25 Year Master Plan for Management
Komodo National Park

Book 3
Site Planning
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Site Planning

Proposed by Komodo National Park’s Authority
Assisted by The Nature Conservancy and Gajah Mada University,
and supported by Manggarai District Authority.

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1. SITE PLANNING FOR KOMODO NATIONAL PARK

Effective site planning within Komodo National Park (Fig. 1) is dependent upon:

- accurate information concerning the fauna (Figs. 2 and 3) and flora (Fig. 4),
- the ecological and biological processes at work (e.g. Fig. 5),
- human populations (Fig. 6),
- the socio-cultural factors present,
- the legal and political situation, and
- the interaction of these various factors.

Limited accurate information is currently available, making it necessary to acquire additional information. An overview of the landscape is provided in this volume (including existing facilities), however, Environmental Impact Assessments (EIA or AMDAL, particularly for eco-tourism and marine resource use), are needed before detailed plans can be drawn up. The final section of this volume deals with suggestions for the needed EIAs. Following completion of the EIAs, detailed site plans should be drawn up and implemented and detailed regulations should be drafted for the proposed zoning plan (Fig. 7) of Komodo National Park.
Figure 1. Borders of Komodo National Park, according to the revision of November 1998.
Figure 2. Cetacean migration routes, swiftlet nesting sites, sites where manta rays aggregate, and turtle nesting beaches. Sketch map based on interviews with Park rangers and staff of the TNC Komodo Field Office, and on the cetacean surveys held in May and October 1999.
Figure 3. Spatial distribution of the Komodo dragon, two bird species and five mammal species in Komodo National Park. Based on reports from Park rangers.
Figure 4. Vegetation cover in Komodo National Park. Forest cover is based on visual interpretation of Landsat images taken on October 19, 1992 and May 3, 1992. Cover of mangrove and sea grass is based on interviews with Park rangers and staff of the TNC Komodo Field Office.
Figure 5. Grouper spawning aggregation sites. Up to now, 12 fish spawning aggregation sites were identified by the TNC Komodo Field Office. At sites 1-10, abundance, size, and behavior of 11 commercial grouper species and Napoleon wrasse are monitored during full moon and new moon by SCUBA divers.
Figure 6. Villages in the Komodo area. Population numbers are based on a survey of population statistics by Komodo Field Office staff. The numbers pertain to 1999, or, if not available, to 1998 (Mesa, Labuan Bajo, Golomori, Warloka). For Gorontalo and Seraya Kecil, no separate statistics are collected (inhabitants are included in the statistic for Labuan Bajo).
Figure 7. Proposed zoning for Komodo National Park, within presently designated borders.
2. DESCRIPTION OF THE LANDSCAPE

The Komodo National Park (KNP) is a conservation area in the Lesser Sunda region consisting of island groups and their surrounding waters. It is located East of the Wallacea line and has a highly unique landscape (Fig. 8). KNP is highly valuable, containing a wealth of biological and cultural resources. KNP contains savanna, plain woodland, some tropical rain forest on the mountain tops, coastal forest, mangrove forest, marine waters, and a range of mountains and hills (Figs. 4 and 9). The area is influenced by the monsoon winds, and the climate in general is dry. In certain landscapes, such as the hills and the mountains, the climate is more humid.

Geographically the National Park lies between the island of Sumbawa and the island of Flores, and between two seas, the Sulawesi or Flores sea to the North, and the Sumba Strait and Indonesian Ocean to the South (Fig. 10). The current coordinates of KNP are 119°20′95″ up to 119°49′20″ East longitude and 8°24′35″ up to 8°50′25″ South latitude (Fig. 1). The coordinates for the existing borders of KNP are based on the work chart by PKA, which was signed by the Head of the Forestry and Plantation Planning Department Ir. Roedjat MSc on 20 November 1998. The sources for this work chart are SK Menteri Kehutanan RI No. 306/KPTS-II/92 Tanggal 29-2-1991 and Marine Chart Indonesia No. 295. The current size of Komodo National Park is 1,817 km², including 603 km² land and 1,214 km² (67%) marine waters. Proposed extensions for the Park will add another 25 km² of land and 479 km² of marine waters (Fig. 11). Proposed buffer zones are to be co-managed with the local government.

The Komodo National Park includes Komodo Island, Rinca Island, Padar Island, Gilimotang Island, the small isles surrounding these four islands and marine waters. Administratively it is included in the Manggarai district, West Flores, East Nusa Tenggara province. The proposed extension on the West side of the Park is located in the Bima district, Sumbawa, West Nusa Tenggara. Komodo National Park’s landscape can be subdivided into two main components, terrestrial and marine. These components are described in more detail below. Each component has its own unique features, both are important and are interdependent.

2.1 THE TERRESTRIAL LANDSCAPE

2.1.1 Komodo Island

Topography
Komodo Island is located to the East of Sumbawa Island and is separated from it by the Sape strait. The coastline of Komodo Island is 181 km long. Komodo is currently the most Western located (larger) island of a number of islands in the Komodo National Park, and covers a surface area of about 336 square kilometers. The island is approximately 36 km long (North-South). The height of the land from sea level varies from 0-735 m. To the North, a range of mountains and hills surrounds the bay of Loh Liang in a semi-circle. This Northern mountain range consists of Mount Satalibo (735 m), Mount Ara (510 m), Mount Todo Klea (560 m) and Poreng Hill to the North-East (Fig. 9). Another range of hills abounds to the North-West of Mt. Satalibo and in several places towards the North coast of Komodo. In the central part of the island, the landscape is relatively flat, but in the South, starting from Mt. Komodo (500 m above sea level) continuing to the South, the land stretches in plains with rugged hills. The coastal region often consists of steep and sheer rocky cliffs, although in several places there are white sandy beaches that offer a splendid view.
Figure 8. Elevation and depth contours, Komodo area.
Figure 9. Rivers, mountains peaks and water sources in Komodo National Park. Data were collected and digitized by the GIS facility of the Park authority.
Figure 10. Komodo area, situated between Nusa Tenggara Timur and Nusa Tenggara Barat, as charted by Dinas Hidro-Oceanografi of the Indonesian Navy.
Figure 11. Borders of Komodo National Park (Nov. 1998), proposed extensions, and proposed buffer zones (Nov. 1999).
As to the relief of the surface, in several places there are deep, rocky and dry erosion gullies. On the spine of the hills or mountains there are gullies forming narrow valleys, or gorges that seem to have a higher moisture content than the surrounding area on the surface.

**Seasons and Water sources**
The island is relatively arid with few perennial surface water sources (Fig. 9). There are several catchment areas and springs that may provide water throughout the year. In addition there are also perennial springs near the beach, and several streambeds even in the dry season, where water can be found by digging wells. A number of seasonal rivers empty into the area near Loh Liang, with a water debit of approximately 2.50 m³ per day, roughly corresponding to the need of 40 persons per day. Water sources on Komodo island as of 1976 can be seen in Table 2.1. A survey of current water sources should be undertaken, as many of these sources may no longer exist.

Table 2.1. Water sources on Komodo Island

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sebita Gulf</td>
<td>Water spring</td>
</tr>
<tr>
<td>2.</td>
<td>Banu Jomba</td>
<td>Seasonal river, 25 km in rainy season, 0.5 km in dry season</td>
</tr>
<tr>
<td>3.</td>
<td>Wae Sadrar</td>
<td>Seasonal river, 1.2 km in rainy season, 50 m in dry season</td>
</tr>
<tr>
<td>4.</td>
<td>Loh Belanda</td>
<td>Water spring</td>
</tr>
<tr>
<td>5.</td>
<td>Loh Srikaya</td>
<td>Water spring</td>
</tr>
<tr>
<td>6.</td>
<td>Mt. Ara</td>
<td>Seasonal river, 8 km in rainy season, 0.5 km in dry season</td>
</tr>
<tr>
<td>7.</td>
<td>Loh Wia</td>
<td>Water spring</td>
</tr>
<tr>
<td>8.</td>
<td>Wae Kenaitasi</td>
<td>Seasonal river</td>
</tr>
</tbody>
</table>

**Soils and Geology**
Geological phenomena of times long past (early Pleistocene and mid Pleistocene) in the form of volcanic activities, tectonic movements, and extremely large sea level fluctuations have led to interesting geological formations within KNP. The friction at the meeting of two continental plates, Sahul to the East and Sunda to the West, gave rise to numerous volcanic eruptions. The enormous pressure led to the emergence of a coral cluster with a height of 240 m above sea level to the East and North of Todo Klea.

High sea surface fluctuations approximately 18,000 years ago allowed the migration of surface fauna among the islands of Java, Sumatra and Kalimantan. It is highly possible that there was a migration of surface fauna between the islands of Flores and Komodo at that time as well (the sea level at that time was 85 m lower than at present). Volcanic activity in the Komodo National Park area still continues, marked by earthquakes, big and small (Aufenberg, 1970).

Andesite stone dominates Komodo Island, and is spread throughout the Northern part (around Mt Satalibo and the Northwestern part) and the South (from Mt Komodo in Southern direction). Effusive dasitic stone is found from the center to the West, while the center to the East and the Northeastern end are dominated by tuff, marl and volcanic sediment. Komodo island has complex soil, a combination of several soil types including latosol and fertosol, and is greyish-brown. This type of soil generally has a clay texture and during the dry season the soil tends to crack.
Vegetation
The vegetation on Komodo island (Fig. 4) consists of brackish or mangrove forest, coastal forest, savanna and steppes, monsoon forest and quasi-cloud forest. Mangrove forests are found on the East coast, near Sebita, dominant species include *Rhizophora mucronata*, *Ceriops tagal*, *Sonneratia alba*, and *Avicenia* spp. Coastal forest plants include pandan (*Pandanus sp.*), ketapang (*Terminalia catapa*), and keben (*Baringtonia asiatica*). The undergrowth in coastal forests consists of spike grass (*Spinifex litoralis*) that grows mixed with or in association with creeping plants, including *Ipomoea prescaprae*.

The savanna is dominated by lontar palm (*Borassus flabelifer*) distributed from the coast to an altitude of approximately 400 m above sea level. Savannah woodland constitutes the most dominant vegetation community, covering approximately 70% of the existing land surface. Other types of plants that are common are asam (*Tamarindus indicus*) and bidara (*Zizyphus jujuba*). These two plants are able to grow and are found at altitudes of 0 to 500 m above sea level. The lower vegetation consists of a mixture of grasses from 0.5 to 4.0 m in height, including *Setaria* adhaerens, *Chloris barbata* and *Heteropogon contortus*.

Deciduous forest is located at an altitude of less than 500 m above sea level. During the dry season, the trees shed their leaves. The tree species are drought stress resistant. These trees include asam (*Tamarindus indicus*), kepuh (*Sterculia foetida*), kesambi (*Schleicera oleosa*), as well as several grass types, including *Setaria vericillata*, *Brachiaria ramosa*, *Digitaria ascendens*, and *Imperata cilindrica* (alang-alang). This forest type is found in the Northern region of the island, bordering the quasi-cloud forest around Mt. Ara, Mt. Satalibo and Todo Klea, and in the South around Mt. Komodo.

The quasi-cloud forest is located on mountain ridges or high hill pinnacles, at altitudes of 500 to 700 m above sea level. This forest type is generally covered by clouds, or fog, and is cool and humid all year long, with massive dense vegetation. Vegetational diversity is lower than the rainforest communities in Kalimantan, Java or Sumatra. Plant species found in this vegetation type include various species of bamboo (*Bambusa spp.*), rattan (*Callamus spp.*), *Terminalia zollingeri*, *Podocarpus nerifolia*, *Ficus orupacea*, and *Calophyllum spectabile*. Quasi-cloud forest is found on Mt. Ara, Mt. Satalibo and in narrower areas on Mt. Komodo, and Todo Klea.

Fauna
The island Komodo borrows its name from the endemic Komodo dragon (*Varanus komodoensis*), which is widely distributed over the island (Fig. 3). Additional terrestrial fauna includes the wild buffalo (*Bubalus bubalis*), the wild boar (*Sus scrofa*), deer (*Cervus timorensis*), the wild horse, and several types of birds (*Aves*) and other reptiles. The wild fauna on Komodo has a strong appeal for both domestic and international tourists. Its unique wildlife has attracted international scientific interest and been the focus of several research projects.

Land Use
The planting of food crops by the local population, such as rice or vegetables, is uncommon. There exist practically no plantations of perennial plants on the island. Land use on Komodo is dominated by fisheries activities. Fish and seaweed drying requires large relatively flat areas. Residential needs include places of religious worship, the sub-district administrative office (Kelurahan), public roads, schools, a community health center, and the office of Nature Conservation and Protection (PKA). The remainder of the land on Komodo has been declared a
National Park. Current land use patterns are restricted to coastal areas, near fresh water springs. Land use on Komodo Island is centered in Komodo village, in Teluk Slawi bay. Coconut trees and bamboo grass found in the interior may indicate that there used to be land use further inland; it is also possible that other agents may have dispersed these species.

2.1.2 Padar Island

Topography
Padar Island lies between Komodo and Rinca. It is a relatively small island (16 square kilometers) compared to the two main islands, Komodo (336 km²) and Rinca (211 km²). The coastline of Padar is 31 km long. The topography of Padar consists of hills reaching to 269 m above sea level (Mt. Piramide), sloping beaches of clean white sand in the North, and several steep, rocky beaches in the South. The island is approximately 8 km long, stretching from Southwest to Northeast. In the steep portions of the site, there are erosion gullies, dry riverbeds or seasonal rivers.

Seasons and Water Sources
The island’s climate is similar to the other larger islands in East Nusa Tenggara; it is arid, with an average low annual rainfall. It is influenced by monsoon winds, with South-East wind during the months of April to October being dry, and from November through March the West wind blows, which is wet carrying a lot of water vapor. Water sources on Padar are very rare (Fig. 9); the only adequate water spring is located in the center of the island. Fresh water sources are a crucial constraint, and limit the types of activities that can be conducted.

Soils and Geology
Padar’s soils are complex, a mixture of soil types, including latosol and gromusol, and greyish brown in color. The soil contains clay and gravel with a compact structure, and tends to crack when the dry season arrives. Tuff, marl and volcanic sediment formations stretch from Northwest to Northeast of Padar. Alluvium is found at the North Eastern tip, and the balance covering the lowland plains consists of andesite.

Vegetation
Savannah is the dominant vegetation type (Fig. 4). Other vegetation consists of spike grass (Spinifex litoralis), creeping plants (Ipomoea pescaprae) and pandan. Tree species include Asam, Ketapang, Keben (Baringtonia asiatica), sea pine and coconut.

Fauna
Sea birds and seasonal migrants are observed on Padar. The Komodo dragon and deer had gone locally extinct, but the deer have started to return, and there have been unconfirmed sightings of dragons. Wild boar (Sus scrofa), snakes, and turtles are also found on the island. Poaching is still a very significant threat to the deer population on Padar and herewith also hinders the re-establishment of Komodo dragons on this island.

Land Use
The island is a stopover location for local fishermen to rest or take shelter from bad weather. Agricultural activities do not appear to have been conducted in the area. The area could be used for day hikes, beach picnics, photography and sun bathing.
2.1.3 Rinca Island

**Topography**
Rinca Island lies at the most Eastern part of the Komodo National Park area, and is separated from the land surface of Flores by a narrow strait called Strait Molo. The island is rounded to the South with rugged topography, and on the North side it is split in two by a bay called Loh Kima. The island has a surface area of around 211 km², has a total coastline of 172 km, and stretches over a distance of 28 km from Southwest to Northeast. Mt. Doro Ora in the South reaches 667 m above sea level and is the highest mountain on Rinca. The highest mountain in the Northeast part is Mt. Pankarmea (542 m), which forms a rugged mountain range together Mt. Doro Radja (351 m) and several other peaks. In the central and Northwest part the island has a more sloping topography, with small stretches of white sandy beaches. The South coast contains steep cliffs, and sloping narrow beaches.

**Seasons and Water Sources**
Rinca’s climate is similar to Padar and Komodo Islands. The island is influenced by the monsoon winds, so that from November through March the Northwesterly winds blow, carrying a lot of water. During the months of April to October dry winds blow from the Southeast, and there are droughts. The mountain pinnacles, as in the other areas, are almost continuously wrapped in fog or clouds, and have high levels of humidity.

Water sources on Rinca are found at the foot of Mt. Doro Ora, providing water round the year in springs (Fig. 9). There are about eight water sources on this island, almost evenly spread throughout the island, with the largest capacity at the Boe Timba well. Table 2.2 shows the names of sources on Rinca Island as of 1976. This information will be updated through a survey.

Table 2.2. Water sources on Rinca Island

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Loh Buaya</td>
<td>Water spring</td>
</tr>
<tr>
<td>2.</td>
<td>Loh Nelu</td>
<td>Water spring</td>
</tr>
<tr>
<td>3.</td>
<td>Boe Timba</td>
<td>Water spring</td>
</tr>
<tr>
<td>4.</td>
<td>Loh Kima</td>
<td>River</td>
</tr>
<tr>
<td>5.</td>
<td>Lilik</td>
<td>Water spring</td>
</tr>
<tr>
<td>6.</td>
<td>Loh Sanin</td>
<td>Water spring</td>
</tr>
<tr>
<td>7.</td>
<td>Boe Mata</td>
<td>Water spring</td>
</tr>
<tr>
<td>8.</td>
<td>Loh Sidobol</td>
<td>Water spring</td>
</tr>
</tbody>
</table>

Sources:
1. Faculty of Forestry, Gadjah Mada University, 1976

**Soils and Geology**
In general, Rinca’s soils and geology do not vary much from the surrounding islands. One difference, however, is the presence of yellow Mediterranean soil which is very prone to erosion. The geologic formations on this island consist of: 1) coral, 2) alluvium, 3) tuff, 4) marl, and 5) volcanic sediment, such as: 1) andesite and 2) effusive dasitic. These formations are spread
throughout the center and a large part in the North (the Western half) and the balance is in the region around Mt. Doro Raja and Tanjung Koloh. Rinca’s geological history provides an interesting natural resource for tourists. The natural phenomenon of land movements caused by volcanic activity still occurs, and the subsequent landscape dynamics are fascinating for the common tourist as well as for scientific tourists and experts.

Vegetation
In general coastal forest associations are found along the coast, however where there is silt sediment, there are also mangrove forests. At higher altitudes there are deciduous (monsoon) forests along with savanna, and on the pinnacles of hills or mountains are quasi-cloud forests. In quasi-cloud forests several plant species are found, including rattan (*Callamus* spp.), bamboo (*Bambusa* spp.) and various trees species (*Podocarpus nerifolia, Ficus orupacea*, and *Terminalia zollingeri*).

The vegetation on Rinca island (Fig. 4), as is the case on other islands in the Komodo National Park area, is dominated by savanna type vegetation. Among the savanna plain grass vegetation or bushes there are *Borasus* sp. or gebang. The vegetation of the deciduous forest is dominated by *Zizyphus* (bidara), asam and kesambi. The mangrove forests have a high diversity, especially along the north coast, and are dominated by *Rhizopora mucronata*. Other species include *Ceriops tagal, Sonneratia alba*, and *Avecenia mariana*.

Fauna
In addition to the well-known Komodo dragon, a population of feral horses is found on this island (Fig. 3). The wild horse population is found only in the region between Rinca village and Kerora village, and overlaps with the distribution of the wild buffalo. There are also feral dogs present, which compete with the Komodo dragon for food resources, such as deer, wild boar, rodents, birds, and carrion. In addition, they prey on young Komodo dragons. The feral dog population needs to be eliminated.

The long-tailed macaque (*Macaca fascicularis*) is found on Rinca, but not Komodo or Padar islands. This primate species is able to swim, and crossed the narrow straits from Flores. The wider straits between Rinca, Padar and Komodo probably prevented their dispersal further Northwest. Deer (*Cervus timorensis*) are often found in the region of Mt. Tumbuh and Doro Ora up to Loh Dasami. In addition, the wild boar (*Sus scrofa*) population is quite numerous and distributed from the coast up to the savanna woodland and deciduous (monsoon) forest. Wild pigs compete with Komodo dragons for carrion.

Several threatened bird species are found on Rinca (as well as on other islands in the Park). These species include the saw-toothed claw fish eagle (*Pandion heliatus*), the spotted falcon (*Falco moluccensis*) and the orange-footed scrub fowl (*Megapodius reinwardt*). Along the steep coastal cliffs there are swallows (*Colocalia* spp.) and various other sea bird species. The nest mounds of the orange-footed scrub fowl (*Megapodius reinwardt*) are a tourist attraction, primarily for the unique social structure in the bird populations and the nest building behavior. The species is widely distributed across Rinca. Another bird that attracts attention is the wild chicken (*Gallus varius*). This species is spread throughout nearly all of Rinca, starting from the coastal area up to the mountain ranges, and its distribution overlaps with that of the scrub fowl. The roosters of the wild chicken are beautiful, with multicolored feathers.
Land use
As is the case on the other islands, the local community has very simple methods of land use. They only use the land in the relatively sloping coastal region, not too far from the sea. Centers of land use are the villages of Rinca, Kerora, and Loh Buaya. Use of the land, apart from residential, is usually linked to exploitation of marine resources, such as places to dry fish, and mooring places for fishing boats. There is some use of the land for planting, however this is not very intensive. The local people cultivate limited dry fields for planting gogo rice (dry land rice), corn, sweet potato, cassava and coconut palm trees.

2.1.4 Other Small Islands

The KNP includes not only the three larger islands (Komodo, Padar and Rinca), but also numerous smaller islands. The smaller islands in Komodo National Park are primarily located in the Northeast section of the park, between Komodo and Flores and to the North of Rinca and Padar. Several of these islands have interesting landscape potential, including Tatawa, Siaba Besar, Menggian, Papagaran Besar, and Papagaran Kecil. Gili Banta is also quite panoramic and has been proposed for inclusion in the Park. The small islands have a wide variety of beach types. These include beaches with steep slopes, sloping beaches with gravel and sand, white sand sloping beaches, black or red sand beaches, and beaches with mangrove forests and coastal forests. The small islands are generally covered by savanna woodland with lontar palms (Borassus flabelifer) inland. Along the coast, mangrove forest is dominated by Rhizophora stylosa. Other species include Ceriops tagal, Sonneratia alba, Avicenia alba, and A. marina.

Gili Motang is a rather circular shaped island, that lies Southeast of Rinca. The topography is dominated by steep hills, with a few sloping beaches. There is a small promontory at the Northwest tip, and a small bay is found on the coast to the South. Coral is found at the Northwest coast of the island; and the variety of the coral reefs makes it a beautiful place for diving or snorkeling. The coast to the South, West and East face strong winds and also high waves from the Southeast. The beaches are rugged with numerous narrow bays and cliffs.

Small water birds, rats, reptiles and several types of insects are the typical fauna on the smaller islands. On Gili Motang, however, there are also Komodo dragons, deer, wild boar, various sea birds, and the orange-footed scrub fowl. Old nest mounds are widely distributed across the island. Minke whales are often seen along the North coast of Gili Motang from September through December. Dolphins and manta rays are also find in large numbers during that season.

The population of Papagaran Besar is engaged in several activities related to marine exploitation and marine tourism in the area. The ownership status, or right of land use controlled by the local people, is traditionally managed. There is a high probability that some of the land use rights have been illegally sold to people from outside the Komodo National Park.

In addition to the smaller islands in Komodo National Park, there are low emerging reefs and sandbanks. At high tide some of these reefs and banks are submerged, whereas others are always dry. Sandbanks and emerging reefs can be found in particular to the Northeast of Komodo, where they are often used by the fishermen from various origins as a base camp for their operations. Tents are put up, sometimes complete with diving equipment and compressor., usually not far from the diving target. These uses need to be assessed and regulated.
2.2 THE MARINE LANDSCAPE

The marine waters landscape in Komodo National Park is greatly varied, and encompasses an area much vaster than that of the land surface. Approximately 67% of the surface of Komodo National Park consists of sea water. Detailed descriptions of the marine landscape are provided below for the areas surrounding the islands of Komodo, Padar, Rinca and the smaller islands.

2.2.1 Around Komodo Island

The Northern Side

The marine landscape surrounding the island is greatly varied, starting from the marine waters to the North of Komodo where there are beautiful spots such as the bay of Serikaya, Boko, Batumoncong, and smaller bays such as the bay of Sarau, Tala, Sebah and Sebita Bay. In the bay of Batumoncong there is a high diversity of coral and fishes. In the inner bay there is a relatively high variety of algae, such as Turbinaria and Galaxura. At its Northern tip Komodo faces the islands of Gili Lawa Laut, Gili Lawa Darat, and Gili Bugis.

In general there is high habitat diversity, ranging from intertidal areas along the coast and stretching further into the sea where there are sea grass beds (Fig. 4) and coral reefs (Fig. 12). Marine life formations are highly diversified, including many species of sponges, coral, algae, seaweed, sea-grass, cetaceans, turtles, and fish. The impact of damage due to the exploitation of marine resources is low. Soft coral abounds and often covers remnants of coral that were damaged due to fish catching activities. The aesthetic value of the landscape in the North of Komodo in general is of moderate value.

The coral forms an elongated narrow reef along the North coast, with a depth of 2 to 5 meters. Pocillopora, Montipora and Acropora are commonly found coral genera. There are numerous algae species in the area. Common species include Padina, Turbinaria, and Sargassum found in abundance on shallow reefs. The variety of sponges ranges from moderate to high along the coast, and sponges are dominated by the genera Cinachyra, Clathiria, Paratetillia and Plakortis.

In the Northeast, opposite Gili Lawa bay, there are flat reefs consisting of a mixture of sand and sea plants that are somewhat covered by coral. Massive coral is also found on the upper slopes, with an abundance of types such as Acropora, Folios Montipora and Pachyseris on the lower slopes. On the central slopes there is an abundance of the soft corals, Sarcophyton and Sinularia, as well as Xenia. Northeast of Komodo a fairly strong current is found around Sebita down to the South at Batu Tiga, off Tanjung Kuning. The aesthetic value is relatively low, due to fairly high damage on the coral reefs as a result of destructive fishing practices.

The Eastern Side

The Eastern side consists of a broad flood plain, stretching from cape Torokuning to the entrance of Slawi Bay. There is a relatively large islet, Punya, and several smaller islets around the inlet of the bay. This bay has a sheltered beach, however there are also several seasonal currents that enter the bay from the North and end in the South, forming silt sediments down to the inter-tidal zones. The coral variety near Slawi Bay is dominated by table coral Acropora, massive coral Porites, Favids, and Pocillopora. Soft coral is abundant. The reef building coral in this area has been severely degraded.
Figure 12. The spatial distribution of the coral reefs in the Komodo area is not yet thoroughly surveyed, but the depth contours of nautical map 295, on which this map is based, can be used for an approximation. The coral reef area within Park boundaries was estimated at 17 km$^2$, which is the surface area of a 50 m wide strip following the perimeter of the land (grey) and ‘reef flats’ (green) combined.
The exposed coast on the Southeast side of Komodo is generally steep and sometimes forms cliffs while there is limited coral growth. In the area of Logo beach coral cover is quite low. The coral variety is moderate, with common genera including Acropora and Montipora. There are few algae species, however the variety of sponges is high, and is dominated by Xetos, Plakordis, Callyspongia, Thalysias, Liosina, Clatria, and Petrusia.

The Southern Side
The Southern tip of Komodo has a relatively short coastline, consisting of a rugged coast, not sloping, probably due to strong currents and high waves. There are a few islets off the coast that directly face the open sea, exposed to fairly strong winds. As a whole the habitat variety on the Southern coast is low, while the greater part of the coast is steep and forms cliffs. The coral cover is low, except in sheltered areas (such as near Tala island), and generally consists of Acropora, Dendrophylla, and Tubastrea. The variety of algae ranges from low to moderate, with an abundance of Halimeda and red coral algae at certain sites. A sheer cliff face on the coast reaching down to the water is quite scenic. Due to heavy waves beating against the rock, large holes have been created, sometimes forming underwater caves.

The Western Side
The landscape on the Western side of Komodo is more complex than the South coast. There is no mangrove growth or seaweed on the West coast, except for Lajupemali Bay which contains seaweed. Table coral and the soft coral Xenia are also found in the bay. The coral has been damaged by destructive fishing techniques, including dynamite explosions. Other corals in the area include Montipora, Arborescent, Acropora and Fiolechinopora. In Boko bay a fringing reef along the coast creates a funnel-shaped formation. The Southern side of the bay is covered with mixed coral, whereas the Northern side of the bay is dominated by Acropora coral.

2.2.2 Around Padar Island

The Northern Side
The Northern coast is sheltered from the behavior of the big waves, and the coastline is relatively straight. There is a wide bay, shallow in the center, and promontories that thrust into the sea on the two sides of the bay. Smaller islands lie off the coast. In shallow bays flat, very broad coral reefs are found. Seaweed vegetation is dominated by the genera Cymodocea, Enhalus, Syringodium, and Thallasia. Mangrove forest includes Rhizophora (in particular R. stylosa), Sonneratia and Avicenia species, growing along the length of the coast, and also growing on the smaller islands in the center of the bay. Destructive fishing techniques have degraded many areas.

The Eastern Side
The Eastern side of the coast of Padar is dominated by a very wide bay. Adjacent to Rinca there is an extremely strong current. Coral coverage and variety is low, as is the variety of sponges and algae in this area. There are, however, algae with a high economic value present, the red algae Gelidiela and Galxura. In addition, there is also a profusion of Dictyota and Calpomenia.

The Southern Side
This side has a narrow coast, for the greater part consisting of steep coastal walls, with small inlets facing small atolls. Off the coast there are small islands called Padar Kecil and Sarang. Soft coral abunds and Ascidians and Crinoids are common. Algae communities are dominated by Chnoosphora, Gracillarria, Peyssonelia, Rosevingsea and Champa. Fish diversity appears to be
low. On the smaller islands off the Southern coast of Padar, like Padar Kecil, there is heavy and extensive damage due to the exploitation of marine resources. Live coral coverage is low, however, the reefs have an interesting topography.

2.2.3 Around Rinca Island

The Northern Side
The waters to the North of Rinca consist of reefs and small islands off the coast. The North coast stretches in length from Tanjung Toronggikok in the Northwest to the North East of the island, approaching Flores. The greater part of the coastal surface stretches in a straight long line from East to West. There are some small bays in the Eastern part of this coastline, one of them being the bay in which the village Rinca is located. The landscape of the Northern side of Rinca is varied, with mangrove and coastal forests, cliffs, seaweed formations, and coral reefs (Fig. 12). A variety of fish and algae species are present. Live coral coverage is patchy, and there is little soft coral. Damage due to destructive marine exploitation techniques is fairly high. Corals found in the area include the genera Stylophora, Tubipora, Acropora, Muralina, Echinopora and Euphyllia. In shallow coral areas, red and brown algae are commonly found, such as Dictyota, Padina, Coelotrix, Gracillaria, and Hypnea. A variety of seaweed species are also found.

The Eastern Side
The Eastern side of Rinca constitutes a continuation of the North coast up to Torowalu Cape. The Northeastern part of Rinca lies at the strait between Rinca and Flores, Selat Molo, continued by the widening of Rohbong Bay, with two small islands, Rohbong and Muang. Further on to the South the most exposed part consists of Loh Baru Bay, ending at the Torowalu peninsula. The Eastern side of Rinca is varied. Mangrove forest is found in the North. Sand or gravel beaches are located in the central Eastern coastline and cliffs are found at the Southern end. The narrow strait between Rinca and Flores has a narrow line of mangrove forest, with a hazardous current making it difficult to navigate. Reefs connect Rohbong island to the beach on Rinca, and they are covered with a stretch of seaweed, including the species Cymodocea, Halophila, and Thalassia. Near Rohbong bay there is a stretch of reef varying in breadth, with algae genera such as Halimeda, Sargassum, and Padina commonly found. Live coral coverage is low. Common coral genera include Acropora, Anacropora, and Pavona. Loh Baru Bay is a large bay on the East side of Rinca, with a coral ring along the length of the coast. Several spots are damaged due to dynamite bombing by fishermen. Pavona, Diploastrea, Acropora, Porites and Favids are common coral genera. Turbinaria, Padina and Halimeda algae genera are abundant.

The Southern side
The Southern coast of Rinca is characterized by steep cliffs and inlets. A bay called Loh Dasami separates Rinca from the small island Nusakode, creating a deep channel. Towards the Eastern side of the small Nusakoda island there are small inlets, with some promontories towards the sea. There is heavy wave action and strong current in this area. Some mangrove forest formation is found around Nusakode, at the narrow beaches. At Loh Dasami bay (Nusakode channel) there is a steep slope inside the channel, with limited coral growth and low coral variety. The highest coverage percentage for the area is found Northwest of Nusakode. Damage by dynamite bombing is low to moderate. Helimeda algae are abundant, and the variety of fish is moderate, with varied soft coral and a variety of micro-invertebrates such as crinoids (feather stars), ascidians (tunicates), and holothurians (trepang, or sea cucumbers).
The Western Side

The West side of Rinca has narrow, elongated inlets. The shape of the bays is irregular. There is one small island, Sarai, which forms a link between Rinca and Padar. The variety of habitat on the Western side of Rinca is fairly high, including sheltered coral stretches, exposed coral, white sandy beaches, gravel beaches, and mangrove forests. From Loh Ginggo Bay to the Northwest corner of Rinca, the coast consists of cliffs varying from steep to fairly sloping, with sandy or gravel beaches. In Loh Ginggo Bay, branching *Acropora* and table *Echinopora* coral are found offshore. Soft coral and crinoids abound, although sponges are totally absent. Near the mangrove forest there is fairly thick sediment and practically no coral. In the sandy areas there is soft coral, in particular the genera *Sarcophyton* and *Sinularia*. Fish diversity appears low. In the Northern part of Sarai, the coral reef is in quite good condition. However in other locations, the coral reefs have been almost completely destroyed or there are only coral remnants, with soft coral growth, due to destructive fishing practices. Soft corals present include *Sarcophyton* and *Sinularia*.

2.2.4 Around the Smaller islands

Around Gili Motang island

Gili Motang island lies in the Southeast tip of Komodo National Park. The island is rather squarely shaped, with a small peninsula to the North West and several inlets. There are steep slopes leading to the sea. The Western, Southern and Eastern sides of the island face strong winds and also big waves from the South Eastern direction. There is a beach with white sand and gravel, in the Northwestern corner of the island. Live coral cover is low with low diversity. The Southern side of Gili Motang has an irregular cliff line reaching down to the sea. There is very low coral coverage, primarily composed of the genera *Tubastrea* and *Dendrophylla*. A variety of invertebrates, such as crinoids, occupy the stone formations. Soft corals such as *Nepthia* and *Pentatula lutea* are common, as well as crinoids and ascidians. The variety of algae is low, however coralline algae are abundant. On the Northern side of Gili Motang there are some small coral reefs. The shallow bay contains low live coral coverage and diversity. The floor of the bay has shallow sloping terraces, a white sand bottom, and contains large table corals.

Around Gili Banta Island

The island of Gili Banta is not currently included in the Komodo National Park, but has been proposed for inclusion. Administratively, Gili Banta is in West Nusa Tenggara Province, District of Bima. As a whole this island has an irregularly shaped coast, with numerous peninsulas starting from the South up to the Southeast. The Gili Banta Bay is wide. The Western side consists of inlets and a long peninsula in the Northwest corner, called Tanjung Rusa. Nearly the entire North coast consists of a large bay, called Oiungke bay, with a short peninsula in the direction of the North East corner (Tanjung Toro Oiungke).

The Southern side of Gili Banta is dominated by cliffs and white sand beaches, further continued by a stretch of reef off the shore. There is no mangrove forest on the Southern side of Gili Banta. Seaweed communities are found off the coast. The variety of coral and fish is high, with a high percentage of coral coverage. *Acropora* and *Porites* corals are observed, and growth forms include table coral, branching coral and massive coral. The soft coral population is abundant, and includes the genera *Sinularia*, *Sarcophyton* and *Xenia*. Algae (*Porolithon*, *Peyssonelia*, *Gracillaria* and *Salicornia*) and sponges are common. Damage due to blast fishing is generally low, although some specific sites have been severely damaged.
Figure 13. Ranger stations and head office (Labuan Bajo) in the Komodo area.
Figure 14. Tourism facilities in the Komodo area: resorts / hotels, jetties, main harbors and airport.
3. EXISTING FACILITIES

Limited marine and terrestrial facilities currently exist in and around Komodo National Park. The National Park Headquarters are located in Labuan Bajo, Flores. Facilities include an office, housing for permanent staff (sufficient for at least 50 staff), boats (three boats, in disrepair), communication equipment and an information center. KNP Ranger Stations are located throughout the Park (Fig. 13). Offices and facilities for marine tourism services are located on the Flores mainland, in the town of Labuan Bajo, and in Sape and Bima on Sumbawa (Fig. 14). In addition, there are limited and basic tourism facilities available on islands close to the Park. An inventory of the Komodo National Park facilities is given in Table 3.1.

Table 3.1. Inventory of Komodo National Park facilities, as per February 2000.

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### 3.1 TERRESTRIAL FACILITIES

Existing facilities are few, and many are in disrepair. Any further development should be based on the recommendations of an EIA. Any building development within the park will be restricted to that required for park management only. At Loh Liang on Komodo island (Fig. 15), there is a large ranger station with communication facilities, visitor’s center with informational displays, a tourist restaurant, and visitor’s cabins. There are several trails on Komodo (Fig. 16), and a jetty for boats at Loh Liang. There is also a small dive shop run by the Park’s cooperative at the visitor’s center in Loh Liang.

At Loh Buayah on Rinca island (Fig. 17) there is a second larger ranger station with radio communication facilities, a small visitor’s center with informational displays, a small tourist restaurant, and basic visitor’s cabins. There are several trails (Fig. 16) here, and a jetty for boats. Buildings abandoned by a former pearl farming operation in Loh Kima on Rinca island (Fig. 18) are slated for conversion to research facility. There is one large building and two smaller buildings. There are no facilities on Padar Island. Some of the small islands outside the Park have basic tourist cottages available.

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Figure 15. Site plan of the Loh Liang visitors center of Komodo National Park. Not on scale.
Figure 16. Trails for intensive tourism use (blue) and patrols (green) in the Komodo National Park.
Figure 17. Site plan of Loh Buaya ranger station in Komodo National Park. Not on scale.
Figure 18. Site plan of Loh Kima ranger station in Komodo National Park. Not on scale.
3.2 MARINE FACILITIES

Harbors and jettys are available in Flores and Sumbawa (Fig. 14). Mooring buoys (Fig. 19) for small tourist boats have been placed at the 25 locations listed in Table 3.2. Many more moorings are needed at popular diving and snorkeling sites, particularly also for large boats.

Table 3.2. Mooring buoys for small tourist boats, at locations in and around KNP.

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Figure 19. Location of dive sites and mooring buoys in and around Komodo National Park. Moorings are situated near snorkeling sites.
4. ENVIRONMENTAL IMPACT ASSESSMENT (AMDAL)

Komodo National Park is intended to serve a variety of functions, including conservation, sustainable use of marine resources, tourism and research. Zoning and enforcement of appropriate regulations are intended to minimize or eliminate conflicts between objectives. In order to fulfill its functions, the KNP needs to develop its infrastructure and facilities. Care must be taken, however, to ensure that this development does not negatively impact the park or the local communities. A properly designed Environmental Impact Assessment (EIA) should help reduce or eliminate potential negative impacts, and identify appropriate and feasible development options. EIAs are most needed to assess tourism impacts and the use of marine resources. These two uses are the most common, and will have the most impact on the park’s resources and environmental quality. In addition, it is necessary to consider the socio-cultural, economic and political environment, as they will influence the feasibility of specific programs of action.

Priority areas for EIA and carrying capacity studies are therefore the zones where tourism will be developed (the Intensive Tourism Zone and the Wilderness Zone), the zone where sedentary Park resources are harvested (the Traditional Use Zone) and the zone where human populations are settled (the Settlement Zone). Detailed regulations and development criteria for refinement of the zoning plan (Fig. 7) will be designed on the basis of these EIA and carrying capacity studies. Within the above mentioned priority zones, priority will be given to trail development and dive site development in the Wilderness zone. Carrying capacity will be estimated for existing tourism sites in Loh Liang (Fig. 15) and Loh Buayah (Fig. 17) and for other existing trails (Fig. 16) and dive sites (Fig. 19). A detailed EIA and carrying capacity study will also be carried out for development of the research and training facilities in Loh Kima (Fig. 18).

The utilization patterns for existing sites in the Park will be re-assessed and facilities will be re-designed on the basis of the EIA and carrying capacity studies. EIA studies will be designed around a standard set of environmental parameters. An overview of commonly used parameters, the way their values are best measured and methods for mitigation of impact are discussed below.

4.1 IDENTIFYING ENVIRONMENTAL ATTRIBUTES (PARAMETERS)

A number of environmental parameters can be used to characterize the biophysical, socioeconomic and cultural environment. A scoping exercise for eco-tourism has been conducted under the auspices of The Nature Conservancy. A monitoring program for marine resource use is conducted on a routine basis. Based on the scoping exercises, monitoring results and other analytical input, a determination must be made as to which are the most important variables to consider. These variables include (but are not necessarily limited to) the following:

*Atmosphere:* particulate matter, hydrocarbons, sulfur oxides, nitrogen oxide, carbon monoxide, toxic materials, odors
**Water:**
- aquifer safe yield
- flow rate
- fecal coli-form
- pH
- biochemical oxygen demand
- dissolved oxygen
- nutrients (e.g. nitrogen)
- suspended solids
- dissolved solids
- toxins
- mercury
- cyanide
- hydrocarbon pollutants
- biological indicators
  - (micro-invertebrates)

**Ecological:**
- species richness
- species/habitat diversity
- distribution patterns
- population size
- population growth rate
- threatened species
- endemics
- keystone species
- life history characteristics (age/sex composition, interbirth intervals, mortality)
- resource requirements (food, water, shelter)
- interspecific interactions (predation, competition)

**Sound:**
- psychological effects
- physical effects

**Land:**
- soil stability
- land use patterns
- natural hazards (earthquakes, volcanic activity, tsunami, etc.)

**Sociocultural:**
- lifestyle
- religion
- education
- social pressures
- aesthetics
- politics

**Economic:**
- economic stability
- consumption rates
- market access
- market demand
- personal income
Resources: pelagic marine resources
demersal marine resources
fuel resources
non-timber terrestrial resources

Selection of attributes (and indicator species) should be based on appropriateness, responsiveness to environmental change, importance (ecological, economical, socio-cultural), feasibility, cost, ease of measurement, and time required. The attributes selected should reflect all aspects of the environment, which may mean that some attributes that are difficult to measure will have to be included. A brief rationale for inclusion for each of the variables is provided below (modified from Jain et al: Environmental Assessment).

4.1.1 Atmospheric variables

Air quality affects almost every aspect of life on this planet, including health, quality of life, and ecosystem productivity. Each of the following variables is discussed with respect to the current or known situation in the area. The major sources and impacts are identified. Air pollutants, however, can travel long distances, and local air quality is affected by global activities.

**Particulate matter**
These are generated by a number of sources, including forest and savanna fires, development and industry. Anthropogenic fires have been a problem in the area. At present, industry and other development activities in the area are not major contributors. Particulates negatively affect plant productivity, visibility (potentially preventing travel), and health. Fine particles, in particular, are carcinogens.

**Hydrocarbons**
These are primarily given off during fuel combustion and by decomposing organic matter. Boats would be the major anthropogenic contributor in the area. Hydrocarbons negatively affect respiratory health. Hydrocarbon interacts synergistically with nitrogen oxide, creating photochemical smog.

**Sulfur oxides**
These are primarily given off during fuel combustion. Boats would be the major contributor in the area. Sulfur oxides reduce plant productivity, cause metal corrosion, and particularly decrease respiratory health.

**Nitrogen oxide**
These are primarily given off during fuel combustion, as well as by bacterial action in forests and swamps. Boats would be the major anthropogenic contributor in the area. Nitrogen oxide negatively affects plant productivity, corrodes nickel alloys, and health. Nitrogen oxide interacts synergistically with hydrocarbon, creating photochemical smog.

**Carbon monoxide**
This is the most common air pollutant and it is primarily generated by the combustion of organic material. Anthropogenic fires and boat engines would be the primary sources in the area. Carbon monoxide negatively affects cardiovascular health.
Photochemical oxidants
These are created by a chemical interaction between sunlight, hydrocarbons, and nitrogen oxide. They degrade polymers and rubber materials and damage vegetation. Boats would be the major anthropogenic contributor in the area.

Toxic materials
There are numerous toxic materials produced in industry and introduced in development activities. The use of cyanide and other poisons by fishermen is the primary anthropogenic contributor in the area. Cyanide negatively affects health, kills coral reefs, and reduces ecosystem productivity and diversity.

Odors
There are numerous odors produced by industry and other development activities, as well as from natural sources. Malodors in the area primarily result from fishing activities and inappropriate sewage and garbage disposal at present. Malodors can negatively affect physical and psychological health.

4.1.2 Ecological variables
The major goals of the park are to conserve and protect biodiversity, ecosystem processes, and the sustainable resource base. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals are briefly discussed.

Species richness/diversity
Species richness is the total number of species present. Diversity measures the interaction between number of species and their abundance. In general, the more biologically diverse an area is, the greater is its ecological value.

Habitat diversity
Different habitat types support different species, different communities and different ecosystem processes. In general, the greater the number of habitat types, the greater the faunal and floral diversity supported.

Distribution patterns
Distribution patterns can be indicators of the quality of the resource base or inter- or intraspecific interactions. Changes may indicate declines (or improvements) in environmental quality, or the introduction or loss of a competing species.

Population size, age/sex composition, and density
Changes in population size, the age/sex composition, or the density outside of normal variation may indicate changes in environmental quality, the introduction or loss of a predator, prey or competing species.

Population growth rate
The population growth rate can be used to help calculate future expected population size and density. Changes in the growth rate can indicate changes in environmental quality or species relationships.
**Threatened species / endemics**

The park is intended to help conserve threatened and endemic species. Information concerning their natural history is necessary to achieve this goal. Especially for the marine environment of KNP, the knowledge on species diversity is still limited. Information on population dynamics and life history traits of individual species is very scarce indeed.

**Keystone species / economically important species / indicator species**

The park is intended to help conserve keystone and economically important species. Information concerning their natural history is necessary to achieve this goal. Indicator species are useful as barometers of environmental quality.

**Resource requirements (food, water, shelter)**

Information concerning resource requirements are necessary in calculating carrying capacities. Changes to the resource base (additions or subtractions) can alter species relationships and lead to local extinctions.

**Interspecific interactions (predation, competition)**

Information concerning species relationships is necessary is important to calculating carrying capacity and “sustainable” yields. It is important to maintain ecologically sustainable yields. An ecologically sustainable yield is a yield which does not substantially alter the ecological community or ecosystem processes.

### 4.1.3 Water quality variables

Water quality affects almost every aspect of life on this planet, including health, quality of life, and ecosystem productivity. Each of the following variables is discussed with respect to the current or known situation in the area. The major sources and impacts are identified. Water pollutants, however, can travel long distances, and local marine water quality is affected by global activities.

**Aquifer safe yield**

Terrestrial development activities are limited by the availability of fresh water. Plant and animal distribution patterns are dependent on maintaining existing aquifers. Extraction rates from wells greater than the recharge rate can lead to salt water intrusion and changes in species distribution patterns.

**Flow variation**

Variation in water flow and velocity can occur naturally or due to the diversion of water through dams, canals, and other means. There is high variation due to natural factors, however, diversion of water for human use is a major factor in the area. Flow variation disrupts ecosystem processes, and has negative impacts on fauna and flora (may change distribution patterns, lead to decreases in population size, etc.).

**Fecal coliform**

Water sources can become contaminated with feces. Improper disposal of sewage is the major anthropogenic contributor. Exposure to fecal coliform can cause intestinal illness.
**pH (acidity / alkalinity)**
Acid and alkali wastes can be toxic to aquatic life. Industrial wastes, accidental chemical spills and mining tailings are the major anthropogenic contributors. Changes in the natural buffer system can decrease productivity (higher fish mortality) and reduce the natural capacity to assimilate organic wastes.

**Biochemical oxygen demand (BOD)**
BOD measures the amount of oxygen needed to biologically degrade organic material present; it indicates the total amount of dissolved oxygen required. The BOD indicates the degree of organic pollution. Normal industrial and municipal activities (e.g., sewage, laundry wastes) are the primary anthropogenic contributors. High levels of organic pollutants can lead to increased risk of disease, algae blooms leading to fish die-offs, and reduced recreational benefits.

**Dissolved oxygen**
Dissolved oxygen is required by aerobic aquatic organisms for their metabolic processes. Anaerobic organisms use oxygen that is chemically bound (e.g., sulfur). Normal industrial and municipal activities (e.g., sewage, laundry wastes), as well as watercraft operation (releases oils which interfere with reaeration), and site preparation, are the primary anthropogenic contributors. Low levels of DO (less than 5 mg/L) can lead to fish die-offs, and reduced growth and reproduction.

**Nutrients (nitrogen, phosphate, carbon, iron, trace minerals)**
Increased nutrients can lead to eutrophication and algal blooms. Major anthropogenic contributors are sewage waste and fertilizer run-off. High nutrient input can lead fish die-offs, increases in insects (including mosquitoes), foul smelling water, and reductions in recreational potential.

**Suspended solids**
Suspended solids may contain organic or inert substances that are not in solution. Dredging, gravel washing, site clearing, and mining tailings are all major anthropogenic contributors. Suspended solids can reduce productivity (reduces intensity of solar radiation) and affects the health of aquatic organisms. Water that is turbid (high in suspended solids) is costly to filter for drinking water.

**Dissolved solids (TDS)**
Dissolved solids in high quantities can have physiological effects (due to high salt content) and may be objectionable due to mineral tastes. Major anthropogenic contributors are mining tailings, waste disposal, and accidental spills. High salt content can affect blood pressure, high sulfates may have a laxative effect. Methemoglobinemia (blue baby disease) is caused by the combination of nitrate and nitrite.

**Toxins (particularly mercury and cyanide)**
Toxins include heavy metals, pesticides, cyanide, ammonia, sulfides, and petrochemical wastes. Industrial wastes, accidental chemical spills, and destructive fishing practices (cyanide fishing) are the primary anthropogenic contributors. Increased die-offs of fish and other aquatic life are a primary impact. Toxins in low levels may be bio-accumulated and passed up the food chain, resulting in potentially lethal health problems for humans (e.g., mercury).
**Hydrocarbons**
Oil pollutants are highly damaging to the coastal marine environment. Major anthropogenic contributors include ship discharges, wastes from oil refineries, and accidental spills. Negative impacts include coating and destroying algae and plankton, interfering with reaeration and photosynthesis processes, killing off aquatic life (including marine mammals and seabirds), and destruction of spawning areas.

**Biological indicators (invertebrates)**
Changes in an aquatic community occur regularly; the important factor is that the basic community structure and composition remain. Some invertebrate species are quite sensitive to pollution and respond rapidly, either increasing or decreasing in population size, depending upon the species and type of pollution. These species are used as biological indicators of the environmental quality of the area.

**Thermal discharge**
Temperature plays an important role in the regulation of natural processes in the aquatic environment. Thermal power generations, industrial operations, and large deep reservoir flow release are potential major anthropogenic contributors. Aquatic life is extremely sensitive to changes in water temperature. Changes in temperature can kill organisms, or stimulate or suppress growth and reproduction. Coral reefs are particularly susceptible to increased water temperatures.

### 4.1.4 Resource variables

The major goals of the park are to conserve and protect biodiversity, ecosystem processes, and the sustainable resource base. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals are briefly discussed.

**Pelagic marine resources**
Commercial and non-commercial fishing is the primary livelihood in the area. Monitoring and regulation of fishing activities is necessary to maintaining a sustainable resource base. The protection of spawning sites is a primary focus.

**Demersal marine resources**
Commercial and non-commercial fishing is the primary livelihood in the area. Monitoring and regulation of fishing activities is necessary to maintaining a sustainable resource base. The protection of spawning sites is a primary focus. In general, the collection of sedentary demersal resources is not compatible with the goals and objectives of the Park and should be banned completely from all zones except traditional use zones.

**Fuel resources**
Timber resources are limited within the park. The resource base is too small to allow for sustainable harvesting. The timber resources should be monitored to ensure that they are not illegally harvested. Loss of forest cover will lead to significant loss of biodiversity, increased siltation, and reduced aquatic productivity in the mangrove areas. Especially the mangrove stands in the Park are threatened by harvesting for fuel wood.
Non-timber terrestrial resources
The local people living within enclaves in the park have the right to collect non-timber resources in designated use zones. Monitoring and regulation of resource use is necessary to ensure sustainability.

4.1.5 Sound variables

The major goals of the park are to conserve and protect biodiversity, ecosystem processes, and the sustainable resource base. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals are briefly discussed.

Psychological effects
Loud or annoying noises over a long time period can increase psychological stress. Major anthropogenic sources include music systems and heavy equipment. Increased stress can negatively impact health and reproduction, and increase aggression. Noise pollution could lead to decreased recreation potential.

Physical effects
Direct physical effects from noise pollution include hearing damage or loss, increased cardiovascular response, and increased adrenocortisone levels. Major anthropogenic sources include music systems and heavy equipment. Underwater noise pollution could disrupt migration routes for cetaceans.

4.1.6 Land variables

The major goals of the park are to conserve and protect biodiversity, ecosystem processes, and the sustainable resource base. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals are briefly discussed.

Soil stability
Soil stability is poor; soils are easily eroded in the area. Loss of land cover due to anthropogenic influences (such as fire or land clearing) increases soil loss. Soil loss reduces productivity, impedes restoration, and increases turbidity in aquatic systems.

Land/sea use patterns
Patterns of land and sea use can be used to determine where monitoring and enforcement activities should be concentrated. Current land use is restricted to four small areas on Komodo and Rinca, but there have been recent efforts to colonize additional areas within the park. Increased intensity or expansion into new land or sea areas will have negative impacts on biodiversity and sustainable resource use.

Natural hazards (earthquakes, volcanic activity, tsunami, etc.)
The area is geologically unstable, and natural hazards occur frequently in the region. Facilities development plans need to take these hazards into account in their placement, construction design and the materials used.
4.1.7 Economic variables

In addition to conserving and protecting biodiversity, ecosystem processes, and the sustainable resource base, another goal of the park is self-sufficiency and improving the quality of life for the residents of the Park and of the area directly surrounding the Park. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals are briefly discussed.

**Economic stability**

Economic stability is important to developing and keeping budgets, and to attracting local and foreign tourists. Political stability, sound economic policies, and elimination of corruption in the banking industry are the most contributing factors. Lack of economic stability can lead to increased poaching and lower tourist revenues.

**Consumption rates**

Local, national and regional consumption rates affect resource harvesting in the area. Consumption rates can be affected by availability, cultural trends, cost, and other factors. Increased consumption rates can lead to overharvesting, decreases in biodiversity, and boom-bust economic swings.

**Market access**

Access to market affects resource harvesting; resource harvesting increases with increased market access. Market access can be affected by transportation, cultural trends, costs, product perishability, and other factors. Increased market access can lead to overharvesting, decreases in biodiversity, and boom-bust economic swings. It can also help increase quality of life, economic stability, and personal income.

**Personal income**

Personal income affects resource harvesting; the method and types of resources harvested changes as personal income increases. Personal income can be affected by the unit price received, the ease and cost of harvesting, resource availability and abundance, and other factors. Changes in personal income can lead to overharvesting, decreases in biodiversity, and boom-bust individual economic swings.

4.1.8 Sociocultural variables

In addition to conserving and protecting biodiversity, ecosystem processes, and the sustainable resource base, another goal of the park is self-sufficiency and improving the fisheries in areas directly surrounding the Park and in traditional use zones inside the Park. This should improve the quality of life for the area residents. Each of the following variables is discussed with respect to the current or known situation in the area. The relevance of each variable to the major goals is briefly discussed below.

**Lifestyle**

Lifestyle changes can affect the resource base, both negatively and positively. At present, the park residents live a relatively simple lifestyle, but they have already begun incorporating modern technologies into their daily lives.
Religion
The primary religion is Islam. The tenets of this faith provide some protection to specific species (e.g., monkeys). Changes in religious beliefs can have either positive or negative impacts on biodiversity.

Education
Educational levels are low, and individuals have few options available to make a livelihood. Changes in educational levels can have either positive or negative impacts on biodiversity.

Social pressures
In the past, communities were fairly tightly knit with few outsiders, and social pressure was an important constraint on individual behavior. The influence of social pressure is changing and this may have either positive or negative impacts on biodiversity.

Aesthetics
Aesthetics are important to both local community members and to tourists. Changes in aesthetics can have either positive or negative impacts on tourism as a means of generating park revenues.

Politics
Politics and the political party in charge influence land use and natural resource use policies and regulations. Political changes can have either positive or negative impacts on biodiversity and sustainable resource use.

4.2 MEASURING ENVIRONMENTAL ATTRIBUTES

It is necessary to determine the baseline or current status of each selected environmental attribute, prior to development activities or other management interventions, in order to assess the impacts of these activities. These measurements should take into account geographic and temporal variability, and be of sufficient breadth to make initial predictions concerning trends and normal variability. Measurement methods should be repeatable, accurate, and appropriate. Quantitative methods are preferable to qualitative methods, whenever possible, as they are less subject to observer bias, and are amenable to statistical analyses. Sampling protocols and design should be decided prior to actual data collection. A brief description of potential measurement methods for each of the above attributes is provided below. Measurements of these same attributes need to be repeated during and following the development (or management) activity. Comparison with the baseline data should be made, and adjustments made to the activities if necessary.

4.2.1. Atmospheric measurements

In general these measurements require sophisticated techniques and specialized training. Expensive equipment is often required.

Particulate matter
A high-low blower draws air in through a fiberglass filter at a rate of 35 to 64 cubic feet per minute. The concentration of all particles averaged over a 24 hour period are expressed as micrograms per cubic meter. Increases in particulate matter above 25 nanograms per cubic meter can cause visibility problems, above 200 nanograms per cubic meter causes health problems.
**Hydrocarbons**
There are two different methods to measure total hydrocarbons: flame ionization and spectrophotometric. A three hour average annual concentration (sample taken between 6 and 9 AM) less than .15 parts per million has little negative impact. A value above .15 ppm can lead to smog development.

**Sulfur oxides**
This is typically measured using the pararosanaline method and uses spectrophotometric analysis. A level of .03 parts per million can cause vegetation damage. A level of .2 ppm increases mortality rates. There is an interaction effect with particulate matter; only .04 ppm of sulfur oxide mixed with 160 nanograms per cubic meter can increase mortality rates among patients with respiratory problems.

**Nitrogen oxide**
Nitrogen oxides must be converted to nitrogen dioxide for measurement. The Griess-Saltzman technique is then used. Nitrogen oxide concentrations above .05 ppm pose a hazard to health.

**Carbon monoxide**
Nondispersive infrared spectrometry is used for the continuous measurement of carbon monoxide. Adverse health effects can occur with exposure of over eight hours at 10 ppm.

**Photochemical oxidants**
Ozone is the major product of chemical reactions initiated by sunlight between nitrogen oxides and hydrocarbons. Ethylene is mixed with ambient air resulting in the production of light due to a chemical reaction with the ozone. This light is detected with a photomultiplier cell and the photocurrent is amplified and recorded. Damage to sensitive species of vegetation can occur after four hours exposure to .05 ppm total oxidants.

**Toxic materials**
There are numerous toxins and specific methods are needed for each toxin. Selection of toxins to measure should be based on potential threat.

**Odors**
Odors are measured quantitatively using a scentometer. Concentration is measured in ppm. Qualitative measurements can be made using a trained panel of people. Odors can have direct impact on health and welfare (e.g., due to stress, loss of appetite, nausea).

### 4.2.2. Ecological measurements

As a primary goal of the National Park is to conserve biodiversity and natural processes, these are extremely important variables to monitor. Although the identification of appropriate methods, sampling design, interpretation and analyses of data collected requires highly trained experts, part of the actual data collection can be accomplished by trained park rangers.

**Species richness / diversity**
The number of species present in the area (species richness) and the number of individuals present of each species in the sample (see population size below) can be used to calculate species diversity. A number of formulas are available; the most appropriate measure should be selected.
The loss of species or major changes in population size in species whose population normally does not fluctuate greatly (i.e., K selected or density dependent mortality species) should be an indicator of potential problems and indicate the need to reevaluate development/management activities. The addition of species, specifically exotic introduced species, is also of great concern.

**Habitat diversity**
The number of different habitat types, their location and total area should be identified and mapped using GPS and GIS. Loss of a habitat type or moderate changes in habitat area should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Distribution patterns**
Species distribution patterns should be mapped and overlaid on habitat maps. Loss of corridors or migratory routes between sub-populations, or moderate changes in distribution patterns of non-migratory species should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Population size, age/sex composition, and density**
A variety of methods are available, depending on the species or species group in question. In all methods the number of individuals encountered and their age and sex are recorded. Line transect surveys are relatively simple to use for large arboreal and terrestrial diurnal mammals, and can also be used for marine fauna. Trapping is often used for insects, bats, birds, reptiles, fish, small mammals, and nocturnal animals. The type of trap, location, and baiting are dependent upon the species or species group in question. Density estimates can be calculated based on total area censused or by using mark-recapture methods. Large changes in population size (for K selected species) and/or density should be an indicator of potential problems and indicate the need to reevaluate development/management activities. A "compression effect" results when mobile individuals are concentrated in a small area due to adjacent habitat destruction.

Vegetation measures include line transects, point-quarter methods, quadrats or plots, and point sampling. Line transects and plots are the most popular methods for trees. Saplings and seedlings are often measured using quadrats. Herbaceous cover is often calculated using point sampling. Density is estimated based on the number of individuals per hectare or km². Large changes in population size (for K selected species) or density should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Population growth rate**
This can be measured directly through recording all individuals in the population, and all births, deaths, immigrations, and emigrations over yearly periods. Estimates for a species can be made based on previous data collected, the existing literature, and samples taken at different points in time. Large changes in the population growth rate (for K selected species) should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Threatened species / endemics**
These species should be a focus of baseline data collection and continued monitoring on population size, composition, distribution, growth rate, resource requirements, and interspecific interactions. Depending upon the species, small to moderate changes in population size, composition, distribution, growth rate, the resource base, or interspecific interactions should be
an indicator of potential problems and indicate the need to reevaluate development/management activities. PHVA (Population Habitat Viability Analysis) has been conducted for the Komodo dragon, and should be undertaken for other selected species if necessary.

**Keystone species / economically important species / indicator species**  
These species should be a focus of baseline data collection and continued monitoring on population size, composition, distribution, and growth rate. Depending upon the species, small to moderate changes in population size, composition, distribution, or growth rate should be an indicator of potential problems and indicate the need to reevaluate development/management activities. Life history tables should be constructed for economically important species to use in calculating estimates of “sustainable” yields and to provide guidelines as to which age/sex classes are most appropriate for harvesting.

**Resource requirements (food, water, shelter)**  
Based on direct observations, the literature, or indirect (trace) observations, the required resources for selected species (particularly threatened or endemic species) should be mapped and the total resource base productivity for the species should be estimated (i.e., carrying capacity). Depending on the species, this may require phenological studies, studies of soil or water chemistry, or studies of prey populations. Depending upon the species, small to moderate changes in the resource base should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Inter-specific interactions (predation, competition)**  
Based on direct observations, the literature, or indirect (trace) observations, the baseline rate of specific inter-specific interactions (interactions between species, such as predation and competition) should be established for selected species (particularly threatened or endemic species). Depending upon the species, small to moderate changes in the rate of specific interactions should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

4.2.3 Water measurements

The majority of these tests can be carried out in the field using relatively simple portable test kits. Indicators of poor versus high quality or suggested limits are provided for most of the variables. Degradation of water quality should be an indicator of potential problems and indicate the need to reevaluate development and management activities.

**Aquifer safe yield**  
This is measured through pumping tests. Yield is measured in thousands of acre-feet of water withdrawn per unit of time. The safe yield for extraction should be based on the aquifer recharge rate. Extraction should not exceed recharge.

**Flow variation**  
Simple measuring devices can be commercially purchased and installed in water courses. The rate of discharge is measured in cubic feet per second and flow velocity is measured in feet per second. Ideally, increased variability in flow discharge rate and velocity due to human activities should be avoided.
Fecal coliform
This can be measured through 1) a membrane filter technique, or 2) the multiple tube fermentation technique. The estimated coliform density is based on the number of coliform per 100 ml. Coliform levels should not exceed 20 per 100 ml for surface water supply and 200 per 100 ml for recreational use.

pH (acidity / alkalinity)
This can be measured using pH strips or portable meters. Except in peat swamps, pH level will normally be between 5.0 and 9.0. Changes of greater than 1.0 from the baseline following activities should be avoided.

Biochemical oxygen demand (BOD)
This requires laboratory facilities. It is measured as the amount of oxygen consumed (in mg per liter) by organisms over five days at 20 degrees C. BOD is a relative measure, and should be examined within the context of other variables, such as flow variability.

Dissolved oxygen
Portable DO meters can be used to measure this using titration techniques. The critical range for nearly all fish is a DO between 3 to 6 mg per liter. DO above 6 mg/L acts as a reservoir in case of increased demand.

Nutrients (nitrogen, phosphate, carbon, iron, trace minerals)
Portable meters are available for nitrogen/nitrates and phosphate. They involve chemical conversion and the use of colorimetric scales. They are measured in mg per liter. Algae blooms in lakes are possible above .02 mg/L phosphorus (which is normally limiting).

Suspended solids
These can be filtered out and measured (using a glass fiber mat or membrane filter in a Gooch crucible). Solids that settle out readily can be measured as ml per liter of settled water (Imhoff cone). Turbidity can be measured using portable meters.

Dissolved solids (TDS)
A water sample is evaporated and dried at 103 degrees C in an oven. The resulting residue is weighed and the results are expressed in mg per liter. An alternative method is to use a portable meter to measure electrical conductance as an indicator of dissolved ionic matter. The limit of TDS for potable water is 500 mg/L, for irrigation purposes it is 2,000 mg/L.

Toxins (particularly mercury and cyanide)
Bioassays are typically conducted in a laboratory, and measurements are generally expressed as nanograms per liter. Toxins are often synergistic and this should be taken into account in determining effects. Many toxins are bioaccumulated by living organisms, thus examination of tissue will provide a better sample of cumulative levels.

Hydrocarbons
Oils or grease are extracted from water using standard separation techniques with either petroleum ether or trichlorotrifluoroethane. Qualitative measures include visible oil slicks, coating of beaches and river banks, and oily taste to marine products.
**Biological indicators (invertebrates)**
Mayfly naiads and stonefly nymphs are common in good quality water. Blood and sludge worms, midge larvae, rat-tailed maggot, sewage fly larvae are common in poor quality water. Population size and individual density can be measured using a variety of techniques.

**Thermal discharge**
Water temperature can be measured using thermometers. Measurements should be taken at different times of day, at different depths. High water temperatures can have a negative impact on coral reefs and fish spawning.

### 4.2.4. Resources measurements

Much of the ecological data collected can be used in estimating the resource base. Degradation of the resource base, either through decreased quantity or decreased quality, should be an indicator of potential problems. Clear trends in quality or quantity of the resource base will indicate the need to reevaluate development and management activities.

**Marine resources**
The main characteristics of the population dynamics (trends in numbers and sizes in populations of exploited species) of pelagic and demersal resources should be determined using survey and sampling methods. The quantities and content of wastes should be determined through sampling. Extraction should not be greater than the sustainable rate.

**Non-timber terrestrial resources**
The activities and consumption rates of non-timber terrestrial resources should be determined using survey and sampling methods. The quantities and content of wastes should be determined through sampling. Extraction should not be greater than the sustainable rate.

### 4.2.5 Sound measurements

Loudness (decibels) and frequency measurement require specialized equipment for measurement (sound level meter and integrating noise monitor). Duration requires a stopwatch. Moderate to large increases in loudness, frequency or duration of sounds that cause psychological or physiological stress responses should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

**Psychological effects**
Interviews and surveys of humans can be used to measure psychological impacts. Baseline information is required, with additional data collected during and following development/management interventions. Changes in animal movement patterns or distribution patterns are another potential indicator of problems.

**Physical effects**
An audiometer can be used to measure changes in hearing capability in humans. In general, sound levels should not exceed 75 dBA (sound meter “A” weighted electronic network measurement of decibels). Sounds of 55-60 dBA can cause awakening from sleep.

### 4.2.6 Land measurements
Changes in land availability or moderate increases in erosion should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

Soil stability
Soil loss or erosion should be estimated using computer models. The models require information concerning a number of variables, including soil composition, slope, cover, and the intensity and frequency of erosion factors (wind, rain). Soil composition can be measured through simple portable test kits. Slope and slope length can be measured using a clinometer and measuring tape. Vegetation cover can be determined using a GRS densitometer. Intensity and frequency of erosion factors can be determined through rainfall meters and anemometers.

Land / sea use patterns
Current patterns of land and sea use can be determined through examination of Landsat images (land only), surveys, interviews, and direct observation.

Natural hazards (earthquakes, volcanic activity, tsunami, etc.)
These are often difficult to predict, although it is possible to identify areas of high risk. Facilities and trail development should avoid high risk areas if possible. Monitoring of weather and seismic reports from national and international facilities should be undertaken.

4.2.7 Economic measurements

A natural resource economist should assist with design of data collection and analysis. Non-expected changes in economic parameters should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

Economic stability and growth patterns
This can be measured through calculating the average and standard deviation from surveys of currency exchange rates, market prices of staple goods and fuel, bank interest rates, capital available for loans, and the unemployment rate.

Consumption rates
This should be divided into local and non-local consumption of resources (export goods). This can be measured through interviews, surveys, direct observation, and estimated from export records, known productivity data, and average catch data. Consumption should not exceed the sustainable extraction rate.

Market access
This can be measured through the amount, type, and cost of transport available, surveys of market demand, an examination of export/import records, and an examination of purchasing practices of regional suppliers.

Personal income
This can be measured through interview, survey, and government tax records. Estimates can be made based on other known parameters, such as the average daily catch of a fisherman, the number of days worked per year, and the market price of the type of fish typically caught.
4.2.8 Sociocultural measurements

A social psychologist or sociologist should assist with design of data collection and analysis. These variables are often difficult to measure quantitatively. Non-expected changes in sociocultural parameters should be an indicator of potential problems and indicate the need to reevaluate development/management activities.

Lifestyle
This can be measured through interviews, surveys of individuals, surveys of social institutions, and anthropological studies.

Religion
The number of religious facilities and membership is available through government records although field checks are recommended.

Education
The number of educational institutions, number of teachers and number of students is available through government records.

Social pressures
Social pressures can be measured through interviews and surveys. In addition, an examination of court records, local newspapers, and sermon topics may provide additional insights in the social realities of specific communities.

Aesthetics
This can be measured through interviews and surveys.

Politics
This can be measured through government records as to the composition of the MPR/DPR at the local, regional, and national level, and through interviews and surveys. In addition, an examination of legal regulations, recent political decisions, and local newspapers may provide additional insights.

4.3 MITIGATING IMPACTS

All human activities have impacts on the environment. A cost-benefit analysis should be conducted to decide which costs are acceptable and at what levels. Efforts should be undertaken to mitigate or avoid costs that are not acceptable and which prevent the park from attaining its goals. Brief descriptions of means to accomplish this (mitigation) for each of the variables is presented below.

4.3.1 Atmospheric impact

In most instances it is possible to eliminate or mitigate the impacts of development or management activities negatively impacting atmospheric variables. Atmospheric impact in Komodo National Park will have to be considered in the framework of fire management.
Particulate matter
The primary means of mitigation (alone or in combination) are: reduce emissions at the source (e.g., eliminate fires), the use of particulate removal devices on equipment (e.g., scrubbers, settling chambers), and the use of protected, controlled environments to exclude the emissions (e.g., gas masks, indoor sports facilities).

Hydrocarbons
The primary means of mitigation (alone or in combination) are: reduce emissions directly at the source, reduce or remove pollutants at the site, the use of gas removal devices on equipment (particularly motor vehicles), and the use of protected, controlled environments to exclude the emissions (e.g., gas masks, indoor sports facilities).

Sulfur oxides
The primary means of mitigation (alone or in combination) are: reduce emissions directly at the source, reduce or remove pollutants at the site, the use of gas removal devices on equipment, and the use of protected, controlled environments to exclude the emissions (e.g., gas masks).

Nitrogen oxide
The primary means of mitigation (alone or in combination) are: reduce emissions directly at the source, reduce or remove pollutants at the site, the use of gas removal devices on equipment (particularly motor vehicles), and the use of protected, controlled environments to exclude the emissions (e.g., gas masks, indoor sports facilities).

Carbon monoxide
The primary means of mitigation (alone or in combination) are: reduce emissions directly at the source, reduce or remove pollutants at the site, and the use of gas removal devices on equipment (particularly motor vehicles).

Photochemical oxidants
The primary means of mitigation (alone or in combination) are: reduce emissions directly at the source, reduce or remove pollutants at the site, the use of gas removal devices on equipment (particularly motor vehicles), and the use of protected, controlled environments to exclude the emissions (e.g., gas masks, indoor sports facilities).

Toxic materials
The primary means of mitigation (alone or in combination) are: reduce toxins directly through the use of non-toxic materials and processes, avoid or reduce activities generating toxins, remove hazardous emissions, and move people out of contaminated areas.

Odors
The primary means of mitigation (alone or in combination) are: dilution, counteraction or neutralization, odor masking, reduction in emissions, move people out of the area, and habituation.

4.3.2. Ecological impacts
In many instances it may be possible to eliminate or mitigate the impacts of development or management activities negatively impacting ecological variables.
Species richness / diversity
The primary means of mitigation (alone or in combination) are: avoid over-harvesting, avoid introducing exotic species, eliminate or reduce activities which affect life history parameters, eliminate or reduce activities which cause changes in habitat.

Habitat diversity
The primary means of mitigation (alone or in combination) are: avoid over-harvesting, avoid introducing exotic species, eliminate or reduce activities which affect life history parameters, and eliminate or reduce activities which cause changes in habitat.

Distribution patterns
The primary means of mitigation (alone or in combination) are: avoid creating barriers to movement, and eliminate or reduce activities which cause changes in habitat. Control of destructive fishing practices is one of the most urgent issues for the marine environment in Komodo National Park.

Population size, age/sex composition, and density
The primary means of mitigation (alone or in combination) are: eliminate or reduce activities which affect these parameters, and eliminate or reduce activities which cause changes in habitat. Fishing and habitat destruction in the marine environment are major issues for KNP.

Population growth rate
The primary means of mitigation (alone or in combination) are: eliminate or reduce activities which affect population size, composition and density, and eliminate or reduce activities which cause changes in habitat.

Threatened species / endemics
The primary means of mitigation (alone or in combination) are: eliminate poaching both on the land and in the sea, avoid introducing exotic species which compete or prey upon them, eliminate or reduce activities which affect life history parameters, and eliminate or reduce activities which cause changes in habitat.

Keystone species / economically important species / indicator species
The primary means of mitigation (alone or in combination) are: avoid over-harvesting both on the land and in the sea, avoid introducing exotic species which compete or prey upon them, eliminate or reduce activities which affect life history parameters, and eliminate or reduce activities which cause changes in habitat.

Resource requirements (food, water, shelter)
The primary means of mitigation (alone or in combination) are: eliminate or reduce activities which affect these parameters, and eliminate or reduce activities which cause changes in habitat.

Interspecific interactions (predation, competition)
The primary means of mitigation (alone or in combination) are: avoid introducing exotic species, eliminate or reduce activities which change community composition, and eliminate or reduce activities which cause changes in habitat.
4.3.3 Impacts on water

In most instances it is possible to eliminate or mitigate the impacts of development or management activities negatively impacting hydrological variables.

*Aquifer safe yield*
The primary means of mitigation (alone or in combination) are: eliminate or reduce activities which affect land surface runoff, percolation, the aquifer’s physical nature, or increase / decrease water availability (e.g., landfills, pumping rate modifications), employ correctional techniques to reduce adverse effects (e.g., modify slope and topography), adjust pumping rates, and artificially recharge the aquifer.

*Flow variation*
The primary means of mitigation is to avoid or reduce activities that increase flow variation. These activities include modification of vegetation cover, changes in withdrawal and return flow rates, and construction projects.

*Fecal coliform*
The primary means of mitigation (alone or in combination) are biological or chemical treatment of sewage wastes, and reducing the amount of sewage wastes deposited into the water system.

*pH (acidity / alkalinity)*
The primary means of mitigation (alone or in combination) are reducing or eliminating activities that contribute acid or alkali waste, and waste treatment processes.

*Biochemical oxygen demand (BOD)*
The primary means of mitigation (alone or in combination) are biological or chemical treatment of organic wastes, and reducing the amount of organic wastes deposited into the water system. No sewage water should be deposited in the waters of Komodo National Park.

*Dissolved oxygen*
The primary means of mitigation (alone or in combination) are biological or chemical treatment of organic wastes, and reducing the amount of organic wastes deposited into the water system. No sewage water should be deposited in the waters of Komodo National Park.

*Nutrients (nitrogen, phosphate, carbon, iron, trace minerals)*
The primary means of mitigation (alone or in combination) are: are reducing or eliminating activities that contribute to nutrient overloads, biological or chemical treatment of organic wastes, nutrient removal from the ecosystem (through harvesting species that bioaccumulate the nutrient or overflow), and reducing the amount of organic wastes deposited into the water system.

*Suspended solids*
The primary means of mitigation (alone or in combination) are: reducing or eliminating activities which increase erosion, controlling waste discharge containing suspended solids, eliminate or reduce dust-producing activities (e.g., mining tailings, gravel-washing), and the use of dust reducing technology.
Dissolved solids (TDS)
It is difficult to treat wastes with high TDS. The primary means of mitigation (alone or in combination) are: reducing or eliminating activities that contribute TDS wastes, and the use of deep well injections or lined landfills for waste disposal.

Toxins (particularly mercury and cyanide)
The primary means of mitigation (alone or in combination) are reduction or elimination of direct discharge, and treatment of contaminated wastes.

Hydrocarbons
The primary means of mitigation (alone or in combination) are: reduction or elimination of direct discharge, and treatment of surface run-off or sewage prior to discharge into the environment.

Biological indicators (invertebrates)
The primary means of mitigation is to improve water quality.

Thermal discharge
The primary means of mitigation (alone or in combination) are: the avoidance or reduction of industrial activities that alter water temperature, selective withdrawal from stratified reservoirs, and cooling towers.

4.3.4 Impact on Resources

In most instances it is possible to eliminate or mitigate the impacts of development or management activities negatively impacting resources.

Pelagic marine resources
The primary means of mitigation are the reduction or elimination of destructive fishing practices, and the avoidance of over-harvesting.

Demersal marine resources
The primary means of mitigation are the reduction or elimination of destructive fishing practices, and the enforcement of harvesting prohibitions.

Fuel resources
The primary means of mitigation (alone or in combination) are the use of alternative energy sources (e.g., wind, solar), the use of more fuel-efficient engines, and the enforcement of regulations limiting use.

Non-timber terrestrial resources
The primary means of mitigation (alone or in combination) are the avoidance of over-harvesting and the elimination or reduction of land conversion activities.

4.3.5 Sound impacts

In most instances it is possible to eliminate or mitigate the impacts of development or management activities creating adverse sounds or sound levels.
Psychological effects
The primary means of mitigation (alone or in combination) are: eliminate or reduce noise at the source, the use of insulation, building barriers around the noise source, and the use of protective devices (e.g., ear plugs).

Physical effects
The primary means of mitigation (alone or in combination) are: eliminate or reduce noise at the source, the use of insulation, building barriers around the noise source, and the use of protective devices (e.g., ear plugs).

4.3.6 Impacts on land

In most instances it is possible to eliminate or mitigate the impacts of development or management activities on the land.

Soil stability
The primary means of mitigation (alone or in combination) are: the reduction or elimination of activities that contribute to soil erosion, the restoration of vegetative cover, terracing slopes, and building catch basins near construction sites.

Land use patterns
The primary means of mitigation (alone or in combination) are: the use of GIS and other analytical methods in creating spatial plans prior to development, the creation of buffer zones surrounding use zones, and the use of regulations and zonation.

Natural hazards (earthquakes, volcanic activity, tsunami, etc.)
The primary means of mitigation (alone or in combination) are: the avoidance of construction in high risk areas, building facilities using methods and materials designed to withstand specific hazards, and monitoring seismic and weather forecasts.

4.3.7 Economic impacts

The economy both affects, and is affected by development and management activities inside the National Park area. It is therefore necessary to mitigate negative impacts of the external economy on the park, as well as mitigate negative impacts of park management on the local economy. Mitigation activities discussed below will be restricted to the local economy and the National Park area.

Economic stability
This is largely outside of the park’s mandate, although it can have an enormous impact on the resource utilization in the park. Ensuring stability of park revenues, however, could be mitigated through proper financial planning, the privatization of certain functions, and adherence to budgets.

Consumption rates
Negative impacts of consumption rates can be mitigated through regulations, the provision of alternative resources, and captive breeding programs.
Market access
This is largely outside of the park’s mandate, although it can have an enormous impact on the park. Adverse impacts on transportation routes to market could be mitigated through regulatory changes or alternate transportation routes or methods.

Personal income
Negative impacts on local income can be mitigated through the development of economic alternatives, including pelagic fisheries, mariculture, and eco-tourism.

4.3.8 Sociocultural impacts
Sociocultural variables both affect, and are affected by, the management of the park. Different approaches may be required for villages inside and outside the Park.

Lifestyle
Negative impacts on and by lifestyles can be mitigated through awareness campaigns and increased community participation in park management.

Religion
Negative impacts on and by religion can be mitigated through awareness campaigns and increased community participation in park management.

Education
Negative impacts of low education levels can be mitigated through increased educational opportunities, training workshops, and awareness campaigns.

Social pressures
Negative impacts due to social pressure can be mitigated through awareness campaigns and increased community participation in park management.

Aesthetics
Negative aesthetic impacts can be mitigated through the incorporation of local designs into facilities construction.

Politics
Negative impacts due to politics can be mitigated through awareness campaigns, public participation in free elections, and lobbying of legislative bodies.

4.4 CHARACTERISTICS OF GOOD ENVIRONMENTAL IMPACT STATEMENT (EIS)
A good EIS should exhibit the following characteristics (modified from A. Gilpin’s Environmental Impact Assessment: Cutting Edge for the 21st Century):

- An intelligible summary written in plain language
- Definitions of all acronyms and technical terms
- Clear table of contents
- Authors and contributors clearly identified
- Brief overview of background on project development
Full description of the project or activity proposed, including objectives
Full description of the existing environment affected, including baseline environmental and social parameters
Alternatives considered and rationale for rejection based on preponderance of evidence
Economic, social and environmental justifications for project and the consequences of non-implementation
Review of relevant statues, zonation regulations, environmental objectives, and planning framework
Identify and analyze probable environmental and social impacts and interactions of project proposed
Identify measures to eliminate or mitigate negative environmental and social impacts
Identify the proposed project’s impacts on transportation and communication systems
State proposed duration of infrastructure developments and logistical needs
Identify impacts on social services, such as schools, medical facilities, policing, trash and sewage, parks, and nature reserves.
Identify impacts on endangered and threatened species, ecosystem processes and sustainable resource use
Identify any transborder implications
Analyze effects with respect to time frame (short or long term), duration (temporary or permanent), whether effects are direct or indirect, and if effects are cumulative
Reporting framework for monitoring implementation of required mitigation factors and adherence to agreed upon conditions
Summary of consultations with relevant government agencies, NGOs, the public, and other stakeholders during all stages of the EIA
Any features unique to the proposal
The project’s contribution to conservation, sustainable resource use, and the alleviation of environmental problems

4.5 ENVIRONMENTAL IMPACT ASSESSMENT WITHIN INDONESIA (AMDAL)

EIA (AMDAL) guidelines have been published by the Environmental Impact Management Agency (BAPPEDAL) in 1991. Authority for the implementation of EIA regulations is held at both the central (BAPPEDAL) and provincial (BAPPEDALDA) levels of government. The procedures for an EIA are outlined below (from BAPPEDAL):

1. Proposal developed
   a. by Government -> sectoral agency or non-departmental government institution - >
   b. by Private Sector -> investment board (exempt or approved) ->
2. Project screening and scoping -> outcomes:
   a. exempt from EIA -> permits, licenses issued -> project implemented
   b. project proposal unacceptable -> revise proposal
   c. needs EIA
3. EIA -> develop TOR (30 days)
4. Conduct EIA (90 days)
5. Develop environmental management plan and monitoring plan (30 days)
6. Permits and licenses issued and project begins implementation.