiops truncatus*, an inshore species, also forms schools and feeds mainly on fish but also on squid, which may be caught using organized group-hunting formations (Branch et al., 1994). This species regularly becomes entangled in shark nets in KwaZulu-Natal and concern has been expressed that their birth rate does not match their mortality rate. They have also been reported to have very high hydrocarbon levels in their tissues (Branch et al., 1994). Spinner dolphin *Stenella longirostris* and humpback dolphin *Sousa chinensis* have also been reported from the nearby offshore marine environment (Dutton, 1990). The humpback dolphins live in shallow water and their presence is important as they are severely threatened elsewhere in their range.

All dolphin species are strictly protected but are vulnerable to capture or damage in large gillnets and possibly on long lines set for sharks (for shark fin harvesting, which is known to occur in the area). Dolphins are also vulnerable

to reductions in their prey fish densities due to game fishing and netting. Dolphins are seen on most boat trips to the entrance of the lagoon and out to sea, and are an important tourist attraction.

The humpback whale is a large baleen whale reaching a length of 14-15 m. They are characterized by their very long, narrow flippers, almost one-third the length of the body, and the small dorsal fin that is positioned far back. They spend the summer feeding on krill in the Southern Ocean and then migrate northwards along the west and east coasts of southern Africa to breeding grounds along subtropical and tropical coasts. Humpback whales use an unusual bubble curtain, formed while circling underwater, to catch their prey. They rely on their blubber reserves for nutrients during the winter feeding migrations. They perform spectacular breaches and jumps, and are sociable species. Their numbers were drastically reduced by hunting to less than 10% of the original population size before they were fully protected in 1963. Their populations have recovered strongly in recent decades, although not as strongly as those of the southern right whale *Balaena glacialis*. Repeated sighting of humback whales off the coast of the Bazaruto/VCWS area may indicate that they have a preference for this area. Dutton (1990) reports seeing them feeding off the coast, possibly on the blue-line herring *Herklotsichthys quadrimaculatus*.

Other whales that occur off this coast include fin whale *Balaenoptera physalus*, minke whale *B. acutorostrata*, sperm whale *Physeter macrocephalus* (further offshore) and killer whale *Orcinus orca*. The southern right whale *Balaena glacialis* was previously extensively hunted off the coasts of Namibia, South Africa and Mozambique. Since they were protected in 1963 they have recovered strongly in South Africa (7-8%) but their recovery off Mozambique appears to be slower (Branch et al., 1995). Bottlenosed dolphin *Tursiops truncates* and spinner dolphin are common offshore. The striped dolphin *Stenella coeruleoalba* was not seen probably also occurs here.

Sandy shores on sheltered and exposed coasts:

Phylum Arthropoda: *copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*: Unidentified species of isopods, possibly in the genus *Pontogeloides*, are common under logs and flotsam on the beach. Hermit crabs, probably the land hermit *Coenobita cavipes* or *C. rugosu* , were abundant on the beach above the high tide mark. The ghost crabs *Ocypode ryderi, O. ceratophthalmus, O. cordimana* and *O. madagascarensis* are common on the beach at low tide and are particularly conspicuous at night when they forage in and above the tidal wash. *O. ryderi* is used as bait by local sea fishermen.

Ghost crabs prey on other crabs, such as the sentinel crab *Macrophthalmus* spp., as well as prawns and wedge mussels *Donax faba*. Juvenile ghost crabs achieve the fastest running speed of any crab (2.1 m per second; Kalk, 1995). Their main predators are man, birds and carnivorous crabs, including their own species. Ghost crabs are keystone ecological species due to their abundance and critical role in the beach ecosystem.

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squids*: The burrows of shipworms *Bankia carinata* were found in wood flotsam on the beach. The striped periwinkle *Littoraria glabrata* is common above the high spring-tide level. Several cowries were collected on the sea beach including ring cowrie *Cypraea annulus*, Arabic cowrie *C. arabica*, tiger cowrie *C. tigris* and stippled cowrie *C. staphylaea*. Cowries are over-collected in many parts of the world and require protection.

The violet snail, *Janthina* spp., was observed washed up on the shore. They hang upside down on the sea surface using a bubble raft and feed on by-the-wind-sailors *Velella* and bluebottles *Physalia*. The tropical plough shell, *Bullia* spp., either *B. mozambicensis or B. natalensis*, lives in the wave wash zone and feeds on dead animals, especially stranded jellyfish. The wedge mussel *Donax faba* is abundant on the wave-washed sandy beaches of the marine coast; off Inhaca island they reach densities of > 100/m² (Kalk, 1995). They burrow 2-5 cm beneath the sand surface and feed on diatoms. *D. faba* is unique to the east coast of Africa and occurs in over 30 different colour patterns.

Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*:

Nine green turtle *Chelonia mydas* carapaces were found in the bushes near the fishing village on the north-west shore of the Peninsula near Ponta Chiunzine. They were probably caught in nets in the lagoon or estuary as this species does not normally nest on the African mainland but on central Indian Ocean islands (Branch et al., 1994). Juveniles eat small fish and crustaceans whereas the adults feed almost entirely on marine plants. Other sea turtle species that occur off the marine coast in the vicinity of the VCWS include the olive ridley turtle *Lepidochelys olivacea*, hawksbill turtle *Eretmochelys imbricata*, leatherback *Dermochelys coraicea* and the loggerhead turtle *Caretta caretta*. The loggerhead and leatherback probably nest along the marine coast, as they do in northern Zululand and southern Mozambique to the south. The loggerhead feeds on crabs, molluscs and sea urchins whereas the leatherback feeds on coelenterates, jellyfish and bluebottles. The breeding biology, abundance and conservation status of the sea turtle species that nest on the coast of the African mainland have been very well documented (e.g. Hughes, 1974a & b).

The marine and coastal birds of the Sanctuary have been investigated in a separate report, and a few comments will suffice here. The most conspicuous aquatic birds are the greater flamingo *Phoenicopterus ruber* and the lesser flamingo *P. minor* (known collectively as *halawunha* locally), which occur in large flocks that vary seasonally in size. The lagoonal habitat in and around the Sanctuary is ideal for flamingoes and there is potential for the VCWS to become a world-renowned site for observing these spectacular birds, comparable to Lake Ngami in Botswana (now dry) and Lake Naivasha in Kenya. The greater flamingo feeds by disturbing the bottom sediments, often rotating in a circle, whereas the lesser flamingo feeds by filtering the water. Both feed on small aquatic invertebrates, and their feeding pressure is known

to impact on the density of benthic organisms (Branch et al., 1994). Pollution of the lagoonal water would impact the density of prey organisms of the flamingo. In particular, it is a matter of concern the number of torch batteries that are left lying in the water by fishermen; these batteries contain lead and other contaminants and should never be discarded in the water, 32 batteries were found lying in the water in the Sanctuary during a period of 6 days, all near fishing villages. Every effort should be made to avoid contaminants, such as fuel and fuel residues, sewage, insecticides, herbicides, disinfectants and inorganic fertilizers, from entering the water in the Sanctuary. Flamingoes have been hunted in the past in Mozambique (pers, obs., 1993 near Xai Xai) and may still be hunted clandestinely in the Vilanculos area.

The mangrove and reed swamps are rich habitats for aquatic bird species, including a variety of herons, cormorants, egrets and kingfishers. The shores of the estuarine lagoon, San Sebastian Bay and the marine sandy beach support a wide variety of waders, sandpipers, turnstones, sanderlings, plovers, gulls and terns.

Rocky shores:

Phylum Porifera: *sponges*: The crumpled sponge, *Axinella waltneri,* was observed on inshore reefs.

Phylum Cnidaria: *hydroids, bluebottles, jellyfish, soft corals, sea fans, sea pens, sea anemones, zoanthids and hard corals*: The giant anemone, *Radianthus ritteri*, occurs on coral debris and coral reefs in the VCWS as well as in the tidal shallows and sea grass beds of the lagoon, estuary and Bay. They typically play host to commensal shrimps and clownfish, which are not affected by their stinging tentacles. The giant anemone is an important component of the biota of the VCWS, and should be regarded as a flagship species; they should be the subject of more detailed study.

A zoanthid, *Palythoa nelliae,* forms carpets in pools in the inshore reef in areas that are periodically covered by sand. Other unidentified zoanthids also inhabit rocky ledges and pools. The root-mouthed jellyfish, *Rhizostoma* spp., is commonly seen floating about 2 m below the water surface in offshore and inshore marine environments of the VCWS. Hydroids form colonies of numerous individuals (polyps) and are tree-like or feather-like in form. Several hydroids were observed in rocky pools, possibly the bushy hydroid, *Eudendrium* spp., the thin-walled obelia, *Obelia* spp, and the toothed feather-hydroid, *Aglaopenia* spp. The mushroom coral *Fungia actiniformes* occurs as individuals in intertidal pools.

Phylum Nemertea: *ribbon worms*: Ribbon or proboscis worms probably occur on rocky reefs in the VCWS but were not observed.

Phylum Sipunculida: *peanut worms*: Peanut worms probably occur on rocky reefs in the VCWS but were not observed.

Phylum Annelida: *segmented worms, bristle worms*: Mussel worms, *Pseudonereis* spp., were observed among mussels in the inshore reef. The fireworm, *Eurythoe complanata,* and the beadworm, *Syllis* spp., were observed on the rocky reefs.

Phylum Arthropoda: *copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*: Goose barnacles, *Lepas* spp., were observed on flotsam on the sandy shore inshore of rocky reefs. Toothed barnacles, *Chthamalus* spp., both occur on rocky reefs along the marine coast of the VCWS. Carapaces of the east coast rock lobster, *Panulirus homarus* and the painted rock lobster *P. versicolor* were found inshore of rocky reefs. Dutton (1990) reports that the above two species as well as the penicillate spiny lobster *P. penicillatuts* and the ornate spiny lobster *P. ornatus* are harvested by skin divers at Inhassoro to the north, with exports of lobster tails exceeding 400 tonnes pa. The yellow-banded hermit crab *Clibanarius virescens* and other species of hermit crabs are common in intertidal pools. The tuberculate crab *Plagusia depressa tuberculata* was observed in intertidal pools whereas the Natal rock crab *Grapsus grapsus tenuicrustatus* was conspicuous on rocky ledges above water at low tide.

Phylum Bryozoa: *moss or lace animals*: Many species of bryozoans inhabit the rocky reefs and intertidal rocky ledges, but their identity is unknown.

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squids*: Brown mussels *Perna perna* occur in dense beds along the marine coast. The Cape pearl oyster *Pinctada capensis,* Natal rock oyster *Saccostrea cucculata* and the Cape rock oyster *Striostrea margaritacea* are found on shallow rocky reefs along the marine shore. They are exploited by local fishermen. The black chiton *Onithochiton literatus,* variegated topshell *Oxystele variegata,* variable limpet *Patella concolor,* keyhole limpet *Fissurella natalensis,* blotched nerite *Nerite albicilla,* mulberry shell *Morula granulata* and the crowned turban shell *Turbo coronatus* all occur on rocky reefs in the VCWS.

The zonation of molluscs and other invertebrates in the intertidal zone of the VCWS, with the *Littorina* belt high on the tide line and other species occurring in characteristic bands, is similar to that described for Inhaca Island by Kalk (1995).

Octopus, probably *Octopus granulatus,* were harvested by local fishermen from intertidal pools in the sea but are reportedly less common now than before.

Phylum Echinodermata: *starfish, brittle stars, sea urchins, sea cucumbers, sea lilies, feather stars, sand dollars*: The blocked starfish *Fromia elegans* was seen on the rocky reef off the lighthouse. The spiny brittle star *Ophiocoma valenciae* occurs under rocks on the reef. The oval urchin *Echinometra mathaei,* and other sea urchins, occurs in intertidal rock pools. The sea cucumber *Holothuria insignis* is found under rocks.

Phylum Chordata: ***sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*****:** A colony of striped eel-catfish *Plotosus lineatus* was seen under an overhang in the inshore reef near the lighthouse. Other fish species observed on this reef included devil firefish *Pterois miles,* bluebanded snapper *Lutjanus kasmira*, stonebream *Neoscorpis lithophilus*, lizardfish *Synodus* spp., klipvis, probably *Pavoclinus graminis*, various gobies, barred flagtail *Kuhlia mugil*, flame goatfish *Mulloides vanicolensis*, rockskippers *Antennablennius* and *Istiblennius* spp. and cleaner wrasse *Labroides dimidiatus*.

Spotted grunter *Pomadasys commersonnii,* santer *Cheimerius nufar*, slinger *Chrysoblephus puniceus,* Natal stumpnose *Rhabdosargus sarba,* river snapper *Lutjanus argentimaculatus* and kingfish *Caranx* spp. (the latter known locally as *hokote or karapao*) were recorded in fishermen's catches from the sea near the lighthouse.

Dutton (1990) reported that seine nets pulled over rocky reefs in the Bazaruto archipelago yielded catches of 50-150 kg/net and approximately 58 000 kg of dried fish per year. This level of exploitation does not appear to take place off the VCWS. Dutton (1990) also reported that spearfishing is common and lucrative in the Bazaruto area, with a harvest of over 40 000 kg per year.

Estuarine systems:

Phylum Cnidaria: ***hydroids, bluebottles, jellyfish, soft corals, sea fans, sea pens, sea anemones, zoanthids and hard corals*****:** The giant anemone, *Radianthus ritteri*, occurs on coral debris and coral reefs in the VCWS as well as abundantly in the tidal shallows and seagrass beds of the lagoon, estuary and Bay. They typically play host to commensal shrimps and clownfish, which are not affected by their stinging tentacles. The giant anemone is an important component of the biota of the VCWS, and should be regarded as a flagship species; they should be the subject of more detailed study.

The root-mouthed jellyfish, *Rhizostoma* spp., is commonly seen floating about 2 m below the water surface near the estuary mouth. The Portuguese man-of-war, *Physalia utriculus*, was observed in the estuary.

Phylum Annelida: ***segmented worms, bristle worms*****:** Numerous unidentified segmented worms were seen. Estuarine nereids, *Ceratonereis* spp., and the case worm, *Diopatra* spp., are likely to occur in the estuary.

Phylum Arthropoda: ***copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*****:** Striped barnacles *Balanus amphitrit*, were recorded on fish trap fences in the estuary. The tiger prawn *Penaeus monodon* and the brown prawn *Metapenaeus monoceros* are harvested in the estuarine lagoon and in San Sebastian Bay. *P. monodon* and *M. monoceros* are very important commercial species in Mozambique (Branch et al., 1994). The blue swimming crab *Portunus pelagicus* is harvested in the estuarine lagoon. The mud crab *Scylla serrata* was observed while diving and wading in the southernmost reaches of the estuary near the path to the lighthouse, where it

appears to be less exploited, and more common, than in San Sebastian Bay. The army crab *Dotilla fenestrata* occurs in huge colonies along the shores of the estuary, and is particularly common on the embankment from which one embarks for the journey to the lighthouse. They use tiny pellets of processed sand to construct elaborate burrows.

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squids*: The brack-water mussel *Brachidontes virgiliae* and the estuarine mussel *Arcuatula capensis*, which live in estuaries, and are reported from Mozambique (Branch et al., 1994) and probably occur in the VCWS. The horse mussel *Pinna muricata* is common in suitable habitat and is a menace to people wading in the shallows. A community of small animals lives in association with them. Shells of the smooth platter shell *Loripes clausus* and the sunset clam *Hiatula lunulata* were collected from the estuary.

The shaggy sea hare *Bursatella leachi* was observed in the seaward entrance to the estuary. A slipper limpet, probably *Crepidula* spp., was found on a mangrove stem.

Phylum Echinodermata: *starfish, brittle stars, sea urchins, sea cucumbers, sea lilies, feather stars, sand dollars*: The beaded starfish *Pentaceraster mammillatus* is present in the deeper parts of the estuarine system and is often stranded at low tide. The heart urchin *Echinocardium cordatum,* locally known as *nungu*, is commonly found on the beach at the entrance to the estuarine lagoon, although Branch et al. (1994) report that this species only occurs as far north as Delagoa Bay. The pansy shells *Echinodiscus bisperforatus* (with two closed slits on the test) and *E. auritus* (with the slits extending to the edge of the test) are abundant in the seaward reaches of the estuary as well as in the tidal flats and sea grass meadows.

Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*: The lesser sand shark *Rhinobatos annulatus,* bartail flathead *Platycephalus indicus* (locally known as *nhantsenze),* glassy *Ambassis gymnocephalus* and the smallscale pursemouth *Gerres acinaces* were recorded from the estuarine inlet near the path to the lighthouse. The honeycomb stingray *Himantura uarnak* and the largetooth sawfish *Pristis pectinata* probably occur in the estuarine inlet but were not seen or recorded in fishermen's catches. Sardinelles, *Sardinella* spp., wolfherring, *Chirocentrus* spp., ladyfish *Elops machnata,* thornfish *Terapon jarbua,* Natal stumpnose *Rhabdosargus sarba,* bigeye kingfish *Caranx sexfasciatus,* talang queenfish *Scomberoides commersonnianus,* grunter *Pomadasys furcatum,* and bony *Thryssa vitrirostris* were found in fishermen's catches in the estuary and lagoon. Other species that are likely to occur in the estuary and Bay, but which were not seen, include oxeye tarpon *Megalops cyprinoides* and milkfish *Chanos chanos*. Flathead mullet *Mugil cephalus*, blue-tail mullet *Valamugil buchanani*, and other species of mullet, occur commonly in the estuary.

A very interesting cichlid fish, the black tilapia *Oreochromis placidus*, was seen while skin diving on the fringes of a mangrove swamp at the southern

edge of the estuarine lagoon near the path to the lighthouse. This relatively rare cichlid has been reported from the coastal plain of Mozambique from the lower Zambezi River southwards to the Mkuze River in Zululand (Skelton, 1993) and was first reported in South Africa at Sodwana Bay by Bruton (1975). *O. placidus* is frequently found together with the Mozambique tilapia *Oreochromis mossambicus*, which is known to be extremely tolerant of sweater. *O. placidus* frequents well-vegetated, sheltered habitats in floodplain lagoons and coastal lakes.

Sea meadows and sand banks:

Introduction to ecology of sea meadows: The sea grass meadows of the VCWS represent one of the most productive and diverse habitats in the marine subsystem, together with coral reefs. The sea grass beds are 'anchored' by vast meadows of submerged flowering plants that provide shelter for a mobile and sessile community of invertebrate and vertebrate animals. The sea grasses are typically coated with growths of red coralline algae which together provide a vast surface area under the water that provides shelter, holdfasts and food for the tidal flats community. The extensive system of rhizomes and roots of the sea grasses consolidates the loose, fine mud and sand in which many animals burrow. Furthermore, the sea grasses shed their leaves continuously and through their rapid decay they contribute hundreds of tonnes of detritus annually to marine and coastal systems (Kalk, 1993).

Their rate of production exceeds that of tropical forests and exceeds that produced by seaweeds (McRoy & McMillan, 1977). This detritus is the foundation of the food web of this ecosystem and the sea grasses therefore act as 'nutrient pumps' into the lagoonal system. The sea grass beds also act as a substrate for the sand oysters *Pinctada imbricata* that are heavily exploited by local people. They also provide a fascinating and easily accessible dive site for skin divers and glass-bottomed boat passengers. The plants themselves are eaten by few animals (as in freshwater macrophytes) but the leaves are covered with an epiphytic fauna and flora on which many species browse. The sea grass meadows are also valuable feeding and roosting areas for migrant waders and vast flocks of flamingos.

Kingdom Plantae, division Spermatophyta, subdivision Angiospermae: flowering plants: The sea meadows comprise three main angiosperm species in the VCWS: the *Thalassodendron ciliatum*, *Cymodocea serrulata* and *Thalassia hemprichii.* These species occur in different proportions in the meadows of the tidal flats depending on the degree of exposure, water depth and distance from the sea.

Kingdom Animalia: animals
Phylum Porifera: *sponges*: A large unidentified sponge occurs in shallow water along the fringes of the tidal lagoon near the north shore of the VCWS. These sponges are situated in a hemispherical basin and form a protected microhabitat, in an otherwise very exposed environment, for a variety of commensals, including small crabs, brittlestars, cowries, cone shells, bristle-

worms (polychaetes), nereids and shrimps. A bright yellow sponge, possibly *Haliclona tulearensis*, is also widespread in the sea grass.

Phylum Cnidaria: *hydroids, bluebottles, jellyfish, soft corals, sea fans, sea pens, sea anemones, zoanthids and hard corals*: The giant anemone *Radianthus ritteri* occurs abundantly in the tidal shallows and sea grass beds of the lagoon, estuary and Bay. They typically play host to commensal shrimps and clownfish *Amphiprion allardi*, which are not affected by their stinging tentacles.

The root-mouthed jellyfish, *Rhizostoma* spp., is commonly seen floating about 2 m below the water surface over sea grass meadows. The Portuguese man-of-war, *Physalia utriculus*, was observed in the Bay over sand banks. Comb jellies, probably in the genus *Beroe*, were seen in the Bay.

The mushroom coral *Fungia actiniformes* occurs as individuals in the sea grass beds. *Fungia* first grows on coral reefs as an attached colony but buds in the form of tiny discs, made by one polyp, which breaks off and is carried to sea grass meadows by currents. Here they sink to the bottom and grow (Kalk, 1995).

Among the most interesting benthic invertebrates on the submerged sandy flats in San Sebastian Bay are the sea feathers, *Virgularia gustaviana*, and the sea pens, *Vertillium leloupi*, which are burrowing coelenterates. *V. gustaviana* is an erect, brilliant orange colony of coelenterates in the shape of large feather over 200 mm tall. The 'feather' is supported by a stiff rod made of aggregated calcareous spicules, and the purple autozoid polyps are closely set on the stiff branches of the feather (Kalk, 1995). The submerged part of the orange shaft ends in a bulbous swelling that is buried in the sand. The sea pens have a more compact cream or mauve bodies with purple polyps that are supported by a stiff mass of spicules in a narrow rod. *V. leloupi* grows to about 120 mm tall and has a bulb at the lower end.

Both the sea pens and the sea feathers are supported by hydrostatic pressure by virtue of the water that is drawn into the enteron when the organism erects. When the colony is touched, or impacted by a strong bow wave, it contracts suddenly into the sand by expelling water rapidly through the opened orifices of the siphonozoids and the autozoids (Kalk, 1995; pers. obs., 2002). Sea pens and sea feathers are able to survive exposure at low tide by retracting into the sediment. They emerge again as the tide rises and catch zooplankton by means of their pinnate tentacles, which have typical coelenterate nematocysts (stinging cells). Sea pens and sea feathers are reported to be bioluminescent in the dark (Kalk, 1995).

The sea pens and sea feathers are remarkable examples of the way in which so-called 'lower invertebrates' are able to form complex colonies containing cells that are specialized for different tasks. The colony is thus able to perform tasks, and survive in hostile environments, in competition with highly advanced organisms. The specialized cells in sea feathers include feeding polyps (autozoids), pressure-maintaining polyps (siphonozoids) and stinging

cells (nematocysts). The communities of sea pen and sea feather colonies are easily visible in water depths of 16 m in the shallow channels to the south-west and west of Dugong Camp, and should be of considerable interest to visitors.

Paul Dutton discovered extraordinary volcano-shaped fossil burrows of some unknown underwater animal in the waters surrounding the Bazaruto archipelago (Mason & Ramsay, date unknown); these fossil burrows were subsequently named after him (*Vulcanichnus duttoni*). The author discovered similar burrows on the tidal flats of the VCWS while skin diving to the west of the peninsula. The distribution and abundance of these fossil burrows needs to be investigated.

Phylum Annelida: ***segmented worms, bristle-worms*****:** Bristle worms are common in the sea grass meadows , especially under sponges and in the shelter of fan shells.

Phylum Arthropoda: ***copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*****:** Unidentified species of amphipods and isopods were found among sea grass and sea grass debris.

The east coast rock lobster, *Panulirus homarus*, is harvested by local spearfishermen on a series of rocky reefs in the southern end of San Sebastian Bay. Judging from the small sizes of the carapaces at their fishing camp, this resource has probably been overexploited. The tiger prawn, *Penaeus monodon*, is harvested in San Sebastian Bay. The blue swimming crab or chinaman *Portunus pelagicus* (locally known as *ngange*) is extensively harvested over sea grass beds and tidal sandy flats in San Sebastian Bay, often as a bycatch of the sand oyster trawlery. The crabs are used as a subsistence food by local inhabitants. Dutton (1990) estimated that about 5 760 kg of blue crabs are harvested per year from the Bazaruto archipelago, with about 30% of the catch sold and the balance used for local consumption. Blue swimming crabs fight viciously when touched and should not be handled as they can inflict a nasty bite that may become septic. *P. pelagicus* is commonly sold in markets on the mainland in Mozambique.

The mud or edible crab *Scylla serrata* occurs widely in the Bay but is heavily exploited. They can inflict painful bites with their extremely powerful nippers. Pea crabs, *Pinnotheres* spp., were found inside the shells of bivalves in the sea grass beds. The elbow crab *Myra fugax*, which has very long chelipeds, is occasionally caught in fishermen's nets. Hermit crabs, especially *Dardanus* spp., are abundant in the sea grass beds and inhabit a wide variety of shells. The hermit crab *Aniculus strigatus* inhabits cone shells, *Conus* spp., and is abundant in some areas. They are used as bait by handline fishermen.

Shrimps and prawns are widespread in the sea grass beds and are caught in seine nets. The most common species is the pistol shrimp *Alpheus crassimanus*. This species, and other shrimps, were observed to share their burrows with gobies. The palaemonid shrimp *Harpilius brevicarpalis* was commonly seen in association with the giant green sea anemone *Heteractis*

magnifica in the sea grass beds. The shrimps feed and hide among the tentacles of the anemone. Clown fishes *Amphiprion allardi* are also commensal with this anemone. Well-camouflaged green *Hippolyte* shrimps also inhabit the sea grass beds. Stomatopod shrimps, such as the mantid shrimp *Pseudosquilla ciliata,* make large mounds of sand in the sea grass beds. These remarkable shrimps have the second pair of legs modified into a pair of formidable claws similar to those of the preying mantis. They prey on small fishes and other crustaceans and can inflict deep wounds in the fingers of humans if they are collected!

There is abundant apparently suitable habitat for the sand prawn *Callianassa kraussi* but they were not recorded; according to Branch et al. (1993), the northern range of their distribution is Delagoa Bay, and they do occur at Inhaca Island (Kalk, 1995).

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squid*: Sand oysters *Pinctada imbricata* (locally known as *mapalo*) are collected extensively in the sand flats mainly for food but also for sale. The sand oysters are consumed fresh or salted for later use. *P. imbricata* occurs associated with the sea grasses *Thalassodendron ciliatum* and *Zostera capensis* where they attach themselves to the grass stems using their byssus threads. Dutton (1990) reports on a detailed survey of the densities and yields of *P. imbricata* to the traditional fishery in the Bazaruto archipelago. He estimated that about 1.9 tonnes of dry *mapalo* are harvested each month, with each person collecting about 500 animals per day (6 kg wet weight) for the nine days each month during which they are harvested.

Two species of tropical fan shells (pinnid bivalves) inhabit the sea grass beds and surrounding sand flats. Their large, 10-20 cm long, triangular shells stand upright in the sand with the narrow end pointing downwards, and attached to buried stones by strong byssus threads. The outer edge of the shell, which is razor-sharp, lies at the sand surface. The horse mussel, probably *Pinna muricata,* and the fan shell *Atrina pectinata* are common in suitable habitats in and around sea grass beds. They are damaged by seine nets and trampling, and cause lacerations to the feet of fishermen (and scientists). They host commensal shrimps (*Anchistus* spp.), mantid shrimps *Pseudosquilla ciliata* and pea crabs (*Pinnotheres* spp.).

The tropical cockle *Trachycardium flavum* is abundant on the tidal sand flats where it burrows shallowly into the sand. Cockles can ‘hop’ by suddenly thrusting out the foot – a mechanism for evading predators. The beaked clam *Eumarcia paupercula* is abundant in the sea grass meadows and tidal sand flats, and is probably a keystone species ecologically. Their smooth, convex shells have a buff ground colour and a very variable range of radial markings ranging from cream to brown and purple, often with zigzags, flecks or rays. This species is so abundant that consideration could be given to collecting the dead shells for making ornaments and mobiles. Their shells are often penetrated by the holes of shell borers. The smooth trough shell *Mactra glabata* is also commonly found buried just below the sand surface in the sea grass beds. A scallop, probably *Chlamys senatoria,* is found on the tidal sand

flats. An otter shell, *Lutraria* spp., was collected; this is an unusual record as this genus is not reported from Mozambique by Branch et al. (1994). The coiled collars of eggs laid by the moon shell, *Polinices* spp., were seen on the sand flats. Periwinkles, probably *Littoraria* spp., are extensively harvested by fishermen at Ponta Chiunzine.

Two cowries are common in the sea grass beds – *Cyprea annulus* and *C. moneta*. *C. moneta* is the money cowrie of the nineteenth century slave trade, but has no commercial value anymore. The short-spined murex *Murex brevispinna* lives amongst sea grass on the tidal flats where it feeds on molluscs. Like many other sea grass inhabitants, they are caught in seine nets. Carnivorous cone shells, such as *Conus lividus*, were also recorded in the sea grass beds. They have poisonous secretions that kill their prey and are dangerous to humans. The cone shells feed on acorn worms and tunicates (Kalk, 1995). Small octopuses were caught in seine nets on the tidal flats where they live in the sea grass beds. Many species of unidentified, burrowing molluscs belonging to the genera *Tellina, Codakia, Mactra* and others, occur in the sea grass meadows. Sea slugs were seen occasionally in the sea grass meadows. Cuttlefish *Sepia* spp. (locally known as *toni*) and common octopus *Octopus granulatus* (known locally as *nhamutununu*) were harvested in the entrance to the Bay by local fishermen and are dried on drying racks in the sun. A minute octopus was found in the shell of a bivalve in the sea grass beds.

Dutton (1990) gives a comprehensive list of the principal ornamental mollusc shells that are collected from the Bazaruto archipelago, with an indication of the demand for each species. His findings would apply to the VCWS as well.

Phylum Echinodermata: *starfish, brittle stars, sea urchins, sea cucumbers, sea lilies, feather stars, sand dollars*: The beaded starfish *Pentaceraster mammillatus* (known locally as *tsambalala*) is extremely common and conspicuous because of its large size (up to 22 cm across), bright colours and habit of sitting on top of the sand. They occur throughout the sandy tidal flats, sometimes in densities of >1/m², and are also common in the sea grass beds. They are often stranded at low tide and attempt to creep back to the water using their tube feet, but do not suffer serious desiccation over one tidal cycle. The colours are very variable, including yellow, green, brown, red and grey. Rows of brightly coloured knobs run down each arm and around the body margin. *Protoreaster lincki*, a related species, is also reported from Mozambique (Kalk, 1994). The sand starfish *Astropecten monocanthus* burrows just below the surface of the sand in channels; the five-rayed shape of the buried animal can be clearly seen from above.

The spiny brittle star *Ophiocoma valenciae* is abundant wherever there is cover in the sea grass, under sponges, next to tusk shells or under logs and rocks; other unidentified brittle stars (possibly *Amphiura* and *Amphipolis* spp.) also occur in these habitats. The burrowing brittle star *Amphioplus integer* is widespread in sandy mud where it burrows with two or three arms protruding above the mud for feeding. A pencil urchin, *Prionocidaris baculosa*, occurs in the sea grass meadows. Their banded spines are sold as ornaments. Dried

specimens of a heart urchin, possibly *Lovenia elongatum*, were found stranded on the beach at the entrance to the estuary and in the sea grass meadows, where they were caught in seine nets by local fishermen.

The short-spined sea urchin *Tripneustes gratilla* reaches a test diameter of 145 mm and is common in the sea grass. They often accumulate pieces of algae on their tube feet, which serves as camouflage. Their dried tests often wash up on the shore. The needle urchins *Diadema setosum* and *D. savigny* are widespread in the sea grass beds where they graze on algae. They have an irritant toxin in their hollow spines and should be handled with extreme care. When approached they are able to move their spines towards the intruder as a defensive mechanism.

Sea cucumbers are very common in some parts of the estuarine inlet, in the tidal sand flats and in the sea grass meadows, sometimes in abundance, more so than the author has seen before anywhere along the southern African coast. These peculiar echinoderms have lost their star-shaped symmetry and are elongate with soft, leathery skins. The snake sea cucumber *Synapta maculata* (known locally as *tchekawandala*) reaches a length of >1.2 m and occurs in dense aggregations in deeper channels and shallow areas of the lagoon that remain flooded at high tide. They look extraordinarily like coiled snakes underwater, and often form intertwined masses on the sandy bottom. When they are picked up, they elongate alarmingly and their spicules attach to the skin or dive suite. A commensal shrimp *Periclimenes rex* lives in their cloaca (Kalk, 1995). The black sea cucumber *Pseudocnella sykion* also occurs in the tidal sand flats. A grey sea cucumber with orange markings, probably *Opheodesoma mauritiania*, also occurs in the sea grass meadows.

The black tufted sea cucumber *Holothuria scabra*, known locally as *makajojo*, which is black above and grey below and often has sand adhering to its skin, is less abundant, probably because it has been extensively harvested by fishermen for sale in Vilanculos, where they are dried and exported for human consumption (Branch et al., 1994). Dutton (1990) reported that about 5 781 kg of dried *H. scabra* was exported to the mainland from the Bazaruto archipelago in 1989/90. Over the same period a fishing organization PESCOM commercialized a total of 39 000 kg of *H. scabra* for the islands and adjacent mainland. *H. scabra* occurs singly in shallow water, sometimes half-buried in the sand, and they are harvested by fishermen using two- or three-pronged spears (pers. obs., 2002). They feed by swallowing large quantities of sand and sift out the organic matter. The drying of *makajojo* over a fire requires the use of large amounts of firewood, which also contributes to resource depletion.

Another black sea cucumber, *Holothuria leucospilota*, has the unpleasant (for predators) habit of expelling a mass of stiff, white sticky strings from the cloaca when it is picked up (as the author and his helpers found). These strings are very difficult to remove from skin and wet suits. *H. leucospilota* was found in deeper channels throughout the tidal sand flats.

The sand dollars or pansy shells *Echinodiscus bisperforatus* (100 mm across) and *E. auritus* (200 mm, which is deep purple in colour) are common in the

tidal flats, estuarine lagoon and sea grass meadows. Care needs to be taken that they are not overcollected by tourists, destroyed by seine nets pulled by local fishermen or trampled by gleaners of sand oysters.

Phylum Hemichordata: acorn worms: Concentric worm casts are a characteristic features of the sand flats and sea grass beds. These casts are produced by acorn worms, *Balanoglossus* spp., which are not 'worms' in the primitive sense of the word, but hemichordates that share some anatomical characteristics with Chordates, including the backboned animals. They have a dorsal notochord, a dorsal nerve chord and a rudimentary blood system. They burrow in the sand and can be extremely numerous. They probably play a critical role in releasing nutrients from the sediments into the water column.

Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*: The lesser sand shark *Rhinobatos annulatus* (locally known as *livambelua*) and the devil firefish *Pterois miles* were seen at high tide over the sand flats, the latter somewhat out of its habitat. *P. miles* also colonized the artificial reef, and the jetty, established off Dugong Camp, as did the raccoon butterflyfish *Chaetodon lunula*. Three seahorse specimens, probably *Hippocampus kuda*, were collected (and released) on a sea grass meadow to the north-west of the Peninsula in the entrance to San Sebastian Bay. Despite subsequent searches using snorkels and goggles over a combined period of over four hours, no further sea horses were found and the species identity could not be confirmed. It appears that this protected species has been severely depleted by commercial collectors who sell the dried seahorses to a Chinese trader in Vilanculos, who exports them to the Far East. Sea horses apparently do not have a local Xitsua name but they are called *cavalho marinho* in Portuguese. Alligator pipefish *Syngnathpoides biaculeatus* were more often found in the sea grass, but they are also exploited.

The vertically-swimming shrimpfish or razorfish *Aeoliscus punctulatus* was also seen. Kalk (1994) reports the ghost pipefish *Solenostomus cyanopterus* from sea grass beds off Inhaca Island; they probably occur at the VCWS but were not seen. The ringed snake-eel *Myrichthys colubrinus* was seen guarding its burrows in the sea grass beds; this species has black rings on a yellow body and is often mistaken for a sea snake. The snake-eel is harmless but has a stiff, sharply-pointed tail with which it burrows backwards into the sand. The crested weedfish *Ablabys binotatus*, a well-camouflaged inhabitant of the sea grass beds, has poisonous spines, like many other slow-moving fishes. Whitespotted rabbitfish *Siganus sutor*, domino *Dascyllus trimaculatus*, zebra *Diplodus* spp., tropical halfbeak *Hyporamphus affinis* and bartail flathead *Platycephalus indicus* also occurred in the sea grass beds.

Fishes recorded in the seine net catches of fishermen harvesting the sea grass beds included blue-line herring *Herklotsichthys quadrimaculatus*, white sardine *Sardinella albella* and Indian scad *Decapterus russelli*, which made up the majority of the catch (as in Bazaruto; Dutton, 1990), as well as smaller numbers of sand smelt *Sillago sihama*, flathead mullet *Mugil cephalus*, blue-tail mullet *Valamugil buchanani* (known locally as *muxime*), alligator pipefish

Syngnathpoides biaculeatus, whitespotted rabbitfish *Siganus sutor,* cowfish *Lactoria diaphana,* thornfish *Terapon jarbua* (known locally as *xekelvao*), tropical halfbeak *Hyporamphus affinis,* barred flagtail *Kuhlia mugil,* bartail flathead *Platycephalus indicus,* crested weedfish *Ablabys binotatus,* milkfish *Chanos chanos,* devil firefish *Pterois miles,* black pomfret *Parastromateus niger,* wolf-herring *Chirocentrus dorab,* porky *Stephanolepis auratus,* redspot goatfish *Parupeneus cinnabarinus,* blue-spotted pursemouth *Gerres filamentosus,* tropical flounder *Bothus mancus,* spiny cowfish *Lactoria diaphana,* evileye blaasop (known locally as *nhamulikiti),* lizardfish *Synodus* spp., juvenile kingfish *Caranx* spp. and queenfish *Scomberoides* spp. Many of these species swim in shoals and large numbers may be caught in one seine haul.

The spiny cowfish *Lactoria diaphana,* locally known as *chimbururu* (meaning 'nice to eat') is frequently seen in the sea grass beds and is also caught in seine nets. This species suffers particularly high mortalities as their spines are easily entangled in the nets. Dozens of their carcasses are strewn along the shore although they are included in fish stews in some villages. Although the evileye blaasop *Amblyrhynchotes honckenii* has extremely poisonous flesh, local fishermen have learned how to prepare them for human consumption.

Dutton (1990) reported that 35 different fish species were caught in seine nets in the Bazaruto archipelago. Catches averaged about 80 kg/net/day but harvests up to 840 kg/net/day were made during the months of March to September.

The twobar clownfish *Amphiprion allardi* shelters among the tentacles of the giant anemone *Radianthus ritteri* but their communalism is severely disrupted by seine nets that are constantly dragged over their territory. Local fishermen informed us that the electric ray *Torpedo sinuspersici,* which can deliver an electrical shock of up to 100 volts when disturbed (Kalk, 1995), occurs in the Bay and the estuary.

The dugong: The dugong *Dugong dugon* (known locally as *njanjinguluvi*), is one of four remaining members of the mammalian order Sirenia, (or sea cows), the only living group of mammals that is adapted to feeding exclusively on aquatic plants. Sirenians are distantly related to elephants (Probiscoidea). The three other sirenians are all manatees, the West African, Amazonian and Florida species, which mainly live in estuarine and freshwaters. All four sirenian species are listed as 'Vulnerable to extinction' by the IUCN and appear on Schedule I or II of CITES, depending on the population (Emanoil, 1994). A fifth, modern member of the Sirenia, the Stellar sea cow, which occurred only in the waters around Cooper and Beiring Islands in the North Atlantic Ocean, was hunted to extinction in the late 18th Century, less than 27 years after its discovery.

Dugongs reach a length of 2.5 – 3.2 m and weigh 170-400 kg as adults (Hughes, 1969; Smithers, 1983). They spend their whole life in the water, where they feed, breed and sleep. They are vulnerable, *inter alia,* to habitats changes that alter the availability of their food. Dugongs are known in

Portuguese as *Peixe mulhere*, *Porco d'aqua*, *Makua name* or *mVua,* and in English as 'sea cows' or 'sea pigs'.

Distribution: Historically, the dugong's range extended throughout the tropical and subtropical coastal and island waters of the Indo-West Pacific from East Africa northwards to the Red Sea and eastwards to Vanuatu (Smithers, 1983). They are largely confined to seawater, rarely entering large river mouths (Hughes, 1969), and their distribution is broadly related to the distribution of their food plants, the sea grasses (mainly *Cymodocea, Holidule, Halophila, Syringodium* and *Zostera* spp.; Smithers, 1983). The dugong is now considered to be rare over most of its former range and is only represented by relict populations separated by large areas where it is close to extinction or extinct (Smithers, 1983). Interbreeding between these widely separated populations is unlikely, and the risk of genetic bottlenecking in small, isolated populations is high.

In Africa, the southernmost record for dugong is that of a specimen washed up at Umhlali, 50 km north of Durban, in KwaZulu-Natal, in 1966 (Hughes, 1969). The author examined a dugong carcass on the coast immediately south of Ponto do Ouro in northern Zululand in 1977. Besides these extraordinary records, dugongs are not currently found south of Delagoa Bay in Mozambique. The dearth of dugongs in South Africa is attributable to the lack of suitable seagrass beds in areas protected from heavy surf action.

Their preferred habitat is in coastal lagoons where coral reefs lying offshore provide sheltered conditions from the wave action of typical exposed beaches, and the sandy bottom allows for the growth of their food plants. Off the Kenyan coast, dugongs have been reported to move offshore to feed beyond the coral reefs when the sea is calm, and then to move into sheltered inshore bays when the sea is rough (Kingdon, 1971). Hughes & Oxley-Oxland (1971) reported similar movements off northern Mozambique.

Thirty years ago dugongs were reportedly abundant off the coast of Mozambique, Kenya and Somalia, and they were considered to be less threatened off the east coast of Africa than in the rest of their range; this is no longer the case. In the early 1970s dugongs were confined to isolated populations in Mozambique in Delagoa Bay, Inhambane Bay, the bay adjacent to San Sebastian Peninsula, the inshore waters of the Bazaruto archipelago, at Angoche, off Antponio Enes, off Mossuril, and off Mocimboa da Praia in the north (Hughes, 1971). The population in the Bazaruto area, which numbered about 110 animals in 1990 but has been reduced to 20-40 animals today (Duarte et al., 1997; Dutton, pers. comm. 2002), may be the largest single herd in East Africa. Hughes (1969) reported a small herd of 8-10 animals near Inhaca Island in Delagoa Bay. He also reported a herd of three animals at Citenguele, a group of 20 near Ponto de Bartholemew Dias, and groups of 3-4 in the Bay of San Sebastian. With regard to Inhambane Bay, Hughes (1969) commented that "dugong are still relatively common in that they are often seen in small groups of two to four individuals". Dugongs are apparently "quite common" on the northern coast of Mozambique north of Moma in the Zambezia Province (Smithers, 1983).

Along the East African coast the distribution is discontinuous northwards to Egypt and the Red Sea; most East African populations have been hunted to extinction. Dugongs still occur off Moheli and Anjouan islands in the Comoros (personal observations, 1976, 1977), but they are rare there. Dugongs were previously abundant off the coast of Madagascar in the early part of this century but few are left today. The large herds that occurred off the Mascarene Islands (including Mauritius) reportedly became extinct in 1859. Dugongs were previously common in the Red Sea (Glover Allen, 1942) but they had been reduced to small numbers by 1932 (Nishiwaki, 1972). Herds of over 100 and over 500 were previously recorded off the coasts of Kenya and Somalia respectively (Kingdon, 1971; Marsh et al. 1972).

The most extensive populations left in the world today occur off the northern coasts of Australia. Consequently, most of the data for this species is based on this population. In 1994 it was estimated that there were about 100 000 dugongs in the world; most occurred off northern Australia and in the Arabian region (Emanoil, 1994).

Biology: Dugongs are long-lived animals, with a potential longevity of 70+ years. They reach sexual maturity at about 2.5 m and females have their first calves at a minimum age of 9-10 years. They bear one calf at a time (rarely twins, Hughes & Oxley-Oxland, 1971), with long resting periods between pregnancies. In Mozambique, the young are typically born between November and January (Hughes & Oxley-Oxland 1971), which is also the time of mating. The first pregnancy may be delayed until the 15-17th year (Emanoil, 1994; Anon, 1995). With a possible life span of 70 years, and 5 years intervals between pregnancies, a female would normally produce not more than 12 calves during her lifetime. Pregnancy lasts for 12-13 months (one of the longest gestation periods of any vertebrate, exceeded only by the elephant and the coelacanth) and the calves are born at a length of about 1 m (20-35 kg). They remain close to their mother, frequently riding on or just behind her back. The young are pale cream in colour but darken in age to grey-bronze dorsally, lighter ventrally. Calves suckle milk for about 18 months from a teat located just behind the pectoral flipper. The dugong cow-calf bond is very well developed and the pairs may remain together for up to 2 years. The calving interval is usually 3-5 years average time between calves is variable – from 3-9 years (Anon, 1995).

The outer pair of incisor teeth in the dugong develop into a pair of tusks in males and some old females. Although these tusks are primarily used for uprooting plants during feeding, the parallel scars and scratches that are found on the backs of males and females indicate that they are also used during prenuptial aggression by males, and to position the female during mating.

Typical groups size now ranges between 2-13 animals depending on the total size of the population, although single animals are frequently sighted. Thirty to forty years ago dugongs were often sighted in herds of several hundreds; these large herds now only occur off Australia.

Dugongs spend most of the day browsing over seagrass beds, and consume 10-15% of their body mass in food each day (Best, 1981). The interlacing bristles on the snout are used for detecting and grasping seagrasses and the roughened mouth palate is used as a 'tool' for uprooting roots and tubers. The pectoral flippers may also be used to stuff food into their mouths (Grzimek, 1972). The mouth forms a muzzle that is directed downwards and ends in a horseshoe-shaped disk, which is ideal for rooting through seagrass beds. This method of feeding results in the telltale 'feeding trails' left by dugongs as they move through the seagrass beds (although these 'trails' may also be caused by disturbed sediment). Feeding activity is actively linked with the tides as feeding usually takes place in water 3-4 m deep on an incoming tide, with the animal moving out into the deeper channels on the tide. They typically feed in water 1-12 m deep with a temperature range of 20°-30°C (Grzimek, 1972). In disturbed areas dugongs usually feed at night.

Dugongs have home ranges of 10-120 km² and may travel over long distances (>130 km) between feeding bays (Emanoil, 1994). They are easily visible from the air against the light coloured sands of their habitat.

Dugongs are spindle-shaped, tapering at both ends to produce a streamlined shape. They lack a dorsal fin (as found in some dolphins and whales) and the hind limbs are absent. The tail comprises two horizontally flattened flukes, similar to those of a whale (but dissimilar to those of a manatee, which are rounded like a beaver). The pectoral flippers are short and stubby, almost paddle-like. These limbs are flattened against the side of the animal when swimming, used as stabilizers, and are used for support when resting on the seabed. Dugong locomotion is similar to the porpoising action of dolphins, particularly when moving at their surprisingly high cruising speed of 8-10 km/h (4.3-5.4 knots; Smithers, 1983). When threatened, dugongs can accelerate to twice this speed for short distances. When at rest and feeding, they move slowly through the water column and to the water surface to breathe, lifting only the head and nostrils clear of the water. The skeleton is extremely dense and negatively buoyant and acts as ballast as the dugong moves along the sea bed looking for food. Dugongs generally remain submerged for one to six minutes (Anderson & Birtles 1978). The nostrils are situated on top of the head and are closed by powerful muscular valves when the animal is submerged.

Man is the main predator of the dugong, but they are also hunted by large sharks, saltwater crocodiles and killer whales (Emanoil, 1994). The Chinese community in Mozambique (especially in Vilnaculos and Inhassaro) was identified as early as 1969 as one of the main causes of dugong mortalities (Hughes, 1969), and are still responsible for some dugong deaths today (P Dutton, pers. comm. 2002). Chinese fishers also hunt other endangered species such as sea horses in the Vilanculos area.

Conservation status: Little quantitative information on dugong abundance and distribution exists, but the results of occasional surveys, incidental sightings, accidental drowning and strandings, indicate their number have decreased alarmingly and they can be considered to be threatened throughout most of

their historic range. Dugongs possess many of the life-history characteristics of threatened animals. They are vulnerable to hunting and accidental death as they are large, long lived, relatively slow moving, slow reproductive rate, docile, have relatively poor eyesight (though very sensitive hearing), live in shallow inshore regions, and are easily entangled in gillnets. They are hunted for their flesh, which is tasty and generous. In addition, their tusks and ribs are used for jewelry, their tears fro aphrodisiacs and their oil for medicinal purposes (Emanoil, 1994).

The dugong plays an important ecological role by converting marine angiosperm plants into nutrients, thereby filling a niche of considerable importance for other marine animals, including fishes (Dutton, pers. comm., 2002).

The main causes of dugong mortality are likely to be hunting, accidental death in gillnets (set for sharks) and fish traps (Hughes, 1969), and accidental death from collisions with boats (more frequent for manatees). Gillnets also cause mortalities of dolphins and turtles in Mozambique (Duarte et al, 1997). The loss of feeding grounds for dugongs due to coastal 'development', reduced salinities (due to high levels of river outflow into the sea), sewage discharge (Mackie et al., 1999), changing surface runoff, sedimentation caused by fish traps and other causes, pollution and other causes is an indirect population control mechanism (Emanoil, 1994; pers. obs.). Hughes (1969) reported that up to six dugongs were hunted and sold at the market per *month* at Antonio Enes in Mozambique, and that their catch in the rainy season was probably higher. He also recorded dugong catches of two per month off Mozambique Island, and active hunting in the Bay of Matibane and at Nacala Porto, where five had been caught in the previous four years.

Dugongs need to be strictly protected because of hunting pressures, accidental damage by boats and nets, their low fecundity and vulnerability, loss of habitat, and their status as 'flagship' species in the lagoonal-inshore marine habitat. The dugong and manatee are thought to be the inspiration behind myth of the mermaid, possibly because of their habit of lying on their backs and suckling their young, while supporting the young with a flipper. This legendary association with humans has not afforded them any protection, however, as they have been ruthlessly hunted in recent centuries, in the same way as the great whales. Unlike some of the smaller, more fecund whales, their reproductive rate is too low to support any type of commercial exploitation, and the challenge is to eliminate hunting and accidental deaths throughout their range. ***Large scale, multiple-use marine and coastal reserves are the only long-term hope for the dugong, as it is impractical to conserve them and their habitat in isolation.***

The most urgent research priorities on dugongs in Mozambique are: quantify causes of mortality, determine main demographic trends (population size and trends, breeding rate and success, longevity, mortality rate), quantify availability of food, and monitor public attitudes about the species.

Dugongs in Mozambique: Dugongs are protected in Mozambique and those responsible for their damage and death can, technically, be subject to heavy fines, but there is little implementation of this law. Dugongs are reportedly occasionally harvested and slaughtered in the Bazaruto area, sometimes by public officials.

Dugong populations in the Bazaruto area have been surveyed by aerial census by Ken Tilney, Paul Dutton and others in the recent past. These surveys reveal a decreasing population size from >100 animals over 30 years ago to <50 in recent years (Dutton 1970, 1990; Tinley, 1970). The latest survey revealed 41 animals inshore of the Bazaruto archipelago. Cumming & Mackie (1995) estimated the size of the dugong population in the proposed Greater Bazaruto National Park (BANP) to be about 25 (0.015/km²), based on extrapolation from seven direct sightings. The survey was conducted at low tide in "..near perfect weather conditions". Mackie et al. (1999) conducted an aerial census of dugongs in the proposed BANP using the same method in 1999 and estimated the population size to be about 72 (on the basis of extrapolation from nine original observations), an (unlikely) increase of 47 in five years. This method may have questionable accuracy, and may overestimate the population; this is suggested by Dutton's lower count of 41 in 1990. Whatever the biases of the various sampling methods, it is clear that the numbers of dugongs in the vicinity of the Vilanculos Coastal Wildlife Sanctuary, and the BANP, are very low (<100).

During an informal aerial census conducted over San Sebastian Bay by the author on three dugongs were sighted in the shallow waters of the bay.

In additional to monitoring population size, conservation activities on the dugong in Mozambique include declaration of the dugong as an endangered species, educational campaigns, controls over fishing gear (especially gillnets), surveillance of fishing activities and catches, support of research and conservation activities, establishment of marine sanctuaries and other protected areas, and media campaigns.

The dugong is a high profile species in Mozambique and appears on the logo of the Parque Nacional do Arquipélago do Bazaruto (BANP) and other conservation organizations. 'Dugong Camp' in the Vilanculos Coastal Wildlife Sanctuary is named after this enigmatic animal.

1.3.6 Mangrove swamps:

Introduction to ecology: Five species of mangroves are known from the VCWS and the Bazaruto archipelago: red mangrove *Rhizophora mucronata,* black mangrove *Bruguiera cylindrica,* tagal mangrove *Ceriops tagal,* white mangrove *Avicennia marina* and the tropical mangrove *Sonneratia alba.* Mangrove roots are shallow and some have above-ground pneumatophores to allow them to breathe, exchanging carbon dioxide for oxygen from the air. The mangrove substrate, which is sandy and anoxic with hydrogen sulphide about 5 cm below the surface, is inundated only during spring high tides. The salt marshes associated with the mangrove swamps are colonized by the

following plants: *Arthrocnemum perenne, Sesuvium portulacastrum, Salicornia perrieri, Sporobolus virginicus* and *Digitaria littoralis,* with the dune slack rush *Juncus kraussii* on elevated margins.

The mangrove trees grow in seawater on intertidal mud flats and form the anchor of an important community of plants and animals. Their roots consolidate and trap fine mud and their deciduous leaves contribute to the development of a sediment that is very rich in organic detritus. Mangroves support several species of animals that are not found elsewhere, especially the mudhopper *Periophthalmus sobrinus* and two mangrove snails, *Cerithidea decollata* and *Terebralia palustris.*

The white mangrove is an early pioneer in the establishment of mangrove forests and provides a nursery for other species. Black mangroves typically grow in the middle of established *Avicennia* stands. The red mangrove forms thick hedges along the edges of creeks running through mangrove swamps, whereas the tagal mangrove forms landward thickets on the inner edge of the *Avicennia* forests.

Phylum Arthropoda: *copepods, isopods, amphipods, krill, barnacles, prawns, shrimps, crayfish, crabs*: Unidentified species of amphipods and isopods were found among benthic leaf debris in the mangrove swamps. Local fishermen harvested the tiger prawn *Penaeus monodon* in the mangrove swamps at high tide. Hermit crabs are extremely common in all the mangrove swamps. They commonly colonize the shells of the mangrove whelk *Terebralia palustris*, the knobbled horn shell *Rhinoclavis sinensis* and the truncated mangrove snail *Cerithidea decollata* and may form continuous moving carpets on the substrate in some areas. Barnacles, possibly the striped barnacle *Balanus amphitrite,* are commonly found on the mangrove stems.

The red-clawed mangrove crab *Sesarma meinerti* is extremely common in the mangrove swamps. The fiddler crabs *Uca annulipe* and *U. inversa* occur abundantly in the larger mangrove swamp on the southern end of San Sebastian Bay near the reed swamp. *Sesarme ortmanni*, the land crab *Cardisoma carnifex* and the edible crab *Scylla serrata* are also present.

Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squid*: The truncated mangrove snail *Cerithidea decollata* lives high on the trunks of mangroves and descends to the mud to feed on detritus during low neap tides (Kalk, 1995). The mangrove whelk *Terebralia palustris* is extremely common in the mangrove swamps and is a keystone ecological species. They are the preferred shell of hermit crabs living in the mangals. *T. palustris* crawls over wet mud feeding on diatoms and mangrove leaves. They are large, heavy snails, reaching a length of 120 mm.

Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*: The bigfin mudhopper *Periophthalmus sobrinus* is sparsely distributed in the mangrove swamps, occurring in a pool to the south of the first mangrove swamp to the south of Dugong Camp (where 20 were counted), and in stream courses in the

midst of the large mangal at the southern end of San Sebastian Bay. This keystone species breathes air and can spend long periods out of water. They skip along the mud and take refuge in deep pools. They apparently have no local Xitsua name but are called *peixecobra* in Portuguese.

Other fish species seen in the mangroves included gobies, pipefish, thornfish *Terapon jarbua*, glassy *Ambassis gymnocephalus*, mullet, evileye blaasop *Amblyrhynchotes honckenii*, lesser sandshark *Rhinobatos annulatus* and estuarine roundherring *Gilchristella aestuarius*.

There is abundant evidence of the presence of the Cape clawless otter *Aonyx capensis* in the Sanctuary in the form of their tracks and feeding marks, but they are rarely seen as they are primarily crepuscular. They appear to occur in all the mangrove swamps and reed swamps as well as along the estuarine lagoon. Their main prey is crabs, which are abundant in the mangrove and reed swamps and along the marine coast. On the marine coast they eat, *inter alia*, the tuberculate crab *Plagusia depressa tuberculata* whereas their prey in the mangrove swamps appears to be mainly fiddler crabs, *Uca* spp., especially Urville's fiddler crab *Uca urvillei*, and the pink-clawed fiddler crab, *Uca lactea annulipes*, which are abundant. On the edge of the estuarine lagoon we found evidence of otters feeding on the ubiquitous army crab, *Dotilla fenstrata*, and the mud crab, *Scylla serrata*. Otters also feed on fish and octopus (Branch et al., 1994).

1.3.7 Seascapes: The dramatic seascapes and coastal scenery should be regarded as part of the biodiversity of the Sanctuary, and should be managed as such. Development should be carried out in such a way that the overall scenery is not damaged, i.e., buildings should be built using natural products and should blend in with the landscape and seascape, as Dugong Camp does; any development in the vicinity of the old Portuguese lighthouse on the marine dunes should not mar the seascape; roads, jetties, pipelines, power lines, airstrips, rubbish heaps, sewerage disposal works, water purification systems, market gardens, aquaculture facilities, stock farming facilities should be planned and installed in such a way that they do not damage the overall aesthetics and 'personality' of the environment.

Particularly spectacular views should be optimized by being incorporated into hiking and horse-riding trails. These views could include the view from the top of the sandy cliffs on the north-west edge of the Sanctuary, over the lagoon and flamingo colonies; the view of the estuarine lagoon from the top of the plateau on the way to the lighthouse; the view into the small mangal bay on the west side of the Peninsula; the view across the mangrove swaps from the plateau to the east of the main camp, looking southwards, and many others. Light airplane trips over the Sanctuary are likely to be very popular touristic attractions as the variety of seascapes, landscapes, cultural activities as well as large marine life that is observed is probably unique. On one hour trip undertaken by the author, we saw humpback whales, giant manta rays, dugongs, turtles, basking sharks, dolphins, flocks of flamingoes, traditional fish traps, dozens of dhows as well as magnificent open sea, undersea reef, sandy beach, coastal dune, estuary and lagoon scenery.

1.3.8 Cultural diversity: The traditional fishing villages within the VCWS are an important component of the cultural diversity of the Sanctuary. Their values include traditional boat-building practices (a fascinating outdoor boat-building workshop exists adjacent to the shore near the mangrove swamp to the south-east of Dugong Camp), traditional fishing tackle and methods, traditional salting, drying and cooking methods, and the diversity of their catches. Oral traditions in relation to fish and fishing are also important cultural elements.

The traditional fishing tackle used in the Sanctuary includes valve traps, set singly or in palisade fences, handmade rods, line and reels made almost entirely from the leafs, stem and branches of the *Phoenix* palm, and traditional fish throwing spears. Handmade seine nets and gill nets are no longer in evidence but would have been used before multi- and monofilament nylon and cotton nets became available, probably in the 1950s and 1960s.

Dugout canoes and wooden dhows are still made in the traditional way, although the availability of large tree trunks appears to be a limitation now. The ribs and elbow joints in the dhows are made from mangrove wood, and handmade as well as commercial nails and wooden dowels are used for attaching the hull planks to the ribs. Handmade adzes and axes are used to shape the timbers. The traditions of making dhows and dugout canoes are an important part of the local culture and should be properly recorded and archived.

Handmade items associated with the preservation and cooking of fishes include: gourds, clay pots, wooden basins, hollowed-out trunks and abandoned dug-out canoes that contain the brine solution used to salt fish; simple stick holders for smoking fish over a fire, reed or grass mats used for drying fish in the sun, usually suspended above ground level; handmade knives for scaling and filleting fish; baskets woven from lala palm leaves to carry the catch; small thatched huts for storing dried and salted fish.

2. Research priorities:

2.1 Phylum Porifera: The role of the large sponge that is common in shallow inshore habitats to the north of the Peninsula needs to be investigated as they appear to play an important role as shelters for other animals.

2.2 Phylum Cnidaria: The giant anemone, *Radianthus ritteri*, is an important component of the biota of the VCWS, and should be regarded as a flagship species; they should be subject to more detailed study in terms of their role as a shelter for other species in a harsh, exposed environment. The taxonomy, diversity and abundance of hard and soft corals on the coral and rocky reefs also need to be studied.

The rootmouthed jellyfish *Rhizostoma* spp. is a keystone species that should be surveyed in depth to ascertain its role in the system.

The extraordinary sea pens and sea feathers of the tidal flats should be properly surveyed in terms of distribution, abundance and conservation status. Their biology and ecology could then be investigated.

2.3 Phylum Arthropoda: The conservation status of prawns, crayfish, shrimps and walking and swimming crabs in the VCWS needs to be ascertained as some of these species are heavily exploited and may require special protection. The ecological role of hermit crabs in the mangrove swamps also needs to be determined.

Special attention should be given to the blue crab *Portunus pelagicus*, mud crab *Scylla serrata*, east coast rock lobster *Panulirus homarus* and tiger prawn *Penaeus monodi* because of their commercial importance, and to ghost crabs *Ocypode* spp., red-clawed mangrove crabs *Sesarme meinerti*, and the fiddler crabs *Uca* spp. and hermit crabs of the mangrove swamps, because of their vital ecological roles.

2.4 Phylum Mollusca: *chitons, bivalves, tusk shells, snails, limpets, sea slugs, octopus, squids*: Bivalves play a very important role in the reef and tidal flats environments and need to be properly surveyed in terms of taxonomy, diversity, abundance and conservation status. The abundant but small oysters on the trunks of mangrove trees offer an interesting opportunity for exploitation. It is obvious that there is a lack of suitable settling areas for the planktonic larvae of the oysters; the establishment of suitable settling stations may form the basis for a small oyster industry. Oysters are also abundant on inshore rocky reefs. Octopus and squid are probably overexploited throughout the Sanctuary. The mangrove whelk *Terebralia palustris* and the truncated mangrove snail *Cerithidea decollata* are very abundant and ecologically important in the mangals and also provides shells for hermit crabs that are major scavengers in that environment.

The giant clams *Tridacna squamosa* and *T. maxima* need to be properly surveyed in terms of abundance and conservation status, as do the cowries *Cypraea* spp., wedge mussels *Donax faba*, horse mussels *Pinna muricata*, fan shells *Atrina pectinata*, sand oysters *Pinctada imbricata* and beaked clams *Eumarcia paupercula*. Intertidal zonation on rocky reefs along the marine coast needs to be studied and compared with the pattern of zonation on Inhaca Island.

2.5 Phylum Echinodermata: *starfish, brittle stars, sea urchins, sea cucumbers, sea lilies, feather stars, sand dollars*: The echinoderms provide very rich opportunities for research in the fields of taxonomy, biology, ecology, sustainable exploitation and conservation status.

The species that are most deserving of further study are the snake sea cucumber *Synapta maculata*, beaded starfish *Pentaceraster mammillatus*, crown-of-thorns starfish *Acanthaster planci* (if it occurs), sand starfish *Astropecten monocanthus*, spiny brittlestar *Ophiocoma valenciae*, heart urchin ?*Lovenia elongatum* or *?Echinocardium cordatum*, short-spined sea urchin *Tripneustes gratilla*, needle urchin *Diadema setosum*, black tufted sea

cucumber *Holothuria scabra* and the sand dollars *Echinodiscus bisperforatus* and *E. auritus*.

The needle urchin *Diadema* spp. has been used internationally as an indicator species for marine habitat degradation (the greater the degradation, the higher their numbers), and should be monitored to determine whether its population is increasing or decreasing.

2.6 Phylum Chordata: *sea squirts, salps, jawless fishes, sharks, rays, bony fishes, turtles, snakes, birds, whales, dolphins, otters, dugongs*: exciting opportunities also exist for further research on various vertebrate animals. The most important candidates are:
Fishes: the commercially important game fish and reef fishes, whale shark *Rhincodon typus*, manta ray *Manta birostris*, devil firefish *Pterois miles*, coelacanth *Latimeria chalumnae*, black tilapia *Oreochromis placidus*, glassy *Ambassis* spp., lesser sandshark *Rhinobatos annulatus*, sea horse *Hippocampous* spp., bigfin mudhopper *Periophthalmus sobrinus*, blue-line herring *Herklotsichthys quadrimaculatus*, white sardine *Sardinella albella*, Indian scat *Decapterus russelli*, barred flagtail *Kuhlia mugil*, flathead mullet *Mugil cephalus*, cowfish *Lactoria diaphana*, milkfish *Chanos chanos* and the queenfish *Scomberoides* spp.
Reptiles: The five species of marine turtles.
Mammals: The dugong *Dugong dugon*, the four species of dolphins and the Cape clawless otter *Aonyx capensis*.

3. Conservation needs and priorities

Introduction: The largest components of the marine and coastal environment within the VCWS are the tidal flats and sea grass beds in San Sebastian Bay, the elongate estuarine lagoon, the offshore rocky and coral-encrusted reefs, the open sea environment, and the mangrove and reed swamps. Fortunately the recruitment of invertebrates and fishes into the inshore tidal flats areas in the lagoon and estuary is largely by means of planktonic larval stages that originate in the open sea and from offshore reefs. The condition of the offshore environment, which is subject to less intensive harvesting pressure than the inshore environment, will therefore determine the recruitment rates into the shallower, inshore areas. This is a fortunate situation as it means that the inshore environments will constantly be restocked. This regular replenishment will only take place, however, if the offshore environments, including the open sea and coral and rocky reefs, remain in good condition, and the habitats in the inshore environment are not excessively damaged by the harvesting practices. There is a real danger of the latter as the enormous seine nets that are pulled across the tidal flats and in the estuarine lagoon cause devastation to benthic communities (and have probably been doing so for decades).

It is also very important that populations of animals that spend their whole lives in the lagoon and estuary are not exploited to low levels as they each have a role to play in the ecosystem and their depletion will eventually impact on the ability of offshore species to settle in the inshore environments.

The easy accessibility of the tidal flats, sea grass beds and estuarine inlet make them vulnerable to over-exploitation by netting, spearing, rod-and-line fishing, trapping, the use of tidal traps and pollution. Many of the fishes inhabiting these areas swim in shoals, which increases their vulnerability to nets. Furthermore, many of the invertebrates are relatively sedentary and have means of defence other than mobility, including strong spines; these spines often entangle in nets and result in their capture. Netting mortalities of bycatch, i.e. animals that were not originally targeted by the netting operation but which are killed anyway, is a serious issue, as evidenced by the piles of unused carcasses along the shore after each net haul, and the trail of dismembered, uprooted and disrupted benthic animals that is found if one swims over an area that has recently been seined. Animals that form commensal and symbiotic relationships with one another are particularly vulnerable to disturbance by constant seine netting.

The rarest commodity in the exposed tidal flats and estuarine lagoon is shelter from predators and from the tidal rip. Any plant, animal or other object that provides shelter, whether it is a sea grass, fan shell, sponge, large starfish or log, is therefore colonized by a wide variety of smaller animals that benefit from its protection. When these shelters are uprooted by seine nets and other harvesting practices, the entire community suffers. The sea grass beds, in particular, provide a relatively sheltered and stable habitat in an otherwise harsh environment, as evidenced by the vast difference in biodiversity in a sea grass bed as opposed to the barren sandy areas around it. The ploughing up of sea grass beds by weighted seine nets should therefore be a matter of concern, especially as our observations revealed that the catches are meagre, and that many of the animals caught are not utilized yet die from dismemberment and desiccation.

The inshore environments of the Sanctuary are vast and complex and it would take decades of study to comprehend even fragments of their ecological interrelationships. Common sense practices will therefore have to be implemented until this knowledge is available.

Conservation needs

Coral reefs and rocky reefs: The main conservation threats and actions are:

- Overfishing: A closed season for harvesting crayfish should be introduced during the crayfish reproductive season to allow the stocks to recover, as suggested by Dutton (1990)
- Gill nets: The use of gill nets over coral and rocky reefs should be banned.
- Physical damage to the reef through anchoring: Create mooring buoys for anchoring and do not allow anchors to be dropped onto coral reefs. Rocky reefs are less vulnerable to damage.
- Spearfishing: Spearfishing using scuba should be strictly banned over coral and rocky reefs, as it is throughout the world. Spearfishing using snorkels and goggles should also not be allowed on coral reefs in the Sanctuary, and should only be allowed for game fish over rocky reefs, if at all. All semi-commercial spearfishermen hunting over rocky reefs

should be officially registered and provided with appropriate identification documents.

- Setting of nets, traps and long lines: Fishermen should not be allowed to set gill nets, fish traps or long lines over the coral or rocky reefs in the Sanctuary.
- Netting over the reefs: Fishermen should not be allowed to pull seine, trawl or purse seine nets over the coral or rocky reefs in the Sanctuary.
- Rod-and-line fishing: Rod-and-line fishing should not be allowed for any species over the coral reefs, but could be allowed for game fishes over the rocky reefs, subject to control by Sanctuary staff.
- Trampling and direct breakage by divers: Do not allow divers to stand on the coral reefs or to touch them; ensure that all divers are appropriately qualified for open sea diving before they undertake a dive, and ensure that they have the correct buoyancy. Many of the rocky reefs also have fragile encrusted animals and the same rules should apply to them.
- Removal of biota from the reef: Do not allow divers to remove any material from a coral or rocky reef, whether it is live animals, such as *Fungia* corals, pansy shells or cowries, or dead shells, coral skeletons, sea urchin tests, etc. The small-scale removal of organic material from reefs eventually accumulates into a large-scale export of material that is vital to the survival of the reefs.
- Proper education: Ensure that divers and dive supervisors are properly educated about the ecology and vulnerability of coral and rocky reefs before they dive, so that they are part of the management team during a dive rather than opposed to it. The establishment of an interpretation centre at the Camp would assist this process. The education of divers should continue during a dive. The dive supervisor should point out important animals and ecological processes, and should carry an underwater slate for conveying messages and doing drawings. Waterproofed illustrations of prominent fishes and other animals should also be carried under water. Eventually, underwater signs that assist with the identification of prominent reef inhabitants could also be introduced. The education of divers should continue after the dive during debriefing sessions and discussions. Dive supervisors should be encouraged to become competent underwater photographers so that they can record the highlights of a dive, which can be discussed afterwards. Proper education also applies to the management of all the other ecosystems in the Sanctuary.
- Invasion by crown-of-thorns starfish *Acanthaster planci*: Monitor the presence and abundance of *A. planci* should it be recorded on the coral reefs. The invasions of *A. planci* on the Great Barrier Reef in Australia have recently been shown to have been a natural phenomenon that has taken place over millennia (Steene, 1990), although man-made disturbances to the reef may exacerbate the problem. If *A. planci* is recorded on a coral reef within the Sanctuary, professional advice should be sought. It is possible to remove the crown-of-thorns starfish population by systematic collection if the invasion is discovered at an early stage. Thick gloves should be used, and the specimens should be destroyed on land; if they are cut up and replaced in the sea, they may survive.

- Pollution of reef: Care should be taken not to drop batteries or any other foreign objects on any reefs, or to release fuel over a reef.
- Noise pollution: Care should be taken not to create excessive noise over the reefs with outboard motors, sharp objects striking the hull of the boat, or other means.
- Sedimentation of the reefs: This is an ongoing natural cycle about which man can do very little. If increased sedimentation is due to erosion in the catchment of nearby rivers, this erosion could be checked, but this is unlikely to be an issue in the area of the Sanctuary.
- Overdiving of reef: Reef visits should be organized in such a way that the reef does not become congested with divers, which decreases the quality of the diving experience and increases the risk of damage to the reef.
- Ornamental fish collecting: The collection of marine fishes for the international aquarium trade should not be allowed in the VCWS.

3.2.2 Open sea: The main conservation threats and actions are:

- Boat damage to large surface-swimming animals: Boat skippers should be experienced enough to avoid collisions with sea turtles, whale sharks, dugongs, manta rays and humpback whales
- Setting of nets, traps and long lines: It is recommended that the setting of multi-or monofilament gillnets, long lines, fish traps, or the pulling of trawl or purse seine nets, in the open sea environment of the Sanctuary should not be allowed.
- Rod-and-line fishing: Rod-and-line fishing for bottom fish should be strictly controlled in the open sea environment of the Sanctuary. Angling for game fishes should be allowed using boats operated by the Sanctuary staff, subject to local legislation.
- Shark long line fishery: The long line fishery for shark fins that takes place off the Bazaruto archipelago also occurs within the boundaries of the Sanctuary and is a potential threat to sharks as well as to pelagic animals that are caught as a bycatch. This method of fishing should be banned within the VCWS.
- Incidental catch of marine mammals and reptiles: The incidental capture of dolphins, dugongs and sea turtles in gill nets set in the open sea or deeper lagoons is a threat that needs to be handled strictly and in close collaboration with the conservation authorities and national and international conservation bodies.
- Harvesting of marine mammals: Any harvesting of marine mammals (dolphins, whales, dugongs) should be banned.

3.3.3 Sheltered and exposed shores: The main conservation threats and actions are:

- Overfishing: Closed seasons should be introduced to coincide with those recommended for the Inhassaro area to the north (1st July – 1st October) by Dutton (1990). PESCOM and other fish commercializing agents should not purchase undersized *Holothuria. scabra.*

- Harvesting marine turtles and turtle eggs: Measures to protect nesting turtles and turtle eggs need to be introduced. The killing of adult turtles should be completely banned. Vehicle traffic over turtle nesting beaches at night should be strictly controlled.
- Pollution: Local fishermen have the habit of discarding torch batteries in the water, where lead and other pollutants leaks out. Diesel and oil pollution, and contamination of the aquatic environment by fragments of discarded monofilament gillnets and seine nets, are also problems. Educational leaflets on the impact of pollution on marine ecosystems need to be printed and distributed.
- Netting: All nets should be registered to ensure that they confirm with mesh size requirements.
- Hunting of turtles: Evidence that turtles had been hunted was found at the northernmost fishing village on the peninsula. These turtles had probably been caught in nets as the species concerned (*Chelonia mydas*) does not normally breed on the mainland. All turtles are protected internationally and their exploitation in the VCWS should be banned.
- Interference with nesting turtles: There is a risk that visitors will interfere with loggerhead and leatherback turtles while they are nesting. The rule internationally is that visitors should stay well away from turtles when they emerge from the water at night, dig their nests and lay their eggs. The visitors can, under control of informed guides, move closer while the turtle is covering her nest in order to observe the turtles and take photographs. The turtle hatchlings emerge about three months after being laid and immediately scurry into the sea. This event is of much shorter duration than nesting and is therefore difficult to observe.
- Four-wheel drive vehicles: Four-wheel drive vehicles have the potential to cause disruption and damage to marine and coastal beach environments. The damage caused by these vehicles, as well as by four-wheel motor scooters, includes noise pollution, compacting the sand, disturbance of nesting turtles, creation of deep tracks that hatchling turtles have to cross, direct damage to crabs, bird nests and molluscs, providing access to remote and sensitive areas, damage to dune vegetation, damage to crab and mollusc burrows, and the formation of unsightly vehicle tracks on pristine beaches. My recommendation is that four-wheel drive vehicles should not be allowed on the marine beach except for essential management and research purposes.
- Damage to dune vegetation: Dune vegetation may also be trampled by hikers and by the development of inappropriate coastal accommodation on primary or secondary dunes. In general, no development, except for boardwalks for pedestrians, should take place on primary or secondary dunes.
- Sewage disposal: The disposal of human sewage is normally a problem in remore coastal areas with high water tables, but this problem has been adequately dealt with in the VCWS.
- Risks from pesticides and herbicides: The use of pesticides and herbicides in the VCWS should be minimized so as to reduce the risk of pollution of aquatic environments and ground water.

3.3.4 Tidal flats and sea grass meadows: The main conservation threats

and actions are:

- Dredging: Dredging of channels across sea grass meadows for boat access at low tide should not be allowed.

- Moorings: Boat moorings and jetties should not be established in sea grass beds.

- Seine netting: Seine netting unquestionably causes major damage to the sea grass meadows and other biodiverse communities in the tidal sand flats. This damage is caused directly on the plants and animals by the net and through the death of the catch and bycatch, and indirectly due to the severe disruption of the ecological functioning of benthic and pelagic communities.

  The animal groups that are mainly damaged by seine netting are: sea anemones, *Fungia* corals, crabs, bristle-worms, free-living shrimps and prawns, bivalve molluscs, fan shells, horse mussels, snails, octopus, starfish, brittlestars, sea urchins, pansy shells, sea cucumbers, skates, rays, and a very wide variety of small, benthic bony fishes (see above).

  Some animal groups benefit from adaptations for surviving tidal fluctuations to minimize damage by seine nets, whose imminent arrival they detect through the bow wave. They include: sea pens, sea feathers and feather stars (which retract), burrowing gobies, prawns and shrimps (which retreat into their burrows), hermit crabs and large molluscs (which retreat into their shells), some pelagic, fast-swimming fishes and squids (which swim away), communities of animals living under sand anemones, large sponges, fan shells and logs (which hide under their protectors), and survivors of the bycatch (which are adapted to survive exposure to air and desiccation for short periods, such as starfish, sea cucumbers, scallops, hermit crabs, pulmonate molluscs, etc.).

  My recommendation is that the number and kinds of seine nets that are allowed to be used in the Sanctuary should be determined by the Sanctuary staff so that some control can be exercised over the damage caused. One seine net should be permitted per fishing village, and these nets should be multifilament and designed to capture shoaling pelagic fishes that live over the sea grass meadows and tidal flats, rather than benthic species that live on or beneath the substrate.

  The nets should therefore be lightly weighted so that damage to benthic communities is minimized. The author has designed and used such nets with considerable success. The mesh size of the nets should be as large as possible (>5 cm bar mesh, i.e. knot to knot) so as to allow juveniles and specimens that are too small to utilize to escape. Furthermore, the fishermen should be encouraged to throw the bycatch back into the water immediately after capture. Fishermen should also be encouraged to use methods of fish drying, salting and preservation, and cooking, that minimize wastage and loss through predation by birds.

If possible, traditional methods of allocating fishing territories should be re-instituted so that the fish resource is divided equitably among all fishing villages. The allocation of territorial fishing rights in the tidal mud and sand flats surrounding Inhaca Island has been carried out with good effect for centuries, and also occurs in many other parts of Mozambique, in Maputaland and elsewhere in the tropics. On Inhaca Island the fishing territories are even marked with poles stuck in the mud to denote boundaries (pers. obs.). In the Bazaruto archipelago traditional forms of oyster conservation include a voluntary stoppage of oyster gleaning between November and February, and the 'ownership' of oyster gleaning areas (Dutton, 1990).

In general, it would be desirable to re-introduce as many traditional methods of control of resource use as possible. The palisade fish traps of the Kosi estuary in northern KwaZulu-Natal have yielded catches for centuries through the continued use of traditional methods of resource management. The palisade fish traps that the author encountered in several places in the estuarine lagoon of the VCWS appeared to have fallen into disuse as they are not properly maintained and many of the fish traps are missing. The reasons for this disuse need to be ascertained.

The relocation of fishing villages within the VCWS will cause disruptions to patterns of resource use and may create an opportunity to redefine the methods, intensity and efficiency of fishing practices in the Sanctuary.

Furthermore, the use of seine nets in the Sanctuary should be restricted to fishermen who are resident in the Sanctuary. All seine fishermen should be officially registered and provided with appropriate identification documents.

- Gill netting: The capture of fishes using monofilament nylon gill nets is one of the most difficult aquatic resource management issues in the tropics. Monofilament gill nets are undeniably efficient and cost-effective; they are also light, fairly durable, cheap, easy to set (though not easy to untangle), and easy to repair. They are therefore ideally suited to use by subsistence and semi-commercial fishermen operating in remote environs. The problem with gill nets is that they are super-efficient, indiscriminate in their catch, virtually invisible underwater, and difficult to detect and control. It is nevertheless imperative that the use of gill nets in the VCWS is strictly controlled otherwise some species will be lost completely or at least severely depleted. Furthermore, there is the risk that, as local fishermen become more affluent, they will buy even more gill nets and decimate the resource further.

  It is essential, therefore, that strict control over the use of gill nets should be implemented immediately. My recommendations are: (1) all gillnets used in the Sanctuary should be owned by, or at least registered with, the Sanctuary authorities, (2) there should be strict control over the number of gill nets allocated to each fishing village, (3) fishermen who are not

resident in the Sanctuary should not be allowed to deploy gill nets there, (4) only multifilament gill nets should be used in the Sanctuary, no monofilament gill nets, (5) the gill nets should always be surface set so that they catch pelagic fishes and squids and not benthic species, (6) The mesh size of the gill nets should be strictly controlled by the Sanctuary authorities; small mesh sizes (<3 cm bar mesh) should be avoided if possible.

- Collection of specimens: Strict control should be exercised over the collection of pre-selected species of invertebrates or fishes for commercial exploitation, such as *Fungia* corals, crabs, crayfish, prawns, scallops, cowries, other attractive molluscs and their shells, octopus, starfish, brittlestars, sea urchins and their tests, pansy shells and their tests, sea cucumbers, sea horses, pipefishes, flatfishes, blaasops, and other species. There is evidence that sea horses, tufted black sea cucumbers and crayfish are overexploited; many other poorly studied species may also be threatened. Particular attention should be given to species that are regarded as threatened by the IUCN, such as sea horses.

- Collection of curios: The collection of animals and animal tests, shells and skeletons by tourists for curios also needs to be strictly controlled. The best practice would be to ban collecting completely, but this is probably impractical as everyone wants a memento of their visit. Certified collectors and sellers of selected mollusc shells and echinoderm tests could be appointed, and tourists would be required to make purchases from them. Collections could be restricted to the dead shells and tests of common species, such as wedge shells, sand oysters, some sea urchins, mussels, horse mussels, fan shells, cockles, clams, ribbed venus shells, chitons, limpets, topshells, periwinkles, nerites, mangrove whelks, dogwhelks and plough shells. Export permits must be issued for all animals and animal products that are exported. Certain sites should be regarded as core conservation areas and no collecting should be done there.

  The collection by tourists and collectors of the shells (or live animals) of tritons (especially the trumpet triton *Charonia tritonis*), cowries, giant clams (*Tridacna maxima*), venus ears, turbans, murexes, cones, sea hares, nudibranchs, Spanish dancers, octopuses, squids, starfishes, feather stars, brittlestars, pencil urchins, heart urchins, and sea cucumbers, *inter alia*, should not be allowed.

- Pollution: Pollution of the tidal flats by discarded batteries, fuel oils, bilges, discarded net fragments, human waste and other pollutants should be eliminated.
- Spearing of benthic animals: Flatfishes, sea cucumbers, crabs, sand sharks and other species are speared from above water using two- and three-pronged spears, and pelagic and benthic fishes are speared using single-pointed spears. These traditional practices are probably sustainable within limits, except with regard to the sea cucumbers which are very vulnerable to exploitation at low tide in shallow water.

- Spearfishing**:** Fishermen from at least one village in the Bay use snorkels and goggles and standard spearfishing equipment to catch crayfish that inhabit a rocky reef within the lagoon. The crayfish that they capture are small and appear to be overexploited; the fishermen agree with this view. Control needs to be exercised over this fishery.
- Killing of dugongs: The dugong population is very low (see separate section) and is in urgent need of conservation attention. The causes of their decline include accidental capture in gill nets and loss of feeding grounds. As the dugong is a flagship species, every effort needs to be made to implement controls over their accidental and deliberate killing by local people and visiting exploiters of marine resources. The conservation of dugongs (and all other wide-ranging species) will have to take place in close collaboration with the Mozambican authorities and the managers of the Bazaruto archipelago.
- Noise pollution and boat accidents: Excessive use of powered boats in the Bay and over the sea grass beds will be disruptive to the natural community and to other visitors, Whenever possible, tourist visits should be made using non-powered craft, such as dhows, kayaks or canoes, or from the shore. It is recommended that all powered craft that are used in the Sanctuary should be owned and operated by Sanctuary staff, and should be available for hire by visitors. The uncontrolled use of privately owned powered boats will cause major problems in terms of the management of the living resources and of people. Treacherous seas and currents are encountered in some parts of the Sanctuary, particularly near the entrance to the Bay, over the coral reefs, in the surf zone and offshore of the marine beach and rocky reefs. Only experienced skippers who are knowledgeable about local conditions should be allowed to take boats to these areas. Boat accidents are costly to the Sanctuary in terms of reputation as well as financial and logistical resources.

- Lack of knowledge on population sizes of exploited species: Stock assessment surveys need to be carried out urgently on the most important commercial species.

3.3.5 Estuarine lagoon: The main conservation threats and actions are:

- Seine netting: The same concerns on the use of seine nets in the sand flats apply to the estuarine lagoon, except that the estuary is a narrower, more confined environment that is probably easier to over-exploit and which probably has less efficient recruitment of planktonic larvae and other juvenile life-history stages from the sea. The relocation of fishing communities to the estuarine lagoon should therefore be carried out with caution as the estuary almost certainly has a far smaller exploitable standing stock than the lagoon.
- Gill netting: The same concerns with regard to the use of gill nets apply in the estuary, but the estuary is likely to be even more vulnerable to their capacity to overexploit a resource. Gill nets are already extensively used in the estuary and will unquestionably have to be controlled.
- Collection of specimens: The same concerns and recommendations apply to the estuary as to the tidal flats.

- Collection of curios: As above.
- Pollution: Pollution of the estuarine lagoon by discarded batteries, fuel oils, bilges, discarded net fragments, human waste and other pollutants should be eliminated.

4 Spearing of benthic animals: As above.

5 Noise pollution: As above.

1.3.9 **Mangrove swamps:** The main conservation threats and actions are:

- Clearing for building works: Mangrove swamps should not be cleared for marinas or other coastal developments, nor closed off for causeways or bridges.
- Seine netting: The mangrove swamps are very important nurseries for invertebrates and fishes in the Sanctuary and should be afforded an extra level of protection compared to the rest of the lagoon. The aerial breathing roots of many of the mangrove trees offer natural protection against the use of seine nets but the mangals are still vulnerable to overexploitation by other methods. There are also large areas of water around the mangals that can be seined, especially at high tide. This is regularly done, for instance, using long seine nets in the small bay on the north-west corner of the Peninsula
- Gill netting: Gill netting is carried out in the mangals at high tide, mainly to catch lagoonal fish that venture into the mangals to feed. The recommendations with regard to the use of gill nets in the tidal flats mentioned above should apply to the mangals as well.
- Collection of specimens: As above.
- Collection of curios: As above.
- Pollution: Pollution of mangrove swamps by discarded batteries, fuel oils, bilges, discarded net fragments, human waste and other pollutants should be eliminated.
- Removal of timber: The wood of mangrove trees is used to make the elbows and other joints of dhows, as well as small canoes. This use is probably sustainable but should be investigated further.
- Drainage: There is some evidence of drainage channels being dug in the mangals. This is undesirable as it will interfere with the natural functioning of the mangal, which relies on the twice-daily ebb and flow of the tides for its proper ecological functioning.

1.4 Conservation priorities: Conservation priorities in marine and coastal systems of the VCWS include: the protection of Red Data Book species, as well as flagship and keystone species, that are known to be threatened in the Sanctuary (sea horses, tufted black sea cucumber, dugongs, blue crabs, mud crabs, rock lobster, turtles); the development of a management plan for the sustainable use of species with commercial value, such as game fishes; the development of a management plan for maintaining common but ecologically important species at appropriate population levels so that they can play their ecological roles while also being visible to visitors; and the maintenance of essential ecological processes and life-support systems.

1.5 Unique opportunities: The conservation attributes of the VCWS should be seen as a combination of the biotic and cultural diversity of the place. The biotic diversity includes not only the diversity of plant and animal species, but also the diversity of interspecies relationships (commensalisms, symbioses, parasitisms, predator-prey relationships, ecological dependencies, recruitment of planktonic larvae from the sea, etc.) and fossil burrows, as well as the diversity of habitats (seascapes, lagoons, estuaries, sandy shores, muddy shores, mangrove and reed swamps, sea grass meadows, tidal flats, dunes, coral reefs, rocky reefs, sandy bottoms), important ecological events (tidal ebb and flow, seasonal changes, day and night changes in animal behaviour and abundance, inundation and draining of the tidal flats and mangroves).

The cultural diversity includes traditional harvesting practices, traditional methods of resource management, traditional fishing gear, traditional fish preservation and cooking methods, boat-building and sailing styles, traditional knowledge about the coastal and marine environments and their biota, middens and other evidence of past exploitation, and introduced or transplanted coastal plants and trees.

1.6 Incentives for conservation: The major incentive for the conservation of coastal and marine environments in the VCWS is to maintain essential ecological processes and life-support systems so that the marine and coastal environments continue to function naturally and productively, for human and non-human users. A healthily functioning environment provides many free products and services to users, such as food, water, building materials, means of transport, recreational opportunities, educational opportunities, at little cost. In contrast, a severely disrupted environment provides reduced products and services and is very costly to maintain, even at a level of lower productivity, as it is impossible for man to attempt to replicate or fix the multiplicity of natural processes that can break down.

It is neither practical nor desirable to attempt to manage the coastal and marine environments of the VCWS as pristine ecosystems – they have exploited by traditional users for centuries, and will continue to be exploited. Furthermore, the creation of the VCWS relies partly on the ability of tourists to use the resources of the Sanctuary on a sustainable basis. The management goal should therefore be to determine the levels of exploitation that can be sustained over time, taking into account the combined needs of local and visiting communities.

The increased availability to local fishermen of very efficient, and often destructive, fishing gear, such as monofilament gillnets and long lines, is a major problem and needs to be controlled. This development, combined with increases in the local human population, is probably the main threat to the coastal and marine environments of the VCWS.

It is also impractical and undesirable to attempt to manage the VCWS in isolation. The Sanctuary is part of a larger marine and coastal system, and most of its important species originate from outside the system. Conservation within the Sanctuary will only be successful if conservation actions are also successful around the Sanctuary in San Sebastian Bay, around the Bazaruto archipelago, and

offshore. The marine resource management plan within the Sanctuary therefore needs to be part of a larger plan for the whole biome, and it is important that Sanctuary staff play an active role in promoting the development of the broader plan. An important component of the broader plan will be strengthening the law enforcement capacities of local and regional conservation and fisheries officers, and strengthening export controls for marine animals and animal products from Vilanculos. Another component of this broader plan, in which Sanctuary staff could play a leading role, is in the education of local residents, local officials, law enforcement officers, politicians, visitors and staff about the natural and cultural attributes and conservation priorities of the Sanctuary and its surrounds. The establishment of reasonable capacity limits for tourism developments, and the correct siting of these developments, are also important issues. Strengthening the capacity for applied research and monitoring, and the establishment of a field research laboratory, are further considerations.

4. Recommendations on the sustainable utilization of marine and coastal resources

4.1 Hiking, canoeing, horse-riding and diving trails: The VCWS has considerable potential for separate or combined hiking, canoeing, horse-riding and/or diving trails. Night-time hikes should be organized into local mangrove swamps in order to witness the remarkable transformation of these dynamic habitats after dark.

4.2 Coral reef diving: The reefs comprising coral-encrusted rocks off Bazaruto and the San Sebastian Peninsula offer world-class SCUBA diving opportunities for experienced, properly-qualified open sea divers. As sea conditions over these reefs vary from benign to dangerous, it would be essential to have experienced boatmen (and –women) as well as experienced dive supervisors and buddy divers. AS safety would be of paramount importance, it would be essential to meet, and preferably exceed, the safety regulations that are stipulated in Mozambique and South Africa with regarding to boating and diving.

The reefs off the VCWS have spectacular and very diverse populations of invertebrate and vertebrate life, with many true tropical species that cannot be observed at popular dive sites in South Africa, such as Sodwana. The large populations of pelagic and bottom fishes, giant clams, diverse communities of echinoderms, and the diverse symbiotic and commensal associations of animals, are particular attractions. The overall appeal of a diving excursion, during which one is also likely to see dolphins, whale sharks, humpback whales, manta rays and turtles, and to catch pelagic game fish on rod-and-line, adds to the unique experience.

Damage to the reef by boat anchors should be avoided by banning anchoring or by establishing mooring points attached to buoys that are suspended just below the water surface, as is done in the Red Sea, Great Barrier Reef and the Caribbean Sea. Spearfishing and bowfishing, and any collection of live or dead marine animals, including seashells on or near the reefs, should be completely banned throughout the year, whether using free-diving gear or SCUBA, or any collecting apparatus.

Furthermore, divers should not be allowed to touch or stand on the reef; ensuring that all divers are neutrally or slightly positively buoyant is therefore important. The use of buddy lines should be avoided as they often snag the reef. A diver who is so insecure that they need a buddy line should preferably confine his/her diving to shallow inshore waters. No diving apparatus or fishing equipment should be discarded on the reef. Bottom fishing should not be allowed on or near any reefs adjacent to the VCWS although controlled midwater fishing for migratory, pelagic game fishes could be allowed.

4.3 Dhow rides: The Arab dhows that ply the waters of San Sebastian Bay are a very attractive feature to visitors from South Africa, Europe and North America, who are unlikely to have encountered these majestic craft before. Their slow pace, dependence on the wind, and historic character will add unique value to the VCWS experience. Dhow rides could be offered to and from Vilanculos but preferably in the bay off Dugong Camp as half-day trips.

4.4 Canoe and kayak rides: The bay adjacent to the VCWS is relatively safe and amenable to use by canoes or, preferably, the safer and easier-to-use and maintain sit-on-top fibreglass sea kayaks. Kayak trips would add considerably to the quality of the individual visitor experience at the VCWS, without detracting from the visitor experience of others. The dangers that would have to be taken into account when managing sea kayak trips would include: the tidal rip during the change of tide at spring high tide, the sudden appearance of sand banks and shallow shoals at low tide, the threat of being blown away from the camp or the shore by strong offshore winds, exposed rocks and mangrove breathing roots at low tide in some areas, and fatigue, dehydration and heat exhaustion by less-than-fit tourists!

All persons embarking on a canoe trip would need to log their journey, take suitable all-weather clothes and walking shoes (in case they have to walk back), and take drinking water, food, extra paddles, a waterproof map and a whistle. Canoeing excursions should preferably be carried out with a knowledgeable guide who will not only ensure that the journey is safely completed, but also make the overall experience more fulfilling.

Canoeing excursions could be carried out from Dugong Camp south-eastwards towards the mangrove swamps and fishing villages, southwards towards the exposed tidal flats (at low tide), and westwards and then northwards towards the exposed tidal flats, sheltered mangal bay and northern fishing villages. In addition, canoeing trips could be undertaken in the elongate estuarine lagoon on the seaward side of the VCWS using craft based there.

4.5 Use of speed boats, water scooters and other powered water vehicles: It is strongly recommended that the use of powered water vehicles (speed boats, water scooters, hovercrafts, etc.) within the VCWS should be strictly controlled, and that those vehicles that are used in the Sanctuary should preferably not be privately owned. The water vehicles should be owned and rented out by the VCWS to tenants and visitors so that their numbers, and the their destinations and methods of use, can be strictly controlled. If this recommendation is not

implemented the potential exists for the wilderness atmosphere of the VCWS to be completely destroyed by irresponsible and excessive use of powered vehicles. The risk to the natural environment, from fuel pollution, noise pollution, direct disturbance of fishes, reptiles, birds and mammals, as well as of traditional fishermen and dhow operators, would also be considerable.

It is therefore strongly recommended that small fleet of low-powered outboard-powered boats should be available for rent by tenants and visitors. These boats should be clearly coloured and numbered so that they can easily be identified. In addition, the workboats that would be required by the VCWS to operate the Sanctuary, conduct guided tours, bring in supplies and conduct reef dives, should be clearly marked, should be operated by trained VCWS staff only, and should be used for those purposes only.

4.6 Guided tourism: Guided tourism is one of the fastest growing industries in the world, and the VCWS is an ideal place for this form of tourism. The discriminating tourists who visit the VCWS will expect boat tours, hikes, canoe trips and dives that are lead by expert guides, preferably properly trained local people, but also foreign experts. The environment and biota of the VCWS is so diverse, and so different from that with which most visitors will be familiar, that it would be essential for it to be interpreted to them. Guided tours should not only cover the obvious tourist attractions, such as big game, trees, and conspicuous birds, but also subtleties of Nature such as mangrove ecology, the impact of tidal fluctuations, insects and other terrestrial invertebrates, aquatic invertebrates, amphibians, reptiles and small birds and mammals, and understorey and woodland plants, fungi and algae.

The diversity of aquatic invertebrates, in particular, is stunning and a great deal of it can be appreciated by people of all ages, skills and fitness levels as it can be accessed by walking at low tide. The abundant and diverse communities of echinoderms (starfishes, sea cucumbers, sea urchins, heart urchins, sand dollars), sponges, crabs, molluscs and shrimps, although submerged, can easily be seen, interpreted and discussed on foot. This experience can be further enhanced using free-diving gear, glass-bottomed boats and underwater viewing devices (plastic buckets with the base replaced with transparent Perspex). The symbiotic and commensal communities of invertebrates living under sponges and giant starfish in the shallow waters to the west and north of the San Sebastian Peninsula are a special attraction, as are the sea horses and pipefishes in the seagrass beds, the mudhoppers, mangrove snails and crabs in the mangrove and swamps, and the aquatic birds, crocodiles and lungfishes in the freshwater lakes. There are few places on Earth where such a variety of life can be seen without specialized equipment or without travelling long distances

4.7 Establishment of artificial reefs: As far as the free-living marine animals in the bay off the VCWS are concerned, the limiting commodity in their environment is a place to hide or attach oneself. This is indicated by the extent to which any object on or above the sand (rock, shell, mangrove branch or root, boat hull, debris) is festooned with attached life forms, or serves as a focal point around which swimming animals congregate. The establishment of artificial reefs in San Sebastian Bay is therefore likely to be highly successful, on condition that

these artificial reefs cannot be moved by the tidal rip or by wind-induced currents.

Artificial reefs provide many services to the visitor and park manager: they provide reefs in shallow water that are inhabited by a wide variety of life forms (plants, invertebrates, fishes), these reefs are accessible by snorkel divers as well as by passengers in glass-bottomed boats, they increase biodiversity in the immediate vicinity of the camp, and provide prey for birds. Series of artificial reefs can even provide a sustainable harvest of fishes and invertebrates that can be served in the dining room! Artificial reefs also provide an excellent research opportunity by concentrating species in a small area, and by introducing new researchers to the biota. The colonization patterns of artificial reefs also provide interesting study opportunities for professional and amateur biologists alike.

Artificial reefs are best constructed from natural materials, such as logs and rocks, or from materials that are associated with the lagoonal environment, such as the hulls of old dhows. The ribs and hulls of several abandoned dhows are strewn along the shores of the mangal bay to the northwest of Dugong Camp, and along the lagoon to the south, near the fishing villages. These hulls would make efficient and picturesque artificial reefs.

An artificial reef project was started off Dugong Camp during the author's second visit to the VCWS. It is hoped this experiment can be repeated in other places in the lagoon, with out interfering with boating channels. Fishes that colonized the reef during the first week after its establishment included firefishes (*Pterois*, Scorpaenidae), mullet (Mugilidae), juvenile kingfishes (Carangidae), hawkfishes (Cirrhitidae), gobies (Gobiidae), boxfishes (Ostraciidae), blaasops (Tetraodontidae), lizardfishes (Synodontidae), flagtails (Kuhliidae), goatfishes (Mullidae), wrasses (Labridae), seabreams (Sparidae) and butterflyfishes (Chaetodontidae).

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4.8 Use of glass-bottomed boats: Rowing boats, or low-powered powered boats with outboard engines, fitted with transparent acrylic panels in their hulls would provide people who cannot dive with a spectacular view of shallow undersea life in the lagoon. These boats would be most effective in the lagoon to the south, west and north-west of Dugong Camp, in mangal bay, along the fringes of mangrove swamps, and in the estuarine lagoon. The boats should ideally have a small aquarium in them into which hardy forms of marine life, collected by divers, could be temporarily placed for the visitors to examine. These life forms could include starfish, sea cucumbers, large crabs and mollusks. Waterproof sheets illustrating and identifying the most common forms of sea life should also be made available in these boats (and to divers).

Glass-bottomed boats should be used for leisurely, short-distance trips on which the emphasis is on learning about marine life. They should always be accompanied by trained diver/guides. Glass-bottomed boats are used extensively in tourist destinations where clear, warm, shallow water is found, in the southern continental USA, Hawaii, Caribbean nations, Red Sea, Australasia, and in south-east Asia.

4.9 Use of water bicycles: Bicycles equipped with flotation devices, rudders and propellers make excellent, stable, safe and non-polluting means of transport on calm lagoons without strong wave action; they would work perfectly in the VCWS. Similar bicycles used by the author of the Florida Keys enabled him to paddle several hundred metres offshore, to view fishes and turtles in the clear, shallow water, and to enjoy healthy exercise at the same time. Commercially available water bicycles are impossible to capsize and are easy to ride; they could be manufactured locally in South Africa by bicycle repair shops.

Water bicycles would provide an unusual form of non-polluting, quiet recreation for visitors, and would generate income for the VCWS. A small maintenance workshop, and some expertise in bicycle maintenance and fibreglass repair, would be required.

4.10 Use of water boots: Various designs of floating boots are available for recreational use for walking on water. Although these boots are safe and practical to use, it is difficult to make much progress across the water as a particular technique, similar to that used in cross-country skiing, has to be mastered. The author has used them in the USA and England.

4.11 Use of tourist submersibles, submerged scooters and diving helmets: Although tourist submersibles are now popular in the Caribbean, Red Sea and in Japan, the sea and lagoonal conditions at the VCWS are not suitable for their deployment there. Small, submerged scooters, which have recently become available and on which the passenger sits with an air-bubble helmet over his/her head, may be practical to use in the lagoon, but there are probably insufficient objects of interest to see in midwater in the lagoon to justify their deployment. Furthermore, sea conditions off the VCWS are too hostile for their use over coral or rocky reefs. Simple, negatively buoyant diving helmets, which rest on the shoulders of the diver when he/she walks underwater, have been successfully used in calm, shallow lagoons in Mauritius. They could be considered for use of the VCWS in the vicinity of the artificial reefs, but they would be impractical (and possibly dangerous) to use during the strong tidal rips.

4.12 Aquaculture: Several species of fishes that inhabit the freshwater lakes in the VCWS would be suitable for aquaculture, especially Mozambique tilapia *Oreochromis mossambicus*, black tilapia *O. placidus* and sharptooth catfish *Clarias gariepinus*. The yield from the aquaculture venture could provide a steady supply of fresh table fish for the dining room, without depleting fish resources in the lagoon, if the aquaculture project is properly managed.

While the regular harvesting of fishes using seine nets from the freshwater lakes would yield a small catch, this catch is unlikely to be sustainable. Enhanced

feeding of stocked fish in a small natural lake, from which most predators have been excluded, and which is regularly fished to enhance the growth of the remaining stock, would be a more practical solution. We recommend that a small natural lake, near to the main camp, should be extensively netted to remove all the fishes except for large Mozambique tilapia. This lake should then be stocked with additional large, healthy adult specimens of this species, and commercially available (but cheap) fish food should be fed to these fishes on a regular basis. Several reaches of shore should be cleared of all submerged and floating vegetation so that a seine net can be efficiently set, pulled and landed. Catfish should not be cultured together with the tilapias, as they eat the tilapia fry.

As the Mozambique tilapia is a sand-nesting species, it is essential that areas of open sand are available for nesting. The lake should also have gradually sloping, well-illuminated gradient shores where the tilapias can feed on diatoms and other algae (Bruton & Boltt, 1975). The adult fishes need deeper water (>3 m) in which to shelter from aerial predators, and in which they will find well-oxygenated water that does not fluctuate widely in temperature. They reach sizes of >4 kg although the fishes harvested from the lakes in the VCWS are likely to be in the 0.5-1 kg range.

Clarias are less demanding in terms of habitat preferences, and could be harvested on a regular basis from all the freshwater lakes. They are non-guarding, egg scatterers and require recently in inundated shores to spawn (Bruton, 1979). They have a very catholic diet and feed on insects, worms, crustaceans, mollusks, fishes, small birds, reptiles and small mammals. They reach sizes of >30 kg, although the small lakes in the VCWS are unlikely to yield specimens >5 kg.

4.13 Keeping of aquarium fishes: Several marine and freshwaters fishes in the VCWS would be suitable to keep in aquaria for the interest of visitors and staff. The most suitable freshwater species would include killifishes (Aplocheilidae, especially *Nothobranchius*), topminnows (Cyprinodontidae, especially *Aplocheilichthys*), barbs (Cyprinidae, especially *Barbus*), squeakers (Mochocidae, especially *Synodontis*), cichlids (Cichlidae), and labyrinth fishes (Anabantidae, especially *Ctenopoma*). Euryhaline estuarine fishes that could be kept in freshwater aquaria could include glassies (Ambassidae, especially *Ambassis*), silversides (Atherinidae), some pipefishes (Syngnathidae), moonies (Monodactylidae), and gobies (Gobiidae).

It is strongly recommended that exotic freshwater aquarium fishes should **not** be introduced into aquaria at the VCWS; they will inevitably escape or be released into the natural environment. These undesirable exotic fishes include live-bearers in the family Poeciliidae, especially the guppy *Poecilia reticulata*, mosquito fish *Gambusia affinis*, and the swordtail *Xiphophorus helleri*. It is also **not** recommended that any fishes be exported from the VCWS for the international aquarium fish trade, although this possibility could be entertained in the future once the distribution and abundance of the locally occurring killifishes, topminnows, squeakers and cichlids has been determined.

Estuarine and marine fishes that would be suitable for keeping in a saltwater aquarium at the VCWS include: seahorses and pipefishes (Sygnathidae),

seabreams (Sparidae), moray eels (Muraenidae), eel catfishes (Plotosidae), lizardfishes (Synodontidae), flagtails (Kuhliidae), rockcods (Serranidae), cardinalfishes (Apogonidae), snappers (Lutjanidae), goatfishes (Mullidae), butterflyfishes (Chaetodontidae), damselfishes (Pomacentridae), wrasses (Labridae), and boxfishes (Ostraciidae). It is, however, more difficult to maintain a marine than a freshwater aquarium, especially under tropical conditions.

4.14 Harvesting of marine species: Certain marine fishes could be lightly harvested from San Sebastian Bay, the estuarine lagoon and from the adjacent marine coast on an ongoing basis in order to provide fresh fishes for the dining room. These fishes could include tarpon (Megalopidae), certain lagoonal seabreams (Sparidae), kingfishes (Carangidae), mullet (Mugilidae), barracudas (Sphyraenidae), mackerel (Scombridae) and soles (Soleidae). Strict control over the extent of harvesting of these species would have to be maintained, and research should be initiated to measure the impact of this fishery.

4.15 Establishment of interpretation centre: It is strongly recommended that an interpretation centre should be established as a means of educating visitors and staff about the diversity of marine, estuarine, freshwater and terrestrial life in the VCWS. This centre could include: freshwater and marine aquaria; terraria of live reptiles, amphibians and insects; small museum of dried and preserved animal specimens, including sea shells; an herbarium of dried, pressed plant specimens; geological and soil samples; satellite photographs of the VCWS (past and present); small reference library; touch pool of common and hardy marine animals (starfishes, crabs, molluscs, changed regularly); simple monocular microscope for viewing small and microscopic animals; TV and collection of relevant terrestrial and marine wildlife videos; computer with access to the Web; poster displays on the natural history of the VCWS; three-dimensional scale model of the VCWS.

The interpretation centre should also include items of cultural history interest, including arts and crafts from the local community, including jewelry and beadwork; toys made by local children; locally made household goods, such as clay pots and basketware; locally made traditional fishing tackle and hunting equipment; scale models of local architectural styles; photographs of local people and their methods of harvesting fishes, mammals and plants.

4.16 Erect informational boards: Consideration should be given to erecting informational boards at key locations in the VCWS to inform people about the most important ecological characteristics of an area. Commercial companies could possibly sponsor these boards. Informational boards could, for instance, be erected near a mangrove swamp, fishing village, reed swamp, inland lake, tidal flats, estuarine lagoon, dhow harbour, dhow wreck, bird colony, artificial reef, mudskipper habitat, crab colony, etc. Informational boards are commonly erected in coastal and marine sanctuaries around the world.

4.17 Establishment of bird hides: Bird hides would make it possible to view, through binoculars and with the naked eye, the diversity of often-elusive birds in the VCWS. Hides could be erected for terrestrial, freshwater, and marine and coastal birds.

4.18 Establishment of research station: It is further recommended that small field research station should be established within the VCWS. This research station would provide the following services: provide accurate, up-to-date information that can be used for the management of the Sanctuary and its renewable natural resources, provide a constant stream of interesting information for visitors; provide onsite expertise for solving natural resource management problems; produce field guides to the plants and animals of the Sanctuary; possibly lead to the discovery of new as well as rare and endangered species in the VCWS; build up the natural and cultural history collections in the interpretation centre; provide expert natural history guides for use by visitors; provide opportunities for the training of young Mozambican researchers; make a lasting contribution to the better understanding and management of the natural resources of Mozambique; gain credibility with the regional and national government and with the conservation authorities in Mozambique; gain credibility with international conservation bodies, including the Ramsar Convention.

The research station should comprise a wet laboratory, dry laboratory, office, bathroom, storeroom, open-air work areas, jetty, weather station, and accommodation initially for, say, four scientists, with the option of expanding the accommodation facilities further. A well-established research facility could become an important money-earner for the VCWS if well-funded research projects are attracted to the area. The author once operated a field research station adjacent to Lake Sibaya in northern Zululand that regularly accommodated researchers from 12 universities in five countries.

Once the basic research station has been established, with rustic accommodation for, say, four researchers, it will develop a life of its own and should not be a financial drain on the VCWS. African and foreign researchers are likely to welcome the opportunity to conduct research in this interesting part of tropical Africa, and will pay for their own accommodation, subsistence, transport and research costs.

4.19 Preparation of a field guide: It would be highly beneficial to the management and appreciation of the VCWS by visitors and staff, for an illustrated field guide to be produced on the ecology of the Sanctuary. This field guide could begin modestly as a monochrome pamphlet and could eventually build up to become a substantial tome, similar to the field guides on the coastal plain of Maputaland (Bruton & Cooper, 1979), the eastern Cape coast (Lubke et al., 1988) and the whole coast of southern Africa (Day, 1974; Branch et al., 1994). The field guide would summarize the state of knowledge on the ecology of the VCWS and stimulate further research.

4.10 Injuries and waterborne diseases: The managers of the VCWS are aware that there are a number of waterborne diseases in the freshwater lakes of the VCWS, of which bilharzia is probably the most serious. Care should be taken not to wade in these lakes without rubber boots or waders, especially around midday (10h00-14h00) when the cercaria (mobile larval stage) of the bilharzia parasite are most likely to be active.

Injuries can easily be sustained in the marine environment if visitors do not exercise caution. The most common injuries are likely to be: lacerations caused by razor clams, oyster shells attached to mangrove snail shells in the mangals, other sharp mollusc shells, and the sharp breathing roots of mangroves (when wading in the shallows); stings from firefish and jellyfish; penetration of the skin by the spines of sea urchins and the dorsal spine of the stonefish (the latter can be fatal); penetration of the skin by the dorsal and pectoral spines of a variety of fishes, especially scorpaenids and cichlids; 'stings' from stingrays; electric shocks from electric rays (if any); snake, insect and scorpion bites in coastal environments; infection of open wounds.

Guests partaking in boat trips may suffer from heat stroke, sunburn, dehydration, water inhalation, wound infection and possibly drowning. Divers also run the risk of suffering from decompression sickness, the bends or blackouts, as well as drowning. The propeller of an outboard motor is a lethal weapon underwater (the author once treated a diver who lost two fingers in a propeller). It is essential that all tour guides are trained in basic first aid, and that the contact details of the nearest medical doctors are readily available. Details of the nearest decompression chamber should also be readily at hand (do not fly a 'bent' diver to the decompression chamber). A substantial medical aid kit needs to be kept on site, and a smaller kit should be taken on all field trips. Appropriate tropical snake bite anti-serums should be kept refrigerated.

5. Preparation of a research strategy: A research strategy for the VCWS should be drawn up urgently so that future research activities are properly planned and executed. This strategy should be drawn up in consultation with local and foreign experts and research administrators. The research strategy should outline the following:

- Goals and objectives
- The present state of our knowledge
- Key areas in which research is needed, taking into account both conservation and commercial interests
- Guidelines for the preparation of research proposals and the presentation of research reports
- The identification of suitably qualified and experienced researchers to carry out the prioritized research tasks.
- Appointment of a Research Committee to manage the research effort
- Recommendations on the availability of funds for research purposes.

In the marine subsystem, research priorities would probably be defined to provide information and understanding of species that are subject to commercial or recreational exploitation, or which have become rare due to man-induced habitat changes.

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