Frontier Madagascar Environmental Research

REPORT 3

Marine Biodiversity Training Manual

Madagascar Marine Biodiversity Training Project

Frontier Madagascar
2003

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Webster C.L., Fanning E., Hémery G. and Woods-Ballard A.J. (eds)

Darwin Initiative for the Survival of Species
Department for Environment, Food and Rural Affairs, UK Government

Frontier-Madagascar
Institut Halieutique et des Sciences Marines
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Frontier-Madagascar
The Society for Environmental Exploration and The Institute Halieautique et des Sciences Marines (IHSM), part of the University of Toliara have been conducting collaborative research into environmental issues since 2000 under the title of Frontier Madagascar. Frontier Madagascar conducts research into biological diversity and resource utilisation of both marine and coastal terrestrial environments, of which one component is the Frontier Madagascar/Darwin Initiative: Madagascar Marine Biodiversity Training Programme.
Madagascar, the fourth largest Island on the planet is renowned for its high biological and ecological diversity, characterised by its high abundance of endemic species. Madagascar is one of the poorest nations in the world and very dependent on the resources the natural environment provides. As a result conservation and development work is of paramount importance as efforts are made to preserve an environment under pressure from non-sustainable exploitation.

Institute of Marine Sciences (IH.SM)
The Institute Halieautique et des Sciences Marines (IHSM) is part of the University of Toliara, in Madagascar. IHSM is a university centre of learning in the field of marine sciences and runs courses for both undergraduate and postgraduate students. IHSM also provides consultations to government institutions, NGOs and individuals.

The Society for Environmental Exploration (SEE)
The Society is a non-profit making company limited by guarantee and was formed in 1989. The Society's objectives are to advance field research into environmental issues and implement practical projects contributing to the conservation of natural resources. Projects organised by The Society are joint initiatives developed in collaboration with national research agencies in co-operating countries.

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INTRODUCTION

Darwin Initiative Madagascar Marine Biodiversity Training Project

This *Training Manual* aims to contribute to the fields of sustainable development, marine and coastal conservation and environmental education, by reporting on a one year long training programme, the Darwin Initiative Madagascar Marine Biodiversity Training Project (DI MMBTP). This report provides information on the programme of events conducted during the project and is presented as a blue print for future use and adaptation.

The training project was conducted in the region of Toliara, southwest Madagascar, where the marine and coastal ecosystems are under increasing pressure. The aim of the project was to *Aid marine resource security by providing skills to monitor and manage marine biodiversity through the provision of training*. The project aimed to contribute to reaching the objectives of the Convention on Biodiversity of the UN (Jakarta Mandate), signed by Madagascar in 1992 and ratified in 1995.

As a result, the project focussed on the following domains:
- Raising knowledge of marine and coastal ecology (ecosystems and species)
- Providing training in marine biodiversity survey and monitoring methods
- Bringing a sustainable resource use and management approach
- Assisting with the establishment of a specific habitat monitoring plan

The trainees belonged to three groups identified as key actors for the development of management plans concerning the sustainable use of resources in the area. These were:

- Local Coastal Community Representatives (Anakao region, Toliara Province)
- Fisheries Officers (Ministry of Fisheries, Toliara Province)
- Students from the Institute of Marine Sciences (IH.SM, Toliara Province)

The Darwin Initiative, a component of the Department for the Environment, Food and Rural Affairs (DEFRA) of the UK Government, provided the funds to run the project. Activities were co-ordinated by the Society for Environmental Exploration (SEE), implemented through Frontier-Madagascar, a collaboration between The Society for Environmental Exploration (SEE) and the Institute of Marine Sciences (IH.SM), University of Toliara.

Toliara Province

The Toliara Province, located in southwest Madagascar (see Map of Madagascar, Annexe C), is one of the least developed regions of the country despite its major port, Toliara. The three largest economic sectors are fisheries (including aquaculture), tourism and farming. Fisheries and tourism alone generate around US$117 million per year (ONE, 2000).

In the Toliara province, 65% of people inhabit coastal communes and as with most developing countries, the demographic rate is high, 2.8% nationally on average. The latter has also grown a lot faster than the GNP, which means that the population has become poorer by 50% between 1972 and 1992. The level of poverty is of 80% of the population and Madagascar is regularly classed among the 30 poorest countries in the United Nations sustainable human development index (ONE, 2000), a much renowned result of the lack of access to education.

The economic potential of the region is deemed extremely interesting, particularly with regards to ocean products. The longest coral reef assemblage of the Indian Ocean stretches along the West coast of Madagascar (Wells et. al., 1988). The lagoons and mangroves provide a nursery ground for a huge number of species, many of which are exploited at traditional, artisanal and commercial fisheries levels. 50% of the national economy depends on the coastal zone and should a fictional value be placed on reefs and mangroves together, this would be equivalent to 7.6% of the GDP or US$100 million and US$204 million respectively in 2000 (ONE, 2000). Marine products originating from the area are consumed locally and exported nationally, regionally and internationally (MPRH, 2001).

Recent years have witnessed an interesting dynamic between the three sectors mentioned above. Consecutive extremely dry seasons have resulted in a migration of inland human populations to the coast (MINAGRI, 2001. pers.comm.). Many migrants now rely on marine resources for their basic needs while others supplement their traditional agricultural activities with more lucrative ocean related ones, including the exploitation of target resources and the transport of tourists by sea (*Vezo* and *Tanalana* fishermen, 2000. Personal communication).

Due to a severe lack of infrastructure, tourism has been on a low increase with only 130,000 visitors in 1998 and 160,000 in 2000 based on aerial arrivals (MINTOUR, 2000). However, it is worth noting that only 46% of arrivals have tourism only motivation. 25% of tourists interviewed on departure go to the Toliara region (Madio, in Lévy-Perraut 2001). In 2002, the industry plummeted due to the political situation resulting in many Malagasy people turning back to marine and coastal resources for their livelihood.

Identification of threats to marine resources

Since the 1960s, many signs showing the depletion of certain marine species in the region were gradually unveiled by research (Vasseur, 1997) with for example, 33% species loss between 1972 and 1987 on the Grand Récif of Toliara (Vasseur et. al. 1988a & 1988b). At the same time, local fishers have been pointing out the deteriorating situation (Frontier Madagascar 2002a, b). The local coastal community is the main user of the coastal zone, legally set at a 12 miles band by the adhered UNCLOS (IWCO, 1998). Incidentally, this zone is where around 80% of the ocean's biodiversity is concentrated and also the most prone to habitat degradation and depletion of resources. Hence, as the area becomes increasingly affected, it is the local people who will suffer the most.

IH.SM and WWF, among other organisations, have recently confirmed the threatened status of some species and the expansion of habitat degradation in the Region of Toliara, particularly on the Grand Récif but also on some of Anakao reefs (Frontier-Madagascar, in prep.). Factors such as over-exploitation, trampling of the reef flats and the lagoon, hyper-sedimentation originating from the Onilahy river and global warming have all contributed to these results. Frontier-Madagascar having carried out SCUBA surveys on various local sites has made observations on all health stages for different areas (extremely degraded, degraded, recovering and healthy). Yet the area remains of exceptional biological value with the most worrying aspect being the lack of integrated sustainable management strategies in application.

Key problems to be addressed are numerous. For example, some areas and species remain virtually under-exploited while others are over-utilised (FAO, 2002. Personal Communication). Local people lack environmental awareness and general education. People are poor. Few viable solutions are put forward as alternatives to over-exploitation. Funds allocated for integrated sustainable development are dismal (Kofi Annan, 2002). There is poor public representation of interested parties at discussion forums. Information access is restricted. There has been much corruption.

Yet in recent years, a few very positive initiatives have been developed. To begin with, the second stage of the PNAE recognised the importance of the marine environment and included it as a priority in the national strategy. The Malagasy Government also put forward a proposal to UNESCO for four coastal sites to become MaB Reserves (Commission Nationale Malgache pour l'UNESCO, 1998). Furthermore, several feasibility studies have been funded to investigate the potential establishment of additional MCPAs. The Toliara region is part of each of these initiatives with considerable support from EMC/SAGE. For example, the latter have taken the small island of Nosy Ve, which is locally managed by FI.MI.MA.NO, as a national pilot GIZC zone. The status of a larger legally protected and sustainably managed marine zone is yet to come to fruition.

However, there is a distinct lack of local experience in implementing marine sustainable management strategies in the Toliara region and various key players do not possess access to the tools necessary to put plans into place effectively, whether these be applied technical skills, specific knowledge or access to information.

In considering key actors ultimately involved in the present and future sustainable development of the marine and coastal environment of the Toliara Region for the DI training course, SEE concluded that students, local community representatives and fisheries officers were suitable target trainees.

The lectures below are outlines of the topics covered during the training programme and are intended as notes to be built upon by future trainers. These notes are therefore most useful for trainers with an appropriate background and/ or access to suitable literature. Wherever possible local examples should be sought out and used to highlight the points being made.

1 CORAL REEF ECOSYSTEMS

1.1 Distribution and limiting factors for coral reefs

Coral reefs are often compared to tropical forests with high species numbers and ecological complexity. Energy for growth primarily from solar radiation. Situated in areas of maximum luminosity. Coral reefs are generally found between the latitudes of 30° N and 30° S. These latitudes correspond approximately to the 20°C isotherm representing the minimum temperature for normal coral development. The temperature for maximal growth is between 23-25°C. The absences of coral to the west of South America and Africa are due to the presence of upwellings of cold water. Isolated colonies or individuals found in colder water tend to have few massive structures compared to sub-tropical regions. Two exceptions: Lord Howe Island and the Abrolhos Islands situated to the East and West of Australia respectively, which have warm currents.

Optimal development of coral occurs in clear, bright, clean and shallow water. The symbiotic algae "zooxanthellae" needs the light in order to photosynthesise. Productivity limited or absent in areas of dirty or sediment rich water for example at the mouth of rivers.

The highest diversity and percentage cover of coral is on the reef slope. This is probably due to strong currents stopping the accumulation of sediments, which will tend to settle towards the bottom of the reef.

Corals are very sensitive to strong variations of salinity. They are absent for example at areas where there are large discharges of fresh water for example to the east of South America where the Amazon and Orinoco rivers enter the ocean. Some corals are tolerant to extremely high salinity for example in the Persian Gulf, where salinity can reach 40‰.

Wave action is an important factor in coral growth. It limits sedimentation and increases oxygenation of the water. The calcareous skeleton of coral is particularly resistant to wave action, however storms can cause extreme damage to coral reefs.

1.2 Different types of coral reefs

Coral fossils indicate their presence 400 million years ago. However the formation of coral reefs as we see them today, dates to 5000 years ago. The development of coral reefs is strongly influenced by sea level changes. Charles Darwin was the first to formulate a theory as to the evolution of coral atolls. This theory is now largely recognised in the scientific community. For example by this phenomenon, an island subsides progressively into the ocean and reef that is developing around it must always try to stay within the optimal conditions for growth. Finally the island disappears, leaving an oceanic atoll. Since Darwin's theory was formulated it has been proven through observations of the formation of the Enewatek atoll in the central Pacific (Marshall Islands), with a submarine volcanic peek at 1219m depth. Continental masses can also have different types and structures of reefs, for example fringing reefs, platform reefs (within lagoons) and barrier reefs. These reefs are also formed by a process of continental subsidence or elevation.

1.3 Morphology of coral reefs and their distribution.

1.3.1 The lagoon

The lagoon is situated between the land and the barrier or atoll reef, with a depth of between 1 and 90m and often contains micro-atolls.

1.3.2 The reef plateau (1-3m)

The reef plateau is inter-tidal to sub-tidal and can run for metres or kilometres. The surface may be composed of rocky platforms, sand banks, seagrass beds, algae beds, micro atolls and beds of encrusting algae. There is a rich fauna of invertebrates.

1.3.3 The reef crest and the spur and buttress zone (2-18m)

These zones make up the face of the reef between the crest and the seafloor. This zone is constantly exposed to wave action, causing the creation of channels, which disperse the energy of the waves. This area is ideal for coral growth and branching, table and massive corals abound in varying proportions depending upon wave force. Sometimes the peaks collapse leaving large spaces on the reef for new settlement.

1.3.4 The reef slope (18-30m)

This represents the gentle slope to the base of the reef, where sand and sediment dominate to the detriment of the coral.

1.4 The deep part of the reef (30-200m)

This final zone extends to the seafloor. Coral is found to a depth of approximately 70m often in a foliose form, adapted to poor light conditions. Gorgonians, sponges and soft corals are common at depth.

1.5 The abundance of life

Why are there so many organisms living in or on coral reefs? One can also ask the question why the nutrient poor tropical waters have such a diversity of life? Coral reefs survive due to the interdependent nature of their ecosystems. Major contributors to the primary production on coral reefs are the zooxanthellae found within the corallites. These symbiotic micro-algae use light and carbon dioxide to produce organic components rich in energy that can be used by the coral.

Coral reefs are one of the richest ecosystems in the world. They are extremely complex and contain numerous micro-habitats, which shelter numerous different species of flora and fauna. On top of the animals and plants observable on the surface of the reef there are many less evident organisms living in the cracks and crevices. Symbiotic associations are frequent, for example sponges, soft and hard corals, echinoderms and ascidians all provide homes for crustaceans, molluscs and fish. On top of this micro- and macro-scopic life abounds just at the surface of the reef and into the water column. Finally there is the plankton community, a microscopic mix of larvae and adult forms, which represent an important food source for many of the reef inhabitants.

1.6 Ecology of coral reef fish

Reef fish represent an important link in the trophic chain. The architecture of the reef is very complex with caves, crevices, rock falls, reef plateaux, sand banks, and algal beds etc. This diversity of habitats leads to the specialisation of the reef fish. The distribution of reef fish is fundamentally linked to their feeding, protecting and reproducing needs. Most fish live in shallow water where productivity and biodiversity of habitats are highest. This is due to the absorption of light as the water gets deeper which does not allow enough energy for many photosynthetic species to survive.

1.7 The importance of coral reefs

Coral reefs play an essential role in maintaining the equilibrium of tropical coasts. Examples of these ecosystems goods and services are:
Protection of coastlines. Reefs can considerably reduce waves' energy before they reach the coastline, limiting erosion.

Provides sediment for the lagoon and the beaches through erosion by waves.
Building material. Coral reefs are formed by calcareous rocks which are exploited in some regions. This is a non-sustainable, destructive activity using explosives and is illegal in many places.
Fishing industry. Coral reefs provide habitats for many commercially important species.
Tourism. The diversity and beauty of coral reefs attract divers and snorkellers.
Ecological importance due to it high biodiversity.
Medicine. All potentially useful resources for medicine have not yet been discovered. Unfortunately, this ecosystem might disappear before we uncover all is secrets.
Bioindicators for monitoring and detecting pollution and climate changes. Traces of these events may be tracked in the coral's skeleton.

1.8 Dangers to coral reefs

Coral reefs face many dangers, liked to human activities or not. For example: destructive fishing techniques (dynamite fishing, poison, drift nets….), chemical, physical or biological pollution, sedimentation, hot water outflow etc.

1.9 Conservation

Tropical marine ecosystems all over the world are increasingly threatened by overexploitation, pollution and habitat destruction. Practices such as dynamite fishing, coral mining, clearcutting mangroves for wood or aquaculture, overfishing of certain species, aquarium trade, building dams, collecting shells and tourism may all have negative impacts on the health of coral reefs. This overexploitation of resources can be linked to the increase of coastal populations on a global scale (3% per year), particularly in developing countries. Although reefs are themselves very productive systems, corals grow slowly and a damaged reef will take between 15 and 20 years to recover but will not have been productive during that time. Often however reefs suffer from chronic problems and do not have the chance to recover. Considering not only the biological but also the socio-economical importance of coral reefs, it is necessary to act urgently towards their protection and management for a sustainable use.

1.10 Source

Nybakken, J.W., 1997. Marine biology: an ecological approach – 4th edition. Ed. Addison-Wesley Educational Publishers Inc.

Polunin, N.V.C., 2001. Master of Science Course in Tropical Coastal Management, Newcastle-upon-Tyne, UK.

2 ECOLOGY OF CORAL REEF FISH

2.1 High diversity

Coral reefs host higher number of fish than any other marine environment on earth. It is impossible to think of a coral reef without thinking of its many fish with many colours. Fish are the biggest and most abundant organisms and the most obvious on the reef. The distribution of species richness is the same as corals, with the highest diversity in the centre of the Indo-Pacific zone (Philippines and Indonesia), the number of species decreasing in all directions.

Geographic Zone	**Number of species of reef fish**
Philippines	2177
New Guinea	1700
Great Barrier Reef	1500
Seychelles	880
Marshall and Mariana Islands	669
Bahamas	507
Hawaii	448

Source: After Goldman and Talbot, 1976

High fish species diversity on reefs can be explained with relation to the habitat diversity alongside one of a number of theories referring to competition and recruitment.

2.1.1 The competition model

Due to high competition each species will have evolved into its own ecological niche.

2.1.2 Lottery

Fish produce a lot of dispersed larvae in the plankton. This theory introduces the non-specialised concept, i.e. that many species have the same needs, and competition is high. The success to colonise and persistence to stay in the same area are due to settlement chance of the larvae. Therefore it is recruitment not competition that is important

2.1.3 Perturbation/ predation

Fish populations never reach equilibrium. Predation, natural catastrophes and unpredictable recruitment ensure that no species can ever exert eliminatory competition because resources become a limiting factor.

2.1.4 Recruitment limitation

The most recent theory is that of recruitment limitation (1982, 1983) it's based on the idea that recruitment is never sufficient to reach maximum capacity. The adult population varies in recruitment at the larval and not post larval stage.

2.2 Composition of fish population

Although reef fish are highly mobile, they are restricted to a very focussed zone and are essentially sedentary. Many do not migrate and little fish such as gobies, blennies and damsel fish defend territories. Larger fish may migrate towards food sources up to a few kilometres away. An interesting observation is the difference in composition of fish between night and day. Because of the partitioning of the two populations, ecologically similar species can live in the same areas, without entering into direct competition.

2.3 The food web

Of the fish on the reef, 50-70% are carnivorous. Many of these fish are non-specialised, opportunistic carnivores feeding differently during different life-cycle stages, so as not to compete with intraspecifically. Herbivores and coral grazers are the second most important category with dominant families such as Scaridae (parrotfish) and Acanthuridae (surgeonfish). The rest of the fish are classed as omnivores. The only fish to eat plankton are the schools of small fish such as Pomacentridae, Clupeidae and Atherinidae. A secondary effect of the diet of certain fish is that they can augment the nutrition and growth of corals. Some fish will feed on seagrass during the day and return to the reef during the night to defecate material rich in phosphates, thus accelerating coral growths. If one considers that carnivores are common, it is easy to understand why invertebrates will have shells for protection. Why do some invertebrates such as sea cucumbers not protect themselves in this way? They have developed other defences such as toxins or poisons. Fish also have this type of defence in spines or on the surface of their skin.

2.4 The colours of fish

Why in an environment where predation is high are fish so colourful? Biologists are not agreed and these colours may have different functions. They may give a warning to predators of toxin presence. They may camouflage the fish, by either breaking the shape with lines of different colours or by camouflaging them. Finally they may serve as a species recognition guide as fish are highly dependent of their vision from an evolution in clear waters. They may therefore help during mating.

2.5 Symbiosis and mutualisms

A good example of mutualism is the cleaning behaviour specific to some predators such as small fish and small shrimps that eat other fishes' parasites. This phenomenon is found everywhere on the reef and these cleaning fish or shrimps guard cleaning stations, which they show other fish through their colouration. The customer fish arrives at the station and stays still with its mouth open. The cleaning fish can even enter in the mouth or gills. Due to high predation rates on reef, mutualisms are often necessary for survival for example there is a tight relationship between one species of gobie and a shrimp. The shrimp digs a hole in the sand where the fish can find protection and hide and in return, the fish warns the blind shrimp of any dangers through contact with the shrimps antennae and the fish.

2.6 Conclusion

In conclusion one can say reef fish are important for the general ecology of the reef. They help determine zonation of the reef by grazing, which will stop algae from going beyond a certain height and coverage area and therefore stops them from out competing corals. Corallivores in turn do not allow coral to survive in some reef zones and therefore also contribute to the diversity of reefs. The high number of carnivores exert a pressure on the other organisms and contribute to the development of some behaviours, such as cryptic colouration and defence strategies.

2.7 Source

Nybakken, J.W., 1997. Marine biology : an ecological approach – 4th edition. Ed. Addison-Wesley Educational Publishers Inc.

3 ECOLOGY OF SHARKS, THEIR MANAGEMENT AND PROTECTION

3.1 Diversity

There exist over 400 species of sharks. They occupy a large variety of habitats, including: rivers, estuaries, coastal waters and shallow and deep sea waters. To the contrary to general thoughts, there are only a few sharks that do transoceanic migrations. Most have a smaller distribution area, for example in Australia, 54 species are endemic. They stay along the coast and around the islands, some are even restrained to very precise depths. The distributions of elasmobranch species:

- 5% are oceanic and migrate
- 5% live in fresh water
- 35% live between 200 and 2000m depth
- 50% live near the coast
- 5% live in more than one of these habitats.

Most species of sharks are predators, some are carnivores and others plankton filterers, such as the whale shark, basking and megamouth. Predatory sharks are found at the top of the marine food chain, which means there are few shark predators. Food resources are limited at the top of the chain and thus so are the number of sharks. Biological and ecological shark research is difficult due to the nature of the species, low population densities of animals often living in deep waters. So the little data that we have are those collected through fisheries. The role of sharks at the top of the food chain is therefore not well understood and we cannot estimate or predict the effects of their extinction or decline.

3.2 Evolution of sharks

The sharks predate dinosaurs by a hundred million years. They have survived through all species extinctions. They can therefore be used as excellent indicators of human pressures. They can survive natural catastrophes and if their numbers are decreasing it is probably due to man.

3.3 Sharks lifecycle.

The shark lifecycle is characterised by low fecundity, giving birth to a small number of individuals every one to three years, large independent infants, slow growth, late sexual maturity, long life compared to other fish and high natural survival rates at all ages. Pregnancy lasts between three to 24 months with an average of 10-12 months. Reproduction is never once per year. They usually skip a year and therefore only produce once every three years. There are three different types of reproduction in sharks. The embryo may develop in the female's womb such as in humans, or the shark lays an egg but it stays in the female's womb until eclosion, or finally it may lay an independent egg. These characteristics mean that the reproduction rate and population increase rates are low. This has evolved as sharks have few natural predators and do not have to give birth to many new-borns to maintain a stable population. It does however mean that shark populations are slow to recover from the effects of overfishing or other negative impacts if they do.

3.4 The constraints of the slow lifecycle on shark exploitation.

The main difference between sharks and other types of fish is reproduction. Other fish will lay millions of eggs every year. The shark's lifecycle and therefore management at the fisheries level is similar to that of marine mammals and turtles. Nevertheless some small species of sharks will reach maturity after 1 or 2 years and will only live up to 15 years. These are generally the coastal sharks, which can support the fisheries if their stocks are well managed. On the other hand sharks that have a slower lifecycle and may live up to 70 years, generally in deeper waters must be managed cautiously. Another characteristic of shark behaviour is that they will group by age and sex. This means that there are groups of only mature females and if this group is targeted by fishermen it will have a considerable impact on the entire population.

3.5 Their uses

Sharks are fished for their meat and they represent in some regions of the world the principal source of proteins for local populations. The fin market has increased for Southeast Asia. Tourism is another economic use of sharks, which may make more money than fishing, for example in a region of Indonesia, the main attractions are whale-sharks.

3.6 Dangers for sharks

3.6.1 Fishing

Shark fishing has increased due to coastal population increases. Sharks are hunted for their meat, teeth, skin, oil, jaw and fins. Exploitation by man usually goes above stock capacity to generate and keep a stable population. This is backed up by the fact that fishermen everywhere in the world have noticed a decrease in captures.

3.6.2 Shark by-catch

Trawlers' nets will catch sharks as a by-catch, sometimes in higher quantities than the targetted species. The problem with the growing and highly profitable fin market is that trawlers instead of releasing the sharks, will first cut their fins off then release them to die. Furthermore beach seining will capture juveniles, for example at the mouth of the Onilahy River (Southwest Madagascar) fishermen captured juvenile hammerhead sharks.

3.6.3 Habitat destruction

Sharks depend directly on the health of the environment they live in for their reproduction, growth and survival. Because they have such a slow lifecycle, adaptation rates to new conditions are also slow. This is why environmental disturbances such as pollution or reef destruction lead to a slow decline of numbers.

3.7 Shark fisheries management

Nearly everywhere in the world, shark captures have decreased. The main problem is that there is very little data and therefore it is difficult to follow the evolution of the fisheries and identify if species are in danger or not. There are different methods to manage fisheries quotas (maximum sharks fished per season or year), closed seasons during reproductive times and restrictions on fishing gears and capture size. But at the scale of artisanal fisheries, such as in the Toliara region any management is difficult due to the large numbers of fishers and the perceived long-term profitability.

4 ECOLOGY OF MARINE TURTLES THEIR THREATS AND MANAGEMENT

4.1 Biology

Marine turtles are reptiles, which have not evolved very much in the last 100 million years. Together with snakes and crocodiles they are the only marine reptiles. There are 7 species of turtle in the world, 5 of which are found in Malagasy waters:

- Leatherback *Valozoro*
- Loggerhead *Ampombo*
- Green *Fano zaty*
- Hawksbill *Fano hara*
- Olive Ridley *Tsipioke*

The two others live in Australia (Flat back) and Mexico (Kemps Ridley). Most of these species seem to spend most of their time in continental waters (near the coast) and at other times in mid ocean. Males never leave the sea whereas females do to lay their eggs on the beach. Turtles spend their first year in the mid-ocean after which they will spend their time in coastal feeding zones. During laying season males and females will leave the food zone and will mate near nesting beaches. Usually females will come out of the water at night and crawl on the beach to find a spot to make their nests in which they will lay more than 100 eggs. They return to the sea at sunrise. On beaches where they are not disturbed, turtles can come back many times to the exact spot during one reproductive season. It has also been observed that turtles will lay on the same beach where they were born. There are therefore particular nest sites for each group of female turtles. On the other hand males will mate with females from different groups. This ensures gene transfer between different groups of turtles. This is not always the case however, as there are variations in behaviours between species and colonies for the same species. Specific management plans are therefore needed for each case.

4.2 Dangers

4.2.1 Eggs

When the female returns to the sea, the eggs are left on their own. Although the rate of hatching is high, there are many predators (rats, crabs, dogs, pigs, etc.) and man is also a threat. The high protein value and aphrodisiac properties of turtle eggs recognised by some populations have made it a sought after product. Sometimes nests are completely emptied of their eggs meanings the population is not replaced and the number decreases.

4.2.2 Hatchlings

When the new-borns hatch, they find their way to the sea by following the light reflected on the first line of waves, between the nest and the sea they are highly exposed to predators. If there are human activities on the coast, the artificial lighting may misdirect the new-born, leaving them more exposed to predators and traffic etc. Once the new-borns have reached the sea, new predators await them, sharks, seabirds etc. The hatchlings, which manage to go through these obstacles will stay out at sea until they reach sexual maturity. This can take as many as 10 years.

4.2.3 Adults

The reproductive process is very long as sexual maturity is not reached until around 20-30 years. Turtles are threatened by overexploitation for commercial ends, food, or as ornaments. Other impacts affect them, such as pollution, drowning in fishing nets and loss of habitats.

4.3 Conservation status

Of the seven species, six are endangered. The hawksbill turtle and leatherback are classed as critically endangered and all seven species are classed in annex 1 of CITES, which prohibits international trade. In all the world turtle populations are decreasing, for example there are ten times less green turtles in Indonesia than in the 1940's and in French Polynesia less than half. This is why urgent protection action is necessary. The problem has to be approached on an international level, due to the migration of turtles throughout the world. Initial action must however take place at a local level. Marine turtles represent an important draw for ecotourism, a turtle that will be observed through many years, will be worth more than a dead one. It is possible to help turtles, one of the oldest animals on earth by regulating fishing, especially of juveniles.

4.4 Source

Kempf, E., *et al.*, 2000. Les tortues marines – Rapport du WWF sur le statut des espèces

5 ECOLOGY OF CETACEANS (WHALES, DOLPHINS AND PORPOISE)

5.1 General biology of cetaceans

Cetaceans are a group of marine mammals, made up of whales, dolphins and porpoises. They give birth to live young. A cetaceans tail moves in the vertical plane as opposed to that of a fish, which moves in a horizontal plane. Cetaceans eat plankton, invertebrates (for example squid) and small fish. Their hearing is highly developed, which allows them to hunt for prey using echolocation. There are many reproductive strategies but all cetaceans have a long lifecycle and only mate late in their lives. Their reproduction rate is slow. Little is known about these mammal as there are few of them, they live in deep water and only come to the surface to breath making them difficult to study.

5.2 Threats

Human activities have diminished numbers greatly. Whalers hunted the big whales until near extinction, using factory ships that could process the animal directly on board. This was stopped in 1986, when an international moratorium put an end to all whaling, except for scientific purposes. By-catch in fishing nets causes an increasing number of dolphins to drown. Competition with the fishing industry for the same resources and disturbances from other human activities, such as transport, tourism, marine pollution and habitat destruction. In some places animals are still actively hunted for food and bait.

5.3 Status

These animals could provide a valuable resource in the future. As with turtles they are a popular tourist attraction and live animals that can be viewed over a series of years are worth more in the long term.

5.4 Source

Carwardine, M., 1995. Baleines, Dauphins et Marsouins – Le guide visuel de tous les cétacés à travers le monde. Ed Bordas, Col. L'Œil Nature

6 MANGROVES

6.1 Biology of mangroves

Mangroves, *honko* in Malagasy are found on sheltered coasts in many tropical and sub-tropical regions. They are similar to terrestrial plants, but along with seagrasses are the only ones to be found in an intertidal environment. Mangroves are a system with high biodiversity and high primary productivity. Different species of mangrove have different salinity tolerance and freshwater intakes. This is why small forests will have a homogeneity of species whereas we will be able to see zonation of species in larger forests.

6.2 Two main types of mangroves.

Mangroves and angiosperms like terrestrial plants and produce flowers and seeds. They can be classified into two categories.
Soft soil mangroves are the most common and are found in regions with a large fresh water output. They usually form large, complex and highly biodiverse forests, with a limited diversity of fauna where only a few species adapted to high variations of salinity will dominate. Waters tend to be both nutrient and sediment rich.
Hard soil mangroves are only found in tropical and subtropical dry regions. They occur in areas with very little fresh water input and therefore high salinity. These mangroves cover a small surface area and forests grow along creeks in the intertidal zone. Fauna and flora are very diversified in the clear water and are generally characteristic of a rocky coastal environment.

6.3 Conditions for development.

Mangrove trees must resist fresh water evaporation. Selectively permeable membranes and active salt excretion are two methods to do this. Different levels of salinity and immersion periods are two major factors influencing mangrove zonation. All mangrove trees have the same following characteristics; they are evergreen and they use a lot of energy to maintain intercellular water through the use of constantly active mechanisms. This is compensated by the fact that they can photosynthesis all year long, occurring mainly in the tropics. Mangroves have a root system of pneumatophores, which help balance the instability of the sediment and allow for the anoxic conditions by allowing oxygen transfer in the air. The sediments in which the trees grow are often fine, silty and muddy and therefore oxygen penetration is very slow. Therefore to ensure a high enough level of oxygen in the roots, the ends of the roots will surface. Seeds germinate whilst still attached to the tree as the soil is very hostile. These seeds are usually large and pointed so they can penetrate the ground. A protective membrane around the seed allows it to travel by sea for long distances.

6.4 Mangrove fauna

The mangrove ecosystem is mainly based on detritus. Even if a mangrove is not regularly inundated by sediment, organic matter accumulates from falling leaves. This can copious as water retention can involve shedding of leaves, which have been pumped full of toxic levels of salt. The organic matter is retained by the root system at the surface and at depth where the decomposition processes take place. A fresh leaf on the tree has 6% protein, while a year old decomposed leaf will have 22% due to the microbial activity. This bacterial layer is consumed by for example gastropods, which live buried in the sand or hidden under leaves upon which they feed. Faecal material is used by crabs as a food supplement. These gastropods and crustaceans represent an important source of food for fish and other crustaceans. This is why mangroves are important economically as they support commercially important species such as shrimp. By giving them food and shelter to adults and juveniles. Some species of fish migrate everyday between mangroves and seagrass for example with the tides. The epifauna living on the tree is composed of littorinids, oysters and barnacles. The ground is colonised principally by crabs, finally the canopy shelters insects, spider, birds and lemurs in Madagascar or monkeys elsewhere.

6.5 In Madagascar

Madagascar has about 300,000 ha of mangrove forest, which is the largest of all east African countries. 98% of this is on the west coast of the island due to the higher tidal variation. This forest is important not only for its local use by man but also the reproduction site for globally endangered species.

6.6 The importance of mangroves.

6.6.1 Goods

- production of wood and charcoal and for boat construction.
- medicinal uses
- dyes production
- salt production

6.6.2 Services

- grazing
- aquaculture
- protection of coastal soft soil zones
- retention of sediment which protects seagrass and coral reefs
- production of nutrients for transport to other ecosystems
- support fisheries by providing nursery grounds
- buffer zone between land and sea for salinity, nutrients and sediments.

6.7 Threats to mangroves

Mangroves are more and more threatened by the demographic explosion of coastal populations. In the case of Madagascar the biggest threats are grazing and wood cutting. On the other hand in South America and Asia, thousands of hectares of mangroves have been destroyed for aquaculture. Finally in some regions, land originally occupied by mangroves is used as land for new constructions. Mangroves are indispensable ecosystems to the equilibrium of the tropical coast and their destruction will have consequences on other associated ecosystems.

6.8 Source

Bythell, J.C, 2001. Master of Science Course in Tropical Coastal Management, Newcastle-upon-Tyne, UK.

Clubb, G, 2001. FRONTIER lectures

A guide to the seashores of Eastern Africa, 1995. Ed. Matthew D. Richmond

7 SEAGRASS

7.1 General biology of seagrasses

Seagrass are the only terrestrial plant (angiosperms) which are found and live their entire life cycle in a purely marine subtidal and intertidal environment (mangroves develop in intertidal zones). There are 50 species of seagrass in the world. They can be found from the Antarctic to tropical regions. Only seven of the 12 families are found in tropical regions. *Cymodocea, Halodule, Syringodium, Thalassodendron* (Patamogetonaceae), *Enhalus, Halophila, Thalassia* (Hydrocharitaceae).

7.2 Morphology

Most species of seagrass resemble grass from which their name is taken. From a management point of view, the important characteristics of this ecosystem are its capacity to capture and consolidate sediments due to the roots and rhizomes and to reduce the resuspension of sediments by waves and currents. Some species are better at it than others depending on the size of the plant and its leaves.

7.3 Conditions of development

Conditions for growth include: shallow, subtidal waters to a maximum of 20 metres, soft and fine soil to allow development of routes and shelter from wave action. However, for photosynthesis and therefore oxygen consummation a minimum of circulation of water is necessary. Presence of different species depends on the substratum, depth, temperature and solidity, leading to zonation. It is therefore necessary to realise that the presence of a particular species of seagrass in one area is due to the adaptation of the species to normal local conditions. For tropical regions this will be from 20 to 30°C and a salinity of 33‰. Some species can however, adapt to brackish water of estuaries. Seagrass play an important role in shallow waters where sediments are fine and soft. They are the best adapted organisms for such a substrate. The only other species to colonise fine sediment are certain green algae, such as halimeda, udotea, penicillus and caulerpa. However they are not as efficient as seagrass in consolidating the sediment. Through colonisation seagrass can change an environment which is not very productive and relatively uniform, which offers few shelters for the benthic fauna, into an ecosystem dominated by very productive plants with a high habitat diversity.

7.4 Physical properties

7.4.1 Rhizomes and roots

Seagrass stabilise the ground, reduce the resuspension of sediment in the water due to waves or current and reduce susceptibility to erosion.

7.4.2 Leaves

Reduce speed of water, wave action and help catch sediment. Dead leaves littering beaches stabilise sediment and are food sources for many types of organisms. This is why cleaning the beaches in front of hotels can cause an increase in the risk of erosion of beaches.

7.5 Productivity

Seagrass are a very productive ecosystem, they are as productive as the most intensive agriculture. However, it is important to differentiate between the standing crop (leaves and stems) and the total biomass of the plants (leaves, stem, rhizome and roots). For example, the proportion of each part depends on environmental conditions such as water movements, luminosity, or the type of sediments. In the Caribbean, high water movement characterised by settlement of large sediment. The seagrass will therefore need long rhizomes and roots to stay well anchored. Large sediments will also have fewer nutrients than fine ones. Plants will need a large surface of absorption at the root level. Fine sediments have a tendency to be anaerobic and will therefore be poor in oxygen, which will slow down root growth. Penetration of light in the water is also an influencing factor for the leaf/rhizome/root ratio. Primary production of seagrass can be very important, for example in the Philippines, some seagrass have a growth of 19mm per day. This same species replace all its leave in 16 weeks producing 2 to 4 harvests per year.

7.6 Animals living in seagrass

The leaves of seagrass represent a large surface for the colonisation of epiphytic organisms (red encrusting algae, cyanobacterias, diatomes) and epifauna (hydroides, bryozoides, foramminifere). Some species directly eat seagrass (dugongs, turtles, manatees) but most feed on organisms living on the seagrass leaves. Epiphyte productivity can be twice as much as that of the plants themselves. Seagrass represent shelter for juvenile reef fish, where they can find protection and food. Some reef fish will migrate daily between seagrass and the reef.

7.7 Importance of this ecosystem

It is interesting to look at the importance of seagrass from an economical point of view.

- They represent a shelter for post larvae and juveniles of many commercial fish such as groupers and rabbit fish.
- They represent shelter for adult commercial species such as rabbit fish, mogarra, and food for other commercial species such as emperors, snappers, grunts and parrotfish.
- They are the main habitat for certain species of commercial crayfish and lobsters. The destruction of seagrass in Florida had a major impact on the crayfish population *Penaeus duorarum*. The crayfish industry in Australia, which depends on the largest seagrass bed in the world, is worth 60 million dollars per year.
- They represent shelter for post larvae and juveniles of certain species of crayfish, lobsters, crabs, conch for example post larvae *Penaeus esculentus* and *P. semisulcatus* (both species most popular in Asia) live exclusively in seagrass beds.
- They consolidate sediment, attenuate wave energy and prevent erosion from coast. They protect coral reefs from sedimentation. The epiphytes and associated micro algae use nutrients from saltwater outputs and therefore reduce eutrophication phenomenon.
- They represent a direct source food for turtles (green turtle) dugongs, manatees and birds (Red head duck). It has been estimated that less than 10 per cent of seagrass is used for direct grazing of animals.
- They are traditionally used by local communities for basket weaving, salt production, or burning material, stuffing for mattresses, roof building material, fertiliser, fibre used for nitro cellulose and making nets.
- They are also used for more modern purposes – water filters, paper (Germany), chemical products, fertilisers and food (Phillippines and Kenya).

7.8 Are seagrass threatened?

They seem to be vulnerable to natural disturbances. For example a wasting disease in the 1930s has destroyed about 90 per cent of the Zotera along the East coast of North America and most of NW Europe. Seagrass have taken 30 years to recover. It is suspected that this is due to climate change. In Australia in Botany Bay 58 per cent of seagrass was destroyed between 1942 and 1984. A massive mortality of Thalassia in Florida is suspected to have been caused by eutrophication. Estimated drops in seagrass include: 30 to 50 per cent in SE Asia, the Phillippines and Thailand. Severe damage has also been observed in Singapore after being buried under litter.

7.9 What are these threats?

- Natural threats include: cyclones, tsunamis, global warming, climate change, exceptional low tides, intensive grazing by urchins or manatees, anthropogenic disturbance (e.g. sand extraction for building material or navigation).

- Clearing of seagrass beds for tourist attractions.
- Extension of land (Maldives)
- Eutrophication due to used water outputs from towns and agriculture, fertiliser, pesticides etc. The increase of nutrients will facilitate planktonic development of epiphytes and micro algae, which will increase water turbidity and reduce light penetration. Plants will not be able to photosynethesise.
- Sedimentation due to terrestrial erosion after bad management of soil and unsustainable agriculture.
- Destruction due to dynamite fishing, anchorage and propellers.
- Hot water outputs from thermal stations.
- Building piers, jettys, bridges, ports etc.

7.10 Source

Edwards, A., 2001. Master of Science Course in Tropical Coastal Management, Newcastle-upon-Tyne, UK.

A guide to the seashores of Eastern Africa, 1995. Ed. Matthew D. Richmond

8 INTERACTIONS BETWEEN DIFFERENT TROPICAL ECOSYSTEMS

8.1 Definitions

First of all it is necessary to define what is an ecosystem, many definitions have been suggested, here are two examples.

1. An ecosystem is an interactive and open system comprising more than one distinct community and a physical and chemical environment, which can be considered at any scale and in which transfers of matter and energy are continuous (Willis 1997).
2. An ecosystem is a functional unit, constituting many complex communities of plants, animals and micro-organisms and interactions with the non-living environment (UNEP 1998).

The position of an ecosystem in to a biological chain can be regarded as below:
Molecules → Cells → Tissues → Individuals → Population → Communities and habitats → Ecosystem → Coast.

8.2 Studies at the ecosystem scale.

An ecosystem is a productive system because its not static but dynamic and an integrated part of nature. It produces goods and services, and hosts many important processes. It is important to take into consideration, human factors because, humans are part of nature, with man having positive and negative impacts on ecosystems. These are factors that can be reasonably well controlled, as men are targets of management. It is often important to solve problems at the ecosytem level because some measures are more useful at the ecosystem rather than geographic scale. It is necessary to take into account the complexity of the natural system and its dynamics. Ecosystems represent a good unit scale for what will be the response to a management strategy. From a management perspective, all regions are not the same and will therefore need different approaches. The difficulties of studying at this scale include that: most data are static and taxonomically biased (e.g. funghi and bacteria are often forgotten), spatial and temporal information are linked and confused, validity of data is not verified, difficulties are encountered when defining limits to an ecosystem, the processes are complicated and therefore there is difficulty in measuring them and the definitions of ecosystems vary.

8.3 Ecosystems interactions

Food webs are the most useful way to study an ecosystem to understand factors that will influence and control it. Direct interactions in ecosystems include, competition for habitats, shelter and food. Interactions between ecosystems in a general way are anything which allows dispersion of a population e.g. seeds, migration in different stages of life for different animals, migration for reproduction, transfer of organic matter and transfer of nutrients.
Ecosystems in tropical regions such as mangroves, seagrass and coral reefs have well defined functions, each reliant on the others. Mangroves retain excess of fine sediments and absorb terrigenious nutrients. This stops transfer to reefs or seagrass beds, which are less tolerant, i.e. it is a buffer. Mangroves are buffer zones between land and water for salinity, as they regulate the fresh water output by evaporation systems, protecting corals from a high variation of salinity for which they are not tolerant. For example, no reefs exist at the mouth of fresh water sources without mangroves. Some species of fish have daily migrations between reefs and seagrass. Some organisms have life cycle migrations between mangroves, seagrass and reefs, e.g. some crustaceans are born in mangroves, migrate towards seagrass and finally reach the reef. Mangroves and seagrass play an important role in sediment and nutrient retention and are nurseries for post larval stages and juveniles. Seagrass trap sediments and nutrients, which corals cannot tolerate. Coral reefs physically protect seagrass and mangroves, by decreasing wave action and coastal erosion. Reef erosion also creates sediment for seagrass colonies in the lagoons.

8.4 Conclusions

These explanations are simplified views of the interactions that can exist between ecosystems. There is extensive research on sediment and nutrient transfers and water movement between different ecosystems, proving complex and tight links between them. This list gives an overall idea showing why it is necessary to integrate all ecosystems for management plans to be successful. It is useless to try and protect a reef without its associated ecosystems. Furthermore it is important to take into consideration a large region around the study zone, since physical distances can have large spatial effects.

8.5 Source

Bythell, J.C, 2001. Master of Science Course in Tropical Coastal Management, Newcastle-upon-Tyne, UK.

9 TECHNIQUES FOR SURVEYING AND MONITORING

9.1 Introduction

Study of coastal resources gives information on the distribution and abundance of plant and animal communities and populations. This information can be used to determine the health of an ecosystem and compare it to others at a local or global scale. First it is important to know that spatial variation in a marine ecosystem can be great. For example the structure of coral reef communities is remarkably different between the front and the back of the reef. It is important to have strong biological background to conceive an evaluation programme. For example does the behaviour of an animal change from day to day or month to month etc., do tides have an influence etc. This global understanding of ecosystems will help interpret observed variations. Coral reefs or mangroves will show less short term variation than more mobile communities or those with fast successive generations, which may vary daily or monthly. Fish can move in and out of the study zone instantly and the benthic populations can vary in a month, so different techniques adapted to each case are necessary.

9.2 Survey

It is impossible for any biological survey to observe an entire population, this is why it is necessary to examine samples of a population and extrapolate. Most statistical tests are based on the hypothesis that something is random although this seems simple it is not always easy to pick random samples. If a population is homogeneously distributed through a habitat a simple sample is enough to have a good estimation of an entire population. However, this is often not the case. There are different sampling techniques and it is important to choose the appropriate strategy according to the population. There are different steps to the development of a strategy.

9.2.1 Choosing a sample

A sample can be defined naturally like an individual or a leaf etc. or arbitrarily e.g. a quadrat or trap. It is essential to find a compromise between the number of samples to take within an area and the size of the area, e.g. quadrats. A sample can also be based in time e.g. if we look at the pollination of flowers and the number of times they are visited in a period of time.

9.2.2 Number of samples

Most of the time it is defined according to the amount of time and effort allocated to the study. The more time and labour, the more information can be collected. In general a large number of samples will increase precision. However, the number must not overtake the quality.

9.2.3 Choosing random samples

A good estimate of a population can only be obtained through a good random sampling. For example quadrats can be found from random longitudinal and latitudinal co-ordinates. This means the study area must be defined. This method is preferable to a pseudo random technique such as ‘random’ throwing of quadrats, which can be subjective. Another random technique is random walking or swimming for the marine environment where the direction is random for a random distance, then leave a quadrat. Random sampling can create errors for heterogeneous populations. To combat this the best method is stratified random sampling. The total area of study is split equally and the same number of samples are randomly positioned in each sub-area. It can be tempting to have systematic sampling, with samples at regular intervals, some ecologists use these methods and extrapolate to the total population, however this is not random.

9.2.4 Temporal factors in sampling

Most populations vary seasonally or daily or with local climate conditions. It is therefore necessary to take timing into account in the sampling strategy or later in the analysis.

9.3 Monitoring

Monitoring is necessary to detect changes and identify their causes. Most of the main coastal resources: coral reefs, mangroves, seagrass and benthic communities all show considerable spatial and temporal variation. Predictable environmental variations such as tides and seasons must be taken into account. There are also non-predictable events, such as cyclones, *Acanthaster plancii* breakouts or diseases. To identify human impacts it is necessary to distinguish them from natural impacts. Human impacts can be managed whereas natural events cannot. Strong disturbances such as cyclones have immediate visible effects on the ecosystem on the other hand many human impacts and some natural events such as pollution and climate change have slow chronic effects, which are harder to identify. The efficacy of monitoring studies can be improved with satellite images, which give a preview of the study region. These images coupled with well chosen sampling allow extrapolation with minimal error. For coastal vegetation such as mangroves or seagrass, changes of composition and density of populations can be identified from satellite images. However this technique is a lot more limited for coral reef studies as depth is difficult examine. It is necessary to keep a database of long-term monitoring as a high quantity of information can be used for future analysis and comparison. Data should be entered as soon as possible as if not the quality and consistency may be lost, effecting the entire database. A good design for a database will allow fast and efficient data entry so that the efforts in the field are not in vane.

To develop a long-term monitoring scheme, the first step is to know which question you want to answer, this will guide the choice of methods, sites and frequency of monitoring. Its important to choose a site to be representative and not for its proximity or good conditions. Good quality sites can on the other hand be used as controls to identify anthropogenic impacts. Choosing any site has to be done after preliminary studies in the area. The number of chosen sites will be a compromise between collecting the most information and time and labour. Quantitative tropical ecology has been developed in an era where general thinking said that ecosystems where in equilibrium, stabilised by the competition for limited resources, returning to equilibrium after natural perturbation. In the last 20years scientific studies have shown that the frequency of natural perturbation was higher than the ecosystem capacity to recover and therefore environmental changes took place. With such rapid changes, short-term studies gave wrong conclusions. This is why data collected over a long period of time are better for identifying natural variation. These long-term studies also inform us of anthropogenic impacts. Today it is globally recognised that ecosystems are dynamic and constantly changing. Studies which have goals to answer questions on processes controlling changes are important to be able to react pre-emptively. Today’s research programmes will answer what are the changes and what are the extent of these changes? How long do these changes take and what causes and processes regulate those changes?
Monitoring programmes are organised following these steps.

- Determine objectives and decide which questions you want to answer.
- Decide at which scale you want to work.
- Identify principal sources of variation.
- Decide which factors are important and measurable. A preliminary visit to the study site can be useful for this decision.
- Formulate a plan with enough replication.
- Plan the programme with a pilot study, where as much information as possible is collected.
- Consider how to enter and stock data.
- Prepare a database.
- Decide who will undertake the monitoring.

9.3.1 Objectives of monitoring programme

The questions being asked and the time limit research, so limitations must be borne in mind. A rule for an effective monitoring programme is that it is better to have a monitoring programme, which only asks certain questions in a limited region. These can then be replicated each year. A programme asking too many questions in a large area with few replications is not good, as it may not be sustainable. A compromise must be found as to the scale of the programme, with regards to spatial and temporal scales. During the planning process it is important to discuss the aims and objectives with all concerned.

9.3.2 The importance of replication

Marine tropical ecosystems are very complex systems, so one survey will not necessarily give an accurate picture. Replication will improve the accuracy of the work, however pseudo-replication must be avoided, for example, replicate counts over the same transect are not separate replicates.

9.4 Pilot studies

A pilot study allows various questions to be examined and allows the identification of potential sources of variation and planning of the programme. At the end of the pilot study questions can be resolved such as:

- Best compromise between the ideal project and the reality of logistical constraints?
- Which plan is the most appropriate?
- The most appropriate size of the study?
- Is the study repeatable (are sites easily relocateable and will it be the same personnel)?
- Will those chosen for the work provide good quality results?
- What changes will the project be able to detect?
- Will the detected changes fulfil the objectives? If not then these must be changed.

The pilot study also allows identification of logistical problems and considerations and the conditions of the site.

9.5 Source

Dytham, C., 1999. Choosing and using statistics, A Biologist's Guide. Ed. Blackwell Science Ltd, Oxford.

10 UTILISATOIN OF SATELITE IMAGES AND GIS FOR EVALUATION OF RESOURCES AND THE MANAGEMENT OF THE COASTS.

10.1 Satellite images

10.1.1 What are satellite images?

Satellite images are digital images, the result of electromagnetic radiation (EMR) reflected or emitted by the terrain and read by orbiting satellites. EMR is very high energy radiation described by its long wavelength (455-492λ) and frequency (radio). For coastal management, the bands of interest are the visible, the near infra-red, infra-red and radar. The first two bands measure the reflected light from the earth's surface, the infra-red, the reflected heat. These are called passive radiation, as the source is the sun. In the microwaves (radar) this is a measure of received echoes and is therefore active radiation. The atmosphere only lets the visible radiation pass if there are no clouds. On top of this, water vapour, carbon dioxide, ozone and other atmospheric molecules absorb and reflect EMR, especially in the infra-red. The best satellites can be used to resolve the littoral zone at a spatial resolution of 1-80m. The resolution is affected by the size of pixels in that image.

10.2 Spectral resolution

Spectral resolution is monochrome to around 16 bands of frequency, which can be programmed for particular uses. For each pixel the quantity of light reflected in blue green and red bands is recorded by the detectors a digital number. This is usually between 1 and 255 with 0 as no detection (black) and 255 as maximum (white). A lot of satellites use the same level of brightness but some use 64 or 1024. The advantage of a digital image is that it objectively defines the characteristics of different habitats and analyses the image by computer. A computer can be used to classify pixels and map to the habitats. One habitat however, can be represented by more than one pixel value, which renders classification difficult, which will have to be man assisted.

10.3 Treatment of images

Unfortunately once the image is acquired, it cannot be used directly but you need to use a series of treatments. Geometric and bathymetric correction, radiometric normalisation and geometric correction for deformation due to altitude and capture variation are all necessary. These corrections are usually made before sale of an image. There are other corrections to be made as well, including: radiometric correction, for example the lighting depends on the day, the time and the place on earth, therefore to be able to compare to another area on another day, corrections are necessary. Water depth and reflection must also be corrected for.

10.4 Using satellite images

Maps of habitats derived from using remote sensing have become increasingly used for evaluating the status of coastal resources and to base management plans and surveys. Nowadays the most demanded use is for databases to help in management plan decisions and temporal detection of habitat changes. However, from questionnaires it appears that managers ask too much from this technology when dealing with seagrass and coral reefs. On the other hand for mangroves, this tool is very efficient in identifying habitat boundaries, density and even species. The cost of a satellite image varies from 2,500,000 FMG for low resolution 80m per pixel ($35km^2$) to 800,000,000 FMG for a higher resolution image 3m pixel size ($12,000km^2$). Satellite images are often falsely considered as an alternative to field work. Satellite images should compliment field work to make it most cost effective.
The different utilisations of satellite images are for:

- Mapping
- Resource inventory

- Monitoring changes
- Environmental survey
- Mapping sensitive environment
- Mapping management zone boundaries
- Mapping marine grounds
- Field study planning
- Measuring productivity
- Evaluating stocks (in two stages, identify habitats and find those with animals or resources then extrapolate)
- Help aquaculture management
- Detect geomorphological and erosion changes
- Identify water movement and circulation such as sediment plumes

10.5 How do you use these images

First you must classify images, there are three different ways:
1. Photo interpretation, which is visual identification of different habitats, based on colours, textures, tones and contexts. It can give detailed information on nature and distribution of habitats.
2. Unsupervised classification of multispectral images, which is computer image treatment without human intervention. This produces low precision maps with a certain margin of error as the computer decides which pixels correspond to which habitats.
3. Supervised classification, which is the most precise solution. Field studies are undertaken to correlate with spectral signatures of the images and later extrapolate to the rest of the image. Before going to the field survey zones are identified to get pixel correspondence. Then the computer is programmed as to which pixel corresponds to which habitat for further correlation.

There are different procedures for different habitats, for example different numbers of samples. These techniques are very effective for mangroves and effective for seagrass. They are less useful for coral reefs due to the effects of the water column.
These techniques represent a gain of time and money for managers, however specialists are needed for the image treatment and experience in the analysis and exploitation is useful.

10.6 GIS geographic information systems

10.6.1 what is GIS

Data representing reality can be stored and treated and re-used in a simplified form. Geographical information helps compare different surfaces and identify specific conditions. GIS is a decision making tool. It allows geographical data to be transformed to compacted digital data, computerised analysis to look at trends and combine data of different types and assignation of optimum sites. It also allows for the prediction of results and consequences of different scenarios. Finally data can be put into a map table and number format. The advantage of GIS is that data storage and data representation are separated therefore they are more workable and can be represented in different ways. Different data sets can be easily superimposed to look for relationships. It allows better management decisions. GIS allows for a more detailed treatment than most other systems. GIS programmes can treat data from different sources, maps, satellite images, aerial photographs, statistical data, archives and photos etc.

10.6.2 Two different GIS models

10.6.2.1 Vector data model

This system is based on the hypothesis that the real world can be divided into specific elements such as geometrical forms. An object contour is defined by a number of points which can be linked and hold information. Lines and polygons are harder to transform into data points due to the variation in number of points in each object.

10.6.2.2 Raster data model.

This involves the scanning of digital images from an existing map and compilation of a satellite images and data. This model is based on a pixel system where an object is a combination of several pixels. The problem with this is that one pixel can contain two different overlapping sets of information. Usually a pixel will take the value of the greater percentage cover. Raster data are stocked as matrices and can be switched to the vector system.

10.6.2.3 Example

What is the best site for aquaculture in a certain region?

- The farm will have to be placed where salinity is between 20-25%.
- It must not exposed to waves.
- There must be available land to buy.
- It must not be protected
- It must not be polluted
- It needs close roads for transport

By superimposing the different possible zones, considering the different characteristics for the farm the best localisation can be found.

10.7 Source

Green, E.P., 2000. Remote sensing Handbook for Tropical Coastal Management. Ed. Edwards A.J. Pub.UNESCO, Paris

11 IMPACTS OF HUMAN ACTIVITIES ON COASTAL AND MARINE ECOSYSTEMS.

11.1 The mangroves

The ecological, environmental and socio-economic importance of mangroves is largely recognised by different international agencies for example, governmental agencies, NGOs and the scientific and local communities. Mangroves are exploited in a variety of ways by man, nevertheless their value is more than a simple sum of their resources. One must add their services, that is their indirect value to man. Mangrove have received a lot of attention due to the critical situation of fisheries and the many publications on the negative impacts of shrimp farming. This has lead to a new management strategy, which integrates all levels of activities and indirect impacts of deforestation. Due to their intertidal position, the management of these forests is divided between forest departments and fisheries departments, or is included in urban development plans. This has lead to confusion and conflicts between the different users and increased pressure on the ecosystem.

11.1.1 Destruction of mangroves

Man has been exploiting mangroves for their short-term benefits. This is a very intensive and very destructive practice, which has lead to massive degradation of this ecosystem. Overexploitation through traditional uses e.g.

- clearcutting for wood
- clearcutting to use the land for agriculture, salt production, aquaculture
- activities which indirectly use mangroves but have negative impacts such as building port, factories, and other types of development
- transforming mangroves through other activities such as irrigation systems, digging channels etc., which transform the hydrodynamics of the region, pollute the coastal environment, and deviate watercourses
- charcoal production, especially Rhizophora, which burn slowly. In Vietnam, 90% of fuel is from mangrove wood.
- Chipping to produce chipboard.

The intensity of these different pressures vary from one mangrove to another and can act simultaneously. Mangroves in the Golf of Thailand in the province of the Samu Sakhorn and Samu Songkram are typical examples. Mangroves have nearly completely disappeared in these provinces while very abundant a few years ago. They were mainly used as fishing grounds and for wood. The most inland were cut and replaced by salt water pools for salt production. During the wet season, these were also used for shrimp farming. This rotation was used since 1930 and was economically successful. In 1980, intensive shrimp aquaculture contributed to the clear cutting of the rest of the mangroves. Nearly all investors were foreign and the local population was excluded from the market. In 1989 all the shrimp farms collapsed due to the high pressures on the environment. These farms left unproductive land, only to be replaced by urban development or factories.
Guatemala is another example of massive destruction of mangroves. Through charcoal extraction and production of dyes, combined with indirect impact from pollution due to sediments and pesticides, 92% of the mangroves are estimated to have disappeared since 1950. In Costa Rica, 40% of the mangroves have been destroyed since 1979 due to the production of dyes, aquaculture, salt production and coastal development. Finally the mangroves in the Caribbean suffer from coastal development, especially toursitic infrastructures.

11.1.2 By-products

By-products include:

- honey
- grazing (zebu and camels)
- hunting, which can include poaching of rare species for curio markets.

11.1.3 Agriculture and production of salt

In Asia, a large area of mangroves were cut for rice paddies, coconut trees plantations, pineapple and palm oil culture. However the soil quickly becomes acidic and the production drops rapidly. The land is then abandoned, due to its acidity, toxicity in iron and aluminium and poor nutrients. It is also frequent that rice paddies suffer from saltwater intrusion. This is frequent in Vietnam due to typhoons and high waves, which inundate the land. Other indirect effects, not as noticeable as direct loss of habitat, are the change of water flow for irrigation, or chemical dumping from agriculture. In many regions in Asia with a dry season, mangroves are clear cut for the production of salt. The same ponds can be used as shrimp farming during the wet season.

11.1.4 Coastal development

In addition to the physical loss of mangroves due to the industrialisation of the coasts and demographic pressures, pollution from development has important impacts. For example between 1974 and 1990, there has been 157 major oil spill in tropical seas. It takes more than 20 years for intertidal habitats such as mangrove to recover from such incidents.

11.1.5 Aquaculture

For the past 20 years, the biggest threat to mangroves has been the rapid increase of aquaculture. The primary objective of these farms is profit and not feeding local populations. This is causing a conflict between the needs of growing local communities and the constant needs of the farms to expand and impacts on surrounding environments. These farms bring little or no financial support to the local communities and are the cause of social tension. Typically farms are in inhospitable areas, which are viewed as public land and can therefore be easily bought by foreign investors. They then bring in a workforce and the locals are left with no land, no resources and no jobs. All aquaculture activities have an impact on the environment. Algae and shellfish farms require a large amount of space, in conflict with fishing and navigation. They decrease resources through collection of larvae and cause the destruction of humid zones. Discarded nutrients, anti-biotics, other chemicals and organic matter and the introduction of exotic species all have effects. Farms can cause an increase of pathogens in the natural environment, a decrease of fresh water due to excessive use, salinisation of fresh water sources, increase of sedimentation, decrease of dissolved oxygen and an increase in biological and chemical demand for oxygen.

With so many risks of major environmental impacts, it is necessary to establish integrated management plans to avoid negative impacts from one activity to another.

There are 3 types of aquaculture: intensive, semi-intensive and extensive. Semi-intensive is the most sustainable, but still requires large quantities of fresh water, rich in nutrients, cereals and fish and larvae. Most have open systems, taking directly what they need from nature, using it and discarding it back into the natural environment with no recycling. This results in an accumulation of detritus in the surrounding ecosystem.

11.2 Seagrass

Seagrass beds are an indispensable ecosystem for the equilibrium of the tropical coast. Their value has not always been recognised and large areas of seagrass beds have already disappeared.

11.2.1 Anthropogenic impacts

These include:

- coastal pollution from cities and factories
- destruction of reefs (e.g. for coral mining) increasing wave action
- sedimentation due to upstream clearcutting and erosion of soil
- overexploitation of fish causing a loss of equilibrium
- direct destruction through development of infrastructures
- channel dredging for ports etc..
- oil spills

These threats lead to loss of habitat. There can also be large and secondary effects such as decrease in fisheries, beach erosion, mortality or migration of animals (dugongs, turtles, birds), major hydrodynamic changes, transfer of organic matter and sedimentation. Destruction of seagrass leaves a non-productive, poor environment. Seagrass beds can be replanted if there are some individuals left to provide seeds and habitats not regularly disturbed. In Australia, loss of seagrass is associated with coastal development. Seagrass move naturally due to slow changes in external environmental factors. It is necessary to distinguish between human impacts and natural environmental changes to find causes of degradation and apply correct management strategies. Replanting seagrass is one of the techniques used for seagrass bed rehabilitation. This usually involves a compromise between replanting enough for survival of a colony and cost. This type of management is very expensive and isn't always successful. It doesn't resolve the cause of the problem but only manages the outcome, which is usually short-term solution.

11.3 Coral reefs

Coral reefs are a highly productive ecosystem, which are rich in biodiversity and represent a primary economic resource for local communities. This leaves them subject to the pressures of rising coastal populations.

11.3.1 Threats

Threats include:
- direct consumption of resources
- overexploitation
- use of destructive methods of fishing (e.g. nets, explosives, poison)
- indirect exploitation of the reef
- channel dredging for navigation,
- reclamation for development.
- indirect impacts through pollution, oil spills and erosion

The destruction of reefs can be reduced to the goods and services represented by the existence of reefs. For example the loss of this habitat could engender an increase in coastal erosion, a loss of tourism and the decrease of fish stocks.

11.3.2 Identifying threats

It is important to understand the dynamics of the ecosystem in order to distinguish between anthropogenic and natural impacts. Coral reefs are subjected to biological and physical disturbances. These often occur over a large time scale and over a large area making them difficult to study. Cyclones for example are violent, fast phenomenon, which have impressive impacts on reefs. They are however necessary for the regeneration of coral. The problem with anthropological impacts is that their effects are added to these natural impacts. They are also often continuous and do not allow recovery.

11.3.3 In Madagascar, Toliara

In the Toliara region, human impacts on coral reefs have increased since 1960s. Especially on the Grand Recif, signs of degradation: bleaching, overgrowth of algae and urchin outbreaks are visible. This is related to the high levels of sedimentation from erosion of soils and urban pollution, overexploitation of resources (gleaning, fishing). Problems on this reef include:
- bleaching and mortality of branching corals
- colonisation of 90% of the reef slope by soft coral
- proliferation of brown algae during dry season and green algae during wet season
- urchin outbreaks
- increase of coral debris
- increase of turbidity,
- deposit of detritus due to over sedimentation due to deforestation upstream of the Onilahy River.

11.4 Management

Management can include:

- coral transplantation, similar to seagrass transplantation and very expensive
- increase existing regulation and review it
- sensitisation of primary stakeholders
- control of destructive fishing practices
- control of access to fishing areas
- control of collectors and species sold
- creation of an MPA for regeneration of species

These measures have proved successful in other regions of the world. In the particular case of Toliara and Madagascar it is necessary to propose economic alternatives before imposing restrictions and rules on the local population, who live almost exclusively of the sea. These could include artisanal aquaculture (fish or algae), ecotourism, artificial habitats for squids etc.

11.5 Source

Edwards, A., 2001. Master of Science Course in Tropical Coastal Management, Newcastle-upon-Tyne, UK.

Macintosh, M.and Zisman, S., 2001. The Status of Mangrove Ecosystems: Trends in the utilisation and management of mangrove resources. 28pp.

Vasseur, P., 1997. Milieux et Sociétés dans le Sud-Ouest de Madagascar. *Ecosystèmes côtiers en danger dans la région de Tuléar: Analyse des agressions humaines et problèmes de gestion*. Collections “Iles et Archipels”. Ed. Centre de Recherches sur les Espaces Tropicaux de l’Université Michel de Montaigne – Bordeaux 3.

12 ESTIMATING MAXIMUM CAPTURES FOR SUSTAINABLE EXPLOITATION

A fisheries manager first considers what is the maximum catch without affecting reproduction and recruitment of future stock. This is the Maximum Sustainable Yield (MSY). The MSY and effort per catch were the basis for sustainable fisheries management. Since 1970s, management has considered other factors such as distribution of resources, economic efficiency and protection of the environment. If the intensity of fishing passes a critical value, the ecological balance (reproduction/recruitment + growth = natural mortality + fisheries mortality), it will no longer be in equilibrium. This can happen two ways. First, juveniles entering fisheries are captured before reaching a commercially acceptable size (growth overfishing). Secondly, and most importantly, adult socks are reduced to a level where there are not enough individuals to insure stock regeneration (recruiting overexploiation). We will describe estimates of optimal catches for a sustainable exploitation through scientific methods. However, even in the absence of exploitation, a stock can show variations due to natural phenomenon, which are not yet fully understood and therefore the calculation of a single figure is not appropriate.

12.1 Surplus yield model

In a non-exploited stock the competition for resources such as food and space result in an equilibrium between recruitment and natural mortality. When the stock is exploited, the competition is reduced and the number of recruits augmented. On top of this, the larger more fecund individuals are eliminated so the smaller fish can quickly gain access to other resources. These processes allow for an increase in surplus fishable stock (recruitment + growth – mortality = surplus.

This model is based on the hypothesis that growth rate correlates with biomass. If catches are under the surplus yield, the stock biomass increases. If captures are higher than surplus, stock biomass decreases. If a species is introduces in a new environment, its biomass will increase until the environment reaches its maximum capacity to support this new population. The Shaeffer model assumes that an S shaped graph where the rate of biomass increase is maximal when total biomass of stock is at 50% can describe the increase in biomass of a stock with time. This suggests that if a stock is to be exploited, its productivity will be maximal when stock is at 50% total biomass.

In practice, the model approach uses of a series of data of catch and fishing effort data over a period of a few years. It assumes that conditions are in equilibrium. The CPUE are linear functions for the model:

CPUE=a+bf
a and b can be found with collected data and by estimating the best fit curve (regression line). From there the capture curve against effort can be evaluated $Y= af+bf^2$ which should be verified by the collected data (Y is a parabolic function of fishing effort).

The most recent models integrate different growth equations, which directly influence the MSY. The Fox model for example uses an asymmetrical curve compared. The CPUE/effort is no longer a straight line but a parabolic curve which can be converted into a straight line by a natural logarithmic transformation. The Fox model gives a better correlation with field data. For fisheries that target more than one species, we can use the Shaeffer model. The total capture for these three species for example is the sum of the different stocks.

At an effort rate where the curve of the sum of stocks is at its max, species A is overexploited, species B is at its max and C is underexploited. In tropical regions where catches are multi-species, to treat these different species as one stock and manage it for a maximum economic benefit can sometimes be the only option. The surplus yield model has widely been use in fisheries management because it is based only on catches and effort data, which are easy to collect. The most important disadvantage of this model is that it ignores the biological processes (growth, recruitment, mortality etc.) that affect stock biomass. The proportion of the stock that can be exploited is related to fecundity and life span (stock and recruitment), which are factors that are often not taken into account. The maximum catch concept for sustainable exploitation will not fit the case of species with short life spans and high fecundity or when stock is directly linked to recruitment, which varies with years and environmental changes. Finally equilibrium in stock does not take into account that exploitation in itself will change age classes of the population.

12.2 Maximum economic yield

Economical variations can be taken into account in the Shaeffer model and this allows relationships between a sustainable revenue, fishing costs and fishing efforts to be displayed. Economic variations can be displayed by multiplying the weight of captures by price of product. Can then show a capture against effort graph. The cost curve cuts the catch curve as a function of the effort at an economic level where catch profits balance out costs of fishing. Higher effort fisheries lose money. The point where profits are highest is the maximum economic yield (MEY) and is at an effort slightly higher than MSY.

12.3 Catch per recruitment model

This model consists of finding a compromise between catching many small immature fish and a few large mature ones. The classic model considers stock regulation through growth, age of catch and mortality due to fishing.
The hypothesis is that after average age of catch t_0 the probability P of being caught of all individuals is equal. Rate of natural mortality M is the same after age of recruitment. Rate of fishing mortality F is constant after age of first recruitment. The number of individuals at different stages of their lives can be calculated from these three factors.

The problem with this model is that it considers the system as stable and constant when stock exploitation increases, proportion of number of individuals in each age group and biological parameters of stock change. Not taking into account recruitment (divide yield by recruitment, which eliminates this factor on both side of the equation) does not allow this model to give any information on level of recruitment overexploitation. In practice, this model only works for species with low natural mortality rate (<0.5). If mortality rate is high, often the case for tropical species, the maximum catch is at a very high fishing effort, tending towards unlimited.

It is also important to note that fishing effort for a maximum capture estimated here can be different to that for maximum catch for MSY. In many fisheries of short life cycle species, the hypotheses of constant recruitment is false when exploitation increases. If age of 1st catch is lower than age of maturity, there is no recruitment at a high rate of fishing. If age of catch is higher than maturity, but exploitation is too high, recruitment will be insufficient for sustainability. Critical reproductive biomass is difficult to estimate, but is around 20 to 50% of total biomass of a non-exploited stock. This model has evolved to take into account seasonal variations of growth. Also it is possible to estimate recruitment and have a direct value of stock as opposed to a stock value estimated through catch data.

12.4 Biomass model

One of most simple models for overexploitation of biomass is to look at opposed effects of growth and mortality on biomass of a single age group (cohort) in a period of time. After recruitment, total biomass of cohort increases with growth and decreases with mortality. Max biomass reaches a critical value before decreasing with growth. Rate of survival also decreases. Average size and weight for each year of a single species can easily be calculated. The % survival is based on constant mortality rate after year 2. Although this model can be used to estimate age at which a species should be exploited to get maximum biomass, its use is limited because it is only valid for a single cohort. The model is best for species for short life cycles such as crustaceans or some fish where fisheries are based on a single cohort. It is possible to add the price of species or biovalue (biomass*price). Biomass curve is different than biovalue for shrimps for example, where value changes with size and not only weight. For shrimps maximum biovalue is for higher age than maximum biomass.

12.5 Evaluation and monitoring fisheries

The goal of estimating a stock is to establish status of the resource and define levels of sustainable exploitation to propose an adaptable management plan. After collecting baseline data, it is necessary to monitor resources and evaluate efficiency of management plans.

12.5.1 Questions:

- Is catch rate high enough to justify commercial development?
- If yes what is the level, which will allow sustainable exploitation?
- What is the market value of the product and can it cover fishing costs?
- If yes at what level of exploitation will it make profit?

12.5.2 To answer, data is required on the following:

- composition of catch
- distribution of stock
- abundance of stock
- biology of the species
- the environment
- the stock value

12.5.3 Catch composition, distribution and abundance

For data on abundance and spatial and temporal distribution of stock samples at different intervals are required. For geographical distribution it is necessary to sample on the largest surface possible and at different depths. If species are migratory species, it is necessary to sample at regular intervals to see differences in seasons.

12.5.4 Biological data

To estimate the level of exploitation it is necessary to measure:

- growth rate of the species
- mortality rates
- the size of the stock
- reproduction period
- recruitment rates
- length, frequency and CPUE are the most commonly used

Data should be collected through regular sampling with standardised methods. If catch is too large to analyse all individuals (sex, number, weight, size) a sample should be examined.

12.5.5 Environmental parameters

It is important to understand variation of distribution and abundance etc. Factors that can be examined at low cost include:

- salinity
- state of sea
- temperature

Other parameters such as temperature/ salinity profiles with depth are more expensive.

12.6 Stock value

This is often ignored, but is what manages the industry. Analysis of costs and benefits can define feasibility of a fishery.

12.7 How to collect data

Different techniques include questionnaires, direct sampling and observation. It is important to know what data are required before work commences. Data can include:

- Length and frequency data, which is useful for stock distribution. A few individuals per age cohort are required to evaluate different growth parameters.
- Capture and effort and CPUE. For industrial measurements, logbooks are efficient. If questionnaires are too complicated and long to fill in they will not be completed. CPUE measurements show changes in abundance of stocks. However, they are bad indicators of actual stocks. Problems are encountered where efficiency of methods change, and measurements must be readjusted to take this into account. If not, overestimation of MSY and fisheries decline can occur.
- Effort is easier to measure as total number of boats than number of hours spent fishing or number of lines used per boat. However, these are all effective at the right scale.
- Spatial distribution must be taken into account as CPUE can remain the same while stocks are depleted from different areas.
- Multispecies fisheries are difficult to manage and must be treated carefully, as catch of dominant species can hide the decline of others.

12.8 Source

King, M., 1995. Fisheries biology, assessment and management. Ed, Blackwell Science Ltd, Fishing Books News. Oxford.

13 IMPACTS OF EXPLOITATION OF MARINE AND COASTAL RESOURCES

13.1 Introduction

Marine and coastal natural resources are valuable goods. Artisanal fisheries of developing countries provide major income and important protein sources for coastal populations. At a global scale, fishing has developed at a significant rate since the Second World War. From 1945 catches have grown consistently, for example 17.7 million tonnes in 1985 to 85 million tonnes in 1990. However targeted species have changed from big species with high economic value to small pelagic species with less value. Since the 1980s there have been signs of overexploitation. Countries started to realise the need to protect non-target species in danger like dolphins caught in tuna nets. More recently, conferences and codes relating to fisheries have included the 1992 International Conference on Responsible Fishing in Cancun, Mexico and an elaboration of the FAO code of conduct for responsible fisheries in 1996.

13.2 Actual state of fisheries

The FAO has developed a classification regarding under-exploited and overexploited stocks. It is a slow and difficult process of classification. There are two different types of overexploitation, recruitment and growth. Recruitment overexploitation is when a number of new adults cannot renew stock. This applies especially to small pelagic populations which form large aggregations, which can easily be detected and caught in large quantities even if stock are low. Other sensitive groups include those with low reproductive capacity such as turtles, marine mammals, and elasmobranchs. These all face a high risk of extinction. Growth overexploitation is the fishing of immature individuals, biomass is not optimal.

Coastal population increase is most important on coastal regions with coral reefs. It is expected that coastal population may double in the next 30 to 50 years. In the 1993 meeting on coral reefs overexploitation was one of three threats for this ecosystem. It was suggested that in regions where income is low there need to be an increase in sustainable use of the sea.

13.3 Reef fisheries

There are different types of reef fisheries, these can be divided into 3 groups:

1. Coral reefs under relatively low pressure with a presence of big fish that are easy to catch. These large species with a high economical value need to be protected. This is the strategy used by the Great Barrier Reef Marine Park Authority in Australia. Additionally it also keeps a high rate of tourists attracted.
2. Coral reefs under more pressure with large, rare individuals. There is a tendency to fish species with small economical value, for example parrotfish, wrasses, and rabbitfish. Fisheries target adults and sub-adults and this leads to overexploitation of the ecosystem.
3. High anthropogenical pressure due to high population. There is an absence of alternatives and fisheries no longer make money. A loss of equilibrium in the ecosystem results and there is a change in structure towards an algae dominated reef.

13.4 Artisanal fisheries

An example is Madagascar. The coastal population has increased and in 20 years there are double the number of fishermen. In Anakao, Southwest Madagascar, there were only 30 to 50 huts to be found in the 1930's. In the 1990's there were more than 3000 inhabitants in the village, which includes over 450 fishermen, and 500 fishermen in the neighbouring village of Soalara. This increase leads to more pressure on stocks and fishermen have noted a decrease in catches and size. Overexploitation is accompanied by a change in fishing methods and abandoning traditional nets for small nets, seines, and mosquito nets.

13.5 Commercial fisheries

There has been a significant development in the market for fished products. An increase of demand is related to better standards of living in developed countries. Change in tastes and evolution has occurred and fish is no longer considered the meat of the poor but a good quality product. Fishing activity follows demand and there has been an investment in better equipment to increase the quality of product. Development of fishing techniques, for example use of radar has increased the catch but for how long? Already many fisheries have collapsed.

13.6 Threats

There have been direct and indirect impacts on fishing of the coastal and marine environment. Overexploitation is a major problem. If fisheries collapse it can affect the economy of the entire country. Additionally there are considerable secondary effects, which can affect other activities.

13.7 Direct effects on targeted species

The main objective of fisheries is to reach the maximum sustainable yield by increasing effort. To determine this critical point, one must go beyond it, then revert to a smaller level of effort. From past experience it is very difficult to go backwards and reduce fishing efforts. Unpredictable environmental factors can result in a major decline if stocks are threatened. Fisheries target big individuals and this therefore changes the structure of the population. Low fecundity, late maturing species become highly susceptible. In reef fish, many species change sex according to age thus fishing can significantly affect the sex ratio of a population, and reduce reproductive potential. It also has an effect on the genetic diversity of species by constantly targeting the largest and oldest individuals of a population and subsequently you get a loss of genetic information.

13.8 Non targeted species: by-catch

Most fisheries are non-selective and create an enormous amount of by-catch. It is difficult to estimate the exact quantity, but it is has been estimated at well over 10% of the total catch. The FAO estimates that a quarter of total catches approximately 25-29 million tonnes are thrown back dead into the sea. For example studies on shrimps and bottom fish show 27 million tonnes of by-catch for 77 million tons of catch. There is a Maximum by-catch of 39.5 million tonnes, and a minimum by-catch of 17.9 million tonnes. There is however, great variation from one year to another. With regard to species captures it is marine mammals and birds which have caught most of the public attention. A major part of the biomass thrown back are the non targeted species. Better management, new fishing methods, and better resource management is needed. It represents a considerable amount of proteins lost, which could be a solution for a growing population. An example is the shrimping boats of Northwest Madagascar. For every kilogram of shrimps five to ten kilograms of fish are lost. In the 1970s and 80s they circled dolphins by nets because it was known that their presence indicated the presence of tuna. One million dolphins per year were killed. The practice was banned and only 5,000 dolphins are caught each year with the new nets.

13.9 Modification and destruction of habitat (direct)

The worst destruction is caused by the trawlers. In the North sea it is estimated that each 1m² of sea bottom is trawled 7 times per year, digging into it down to 7 cm. The vulnerability of organisms to trawling is dependant on their size, fragility and depth of habitat. Species forming reefs such as corals or calcareous incrusting algae have a very high vulnerability. Benthic species which stabilise substrate such as seagrass are also highly vulnerable. The ICES group recognises that trawling activities result in long term effects. In Germany for example, a study based on 60 years of observation shows a change in composition of species and abundance of benthic communities. Species with slow development and slow rate of reproduction have been replaced with species with fast development, that is pioneer species. The diversity of molluscs and crustaceans has decreased, and the diversity of polychaete worms has increased. Populations of the fish, e.g. sole have also increased because they feed on polychaete worms. This can be interesting since soles are high value species, however a precautionary approach should be taken and conclusions not drawn quickly on such an unbalanced system.

13.10 Indirect effects of overfishing

A fishery managers knows that overexploitation has effects along the food web through predation and competition. It is difficult to separate fishing impact and natural events. There are no control sites where there is no fishing, and therefore these cannot be compared.

13.11 Effect on community structure

There is a change of structure through removal of keystone species and physical change of habitat. For example a change in the food web in Kenya, removal of the urchin predator (i.e. finfish) led to an increase in urchins which led to an increase in bioerosion, this effects the rugosity and there is a shift in the ecosystem equilibrium.

13.12 Effect on large predators: marine mammals and birds

Birds and mammals eat fish and shellfish. They are affected by fisheries if stocks are very low. Competition for resources between man and these species can affect the reproduction of some species of bird due to the reduction of available food source. By-catch of non targeted species can cause a change of structure and diversity of the population through discard of by-catch which favours scavengers, and species such as sharks, rays, dolphins, crabs and birds.

13.13 Effects due to loss of fishing gear (ghost fishing)

Ghost nets are nets that continue fishing long after being lost. They drift and fish species, marine mammals and birds all get caught depending on the time and speed of drift. Once the net has become full of algae it sinks and is less harmful, but can often be full of dead animals by that stage. Artisanal fishing is less likely to cause such problems.

13.14 Source

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14 DESTRUCTIVE FISHING METHODS AND AQUACUTURE

The main activities of coastal communities are based on fishing. There are many fishing methods, some are more destructive than others. Other problems include that many locals prefer to buy small fish as they are cheaper.

14.1 What are the destructive methods?

They are usually used by the *mpihake* which are mainly gleaners.
These include:

- Spearfishing,
- Dynamite
- Speargun
- Poison (*Laro*, Euphorbidae)
- Small mesh nets and beach seines collect very small fish, juveniles and post-larvals

14.2 Collecting seashells

Seashell collectors disturb and damage the reef and associated habitats (e.g. seagrass) by walking on it. They particularly affect corals when they are lifted to find anything underneath. Collecting the shells themselves leads to a loss of equilibrium for example through the collection of Triton's trumpet, one of the predators of *A. plancii*.

14.3 Collecting blocks of corals

Coral is used as a building material and is often harvested in vast quantities.

14.4 Destruction of mangroves for aquaculture

Mangroves are a very important habitat for the reproduction of species (nursery) and are threatened by coastal communities for many reasons including aquaculture. Sensitisation work is required to explain the interactions between ecosystems and the role of mangroves in maintaining fish stocks, which are recognised as valuable by all coastal communities.

Due to the socio-economic importance of coral reefs and mangroves, it is necessary to take urgent action against their degradation.

15 THREATS FOR BIODIVERSITY

15.1 What is biodiversity?

Protection of biodiversity is at the centre of environmental conservation. Definitions varies, but one commonly used one is that: “Biodiversity is the richness of life on earth, the thousands of plants, animals and microscopic organisms, their genes, and the complex ecosystems they form.” Biodiversity needs to be considered at 3 different levels:

- Genes. At a finer scale this means taking into account variation between individuals of a population or between same species with different geographical localisation.
- Species. From bacteria to large predators through multicellular organisms of plants and fungi.
- Community scale. Identifying differences between species of the same community.

All levels of biodiversity are necessary to a monitoring of species and communities. Diversity of species represents the different ecological adaptations and evolutions of species in a particular environment. This diversity gives resources and alternatives to man, who are not always aware of this. Genetic variety is necessary to each species for reproduction, resistance to germs and capacity to adapt to different conditions.

15.2 Measuring biodiversity

There are different methods, but most include a mathematical measure of diversity and evenness of populations.

15.3 Extinction and economy

Governments and communities have to realise that conservation of biodiversity is not just a principle or ethic, but that biodiversity has a real economical value. This shift in the way of thinking can only be accomplished if people feel that they are losing something valuable through ecosystem degradation.

15.4 Trends in extinction

A constant increase in biodiversity has been punctuated by periods of extinction. Most importantly at the end of Permian, 250 million years when 77% to 96% of marine animal species disappeared. These are due to exceptional perturbations such as volcanic explosion and collision with asteroids etc., creating major climatic change to produce an environment where most species will not survive. Extinction of species is a regular phenomenon occurring for many other reasons, such as competition/predation. Extinction is a natural process, but today the high rates are becoming a problem. This is because the rate of speciation has dropped below the extinction rate, and so biodiversity is dropping.

15.5 Economy of environment

Man has consistently overexploited the environment, often in a manner that leads to economic gain. It has become necessary for environmentalists to adopt an economist’s vocabulary in order to persuade the public of the damage being done. Cost/ benefit analysis of an ecosystem allows comparison of costs, impacts and loss of value in long term. Goods are direct uses of resources for local consumption and exploitation. For example in underdeveloped countries populations use resources in intensive way, 80 % of the world depends in large part on plant and animals for their medicine. Around 5000 species are used for Chinese medicine and 2000 in the Amazon basin. Services are indirect benefits through uses of an ecosystem. For example, protection against coastal erosion by a barrier reef. This saves millions through no need to invest in shoreline protection.

15.6 Threats for biodiversity

Without biodiversity, there will be a slower regeneration of species as there is less chance of speciation. There are many human activities that threaten biodiversity, for example:
- habitat destruction,
- fragmentation,
- degradation (pollution),
- overexploitation,
- introduction of alien species,
- increase of disease.

Most endangered species are under pressure from more than one of these factors, which accelerates extinction and complicates conservation efforts. All threats are due to an increase in use of resources directly related to population growth and industrialisation, a consumer society and an acceleration in demand for resources.

15.7 Habitat destruction

Habitat conservation is important for the conservation of biodiversity. For example, tropical forests cover 5% of the earth's surface, but host 50% of its species. Today 180,000km^2 of forest (an area bigger than Florida) are threatened per year. 80,000km^2 are cut down and 100,000km^2 degraded in a way that communities of different organisms are deeply changed. Tropical forests are particularly fragile as once trees are cut, the fine soil, which is poor in nutrients easily washes away with rain. For example, forests in Madagascar with a large variety of endemic species used to cover 112,000km^2. In 1985, only 38,000km^2 were left, the rest having been cut down for agriculture or grazing or destroyed by fire. The cutting of Madagascar's forests will lead to the extinction of many species due tot he high levels of endemism. Other biodiverse and highly threatened habitats include coral reefs and mangroves.

15.8 Habitat fragmentation

In addition to decrease in area, habitats which occupy large area are often divided by roads, fields and cities etc. This leads to fragmentation, which means that there are more edge effects and core zones become closer to those edges. This can limit migratory patterns of birds, mammals and insects, which do not go through uncovered areas due to predators. They will therefore not recolonise other fragments. Isolation of these species can lead to their extinction due to a lack of resources (e.g. seasonal migration for food) and genetic decline in a small population.

15.9 Degradation of habitats and pollution

Pollution often causes medium to long-term chronic impacts, making them difficult to monitor. Common causes include: pesticides, chemical products, used water and agricultural runoff.

15.9.1 Pesticides

A danger of pesticides, like DDT and other organochlorines is that they accumulate up the food web, becoming toxic at the top. This can cause many large predators to become toxic to humans.

15.9.2 Pollution

Pollution contaminates sources of food, fish, shellfish and drinking water. Lakes, rivers and oceans are often used as tips for industrial waste and used household water. Toxic chemical products, even at low concentrations, can reach lethal levels for aquatic filter feeders. Birds and mammals eat these and in turn become contaminated. Waste water, fertilisers, detergents and industrial processes often throw back a large quantity of nitrates and phosphates causing eutrophication of water. A small quantity can stimulate primary productivity and often leads to algal blooms. This reduces light in the water, which reduces photosynthesis, leading to lower oxygen concentrations at the bottom, causing anaerobic decomposition and death of many organisms.

15.10 Exotic species

Species are geographically limited by environmental and climatic boundaries such as oceans, mountains, rivers restrain movements. Geographical isolation leads to evolution into different species in different regions of world. Man completely changes this process by transporting consciously or not species around the world. The majority of introduced species will not survive in new habitats. However, some will become pests, overgrowing endemic plants or eliminating endemic animals, causing habitat changes. For example in Hawaii there are 4,600 introduced plants, around three times the number of endemic species. The effects of exotic species are more pronounced on islands than continents because endemic species are more fragile to any alien species due to total their isolation. Some island where there are no large predators are vulnerable to introduced ones, for example rats introduced to Nose Ve (Southwest Madagascar) were threatening the ground nesting population of red tail tropic birds by eating the eggs. Without deratisation by a local management group and Frontier the population might have disappeared. Exotic species often come to dominate due to the absence of their natural predators and parasites.

15.11 Increase in spreading diseases

Infections from microparasites (virus, bacteria, fungi) or macroparasites (worms) can be a threat for species on the verge of extinction. This is threat is increased as an indirect effect of habitat destruction. If a population is confined to a small area there is a decrease in habitat quality and access to food and an increase in social stress leading to lower resistance and weaker animals prone to diseases.

15.12 Vulnerability

Most threatened species have the same characteristics for example:
- limited geographical boundaries
- only 1 or 2 existing populations
- small populations
- a decline in population numbers
- economical attraction to man (leading to overexploitation.)

15.13 Source

Primack, R.B., 1995. *A Primer of Conservation Biology*. Sinauer Associates Inc.

16 MANAGING BIODIVERSITY

16.1 Conservation of biodiversity at the scale of species and population

Conservation efforts often focus on endangered species, where the numbers of individuals are increasingly critical. In order to successfully maintain a stable population in conditions restricted by human activities, it is necessary to determine the stability of population under certain conditions. Will a species survive in a park? Is a species endangered and why? Many parks or nature reserves have been created to save megafauna, such as elephants, tigers, lions, whales, which are good for the image of the country/region and attract public approval and funds. However these areas have often been created after the number of individuals has been severely reduced through habitat loss, degradation, and, or overexploitation. Protecting these species will not necessarily save them from extinction. Biologists have observed that populations with small number of individuals will disappear more often than large ones. There is a critical number called minimum viable population under which a population cannot persist. Small populations will be subjected to quick extinction for 3 reasons: loss of genetic variation, demographic fluctuation and variation in the environment due to natural catastrophes (droughts and cyclones etc.) From a conservation point of view it is important to be able to decide if a population is stable, in decline or fluctuating. This is done through monitoring. Different strategies can be applied at the population scale:
One such strategy is reintroducing a population to its natural environment, either from individuals born in captivity, or taken from another area. Mammals and birds in captivity require social and behavioural training before they can be released. Reintroducing plants require a different approach depending on the conditions for the seed of young sprouts. Endangered species in nature can be placed into zoos, aquariums or botanical gardens.

IUCN has established 5 categories of species:

- Extinct
- Critically in danger
- In danger
- Rare
- Unknown, or studied

These categories are widely used today to evaluate the status of different species and to help prioritise conservation plans. International conventions and agreements for biological diversity deal with species that are traded on an international scale. Threats on biodiversity are an international responsibility.

16.2 The conservation of biodiversity at the community scale.

Protecting biological communities is the most efficient way for the conservation of biodiversity. Some say it is the only way because we have reduced knowledge for keeping species in captivity. There are three additional ways of “in situ” conservation:

- creation of reserves
- protection measures outside of protected areas
- restoration of communities in their original habitats

However it is necessary to compromise between protecting biodiversity and ecosystems, and using resources.

16.3 Protected areas

The first step is legally protected areas. These can be established in different ways, usually by governmental action at the national, regional, or local level, or by a private organisation. Local communities who want to preserve the local heritage can also create protected areas. For example the island of Nosy Ve (Anakao, Southwest Madagascar). Protection comes from the work of 6 villages, which want to keep this sacred area. Once a zone is under legal protection, it must be decided how much disturbance will be allowed. In 1993 there were 8,619 marine and terrestrial protected areas. This figure only represents 5.9% of the total surface of the planet. Additionally only 3.5% are classed as strictly protected. For the marine environment, in 1993 there were 977 protected areas representing 2 million km². However many of these are “paper parks”, existing only on paper.

16.4 Efficiency for protected areas

If the protected areas only cover a small percentage of the planet, how can they protect biodiversity? Species are concentrated in specific areas and conservation will aim at the oases of biodiversity, areas that host many different species. For example, in most of the African countries, birds are nearly all encountered in protected areas. In Zaire, one can count 100 species of which 89% are found in 39% of the protected areas. In Kenya, 85% of species of birds live in 5.4% of the territory, mostly national parks. This example shows that by selecting the right areas to protect, you can include most targeted species. However the long term survival of these species is uncertain. The size of the population could be severely reduced and the species can still disappear. The size of the protected area and management are essential factors for the survival of the population.

16.5 Prioritising conservation

Because protected areas are financially restrained, a decision must be made regarding what to protect. Some conservationists think that all species must be protected, that they all have equal value, but in reality, species are disappearing every day. Essential questions to ask to minimise losses include

- What needs to be protected?
- Why it needs to be protected?
- When it needs to be protected?
- How can it be protected?

Three criteria can be used to answer:

- Ensure the distinction between communities is known. Biological communities composed of rare and varied species have a higher priority than communities with large number of common species largely distributed.
- Species threatened by extinction will have a higher priority than species in slight decline.
- Exploited species have priority.

An example is the Komodo dragon in Indonesia. It is the largest lizard in the world and is only present on those islands with fast development and is therefore under threat. It is also a great tourist attraction and therefore has significant value. The same analysis can be used with lemurs and many other endemic species.
The creation of new protected areas in developing countries is a priority so that resources and users can be managed according to their needs. The establishment of new protected areas is more important than ever now when there is more and more financial support from Global Environment Fund and private funds for conservation. The GEF gives 1.2 billion dollars per year for the development of environmental projects (1/3 for biodiversity).

16.6 Conception of protected areas

The size and location of protected areas around the world are usually chosen by a number of factors including the distribution, the value of land, and the political efforts of the citizen for the protection of the environment. In many cases the area chosen has no major economical value and depends on the space and money available as opposed to the area needed for the best results. Questions to be addressed for a new park include:

- What is the size necessary to protect the targeted species?
- Is one large zone better than multiple smaller ones?
- How many individuals of the threatened species should be included in the area for survival?
- What is the best shape of the protected area?
- When there is more than one protected area should they be linked?

16.7 Size

One large protected area will reduce the border phenomenon, it will include more species and types of habitats. Practically and in general a new protected area must be designed to be the largest possible. The main argument for many small ones is that they can buffer from major catastrophes and epidemics. Generally the size of the protected area will depend on the species that need protection. For example it will need to be much larger for elephants than for lizards. Once the size is defined, natural events and human activities may disappear. There will be a change of habitats through suppression of these factors. For example ageing of a forest by stopping fires or grazing. This needs to be taken into account when designing the protected area. In each case, there is a need for balance between a completely natural state where species and pressures can not be controlled and a garden where species can only survive through human intervention. The Single Large or Several Small debate regarding park size has no definitive answer and must be addressed for each individual case.

16.8 Men and parks

The use of resources of a park by local populations or visitors must be a central part of management. If communities are thrown out of a particular habitat that needs protection, they may not support the park and cause further problems, or breach any attempt of regulating the uses of that habitat. If the goals of a protected area are explained to the local populations, and if the local populations agree to follow the rules then this protected area can keep these communities in the park. The best scenario is when local communities are directly involved in the management plan and they gain from the positive impacts on resource and economical outcomes. This is generally not the case. The Top-down strategy where the government imposes a national decision at the local scale has to be consolidated with a bottom up strategy where local communities can reach their development goals. UNESCO has tried this type of approach with the creation of “Man and Biosphere Reserves” where there is an effort to integrate human activities, research and protection of the environment. These are based on the buffer zone theory.

16.9 Reducing the boundary effect and fragmentation

Round protected areas minimise boundary effects. A round form is difficult to implement, it is dependant on available land, natural limits, and infrastructures. These limits must be avoided as train tracks and roads do not correspond to natural border of ecosystem. Problems are encountered when governments choose to put big axes (roads) in the middle of parks, avoiding disputes with private owners since the land is public. If possible protected areas must have the entire ecosystem as the unit of management.

16.10 Wildlife corridors

If there are many little reserves, they should be linked. Use of wildlife corridors allows plants and animals to disperse. However there are major problems for corridors, these include the transfer of diseases from one area to another and an increased exposure to predators which often congregate on the migration paths.

16.11 Managing a protected area

Once the protected area is in place it must be well managed to reach the goals set and maintain biodiversity. It is easier to let nature take its own course. In reality humans have already modified the environment so that it needs management for species to survive and allow the ecosystems to be protected from further degradation. This should be considered on an individual case basis.

16.12 Conservation outside protected area boundaries

Conservation strategies need to take into account external factors such as pollution, habitat destruction and disease. A protected area cannot protect all species in an area and there are some species outside protected areas that also need protection. Through education, private land owners can become useful tools.

16.13 Ecosystem management

There are several important themes, which include:

- understanding the links between different levels of an ecosystem, these include individual, species, community, and ecosystem
- managing to the appropriate level and not incorporating artificial boundaries and administrative boundaries
- monitoring of an ecosystem and the use of results to readjust management plans
- co-operation and integration of local, regional, national and international organisations

- recognise that man is an integrated part of the ecosystem and admit that human values influence conservation goals

16.14 Restoration

Four different approaches exist:
- No action: too expensive and not conclusive the ecosystem will recover on its own.
- Restoration: an active program to reintroduce species and plants.
- Rehabilitation: restore at least a couple functions and a couple of species of the ecosystem.
- Replacement: replacement of one degraded ecosystem by another, more productive one.

16.15 Source

Primack, R.B., 1995. *A Primer of Conservation Biology*. Sinauer Associates Inc.

17 FISHERIES MANAGEMENT

17.1 Introduction

Fisheries Management does not have a good reputation due to the world-wide decrease of stocks, and the decrease of the CPUE. Despite improvement of technologies, this is caused by: decreased abundance, size of fish and reproduction potential, replacing high value species with low value ones, recruitment failure and habitat degradation.
Why is this? Is it due to the biology of the fish? The 1995 meeting of the American Fisheries Society said no. The management approach must be revised.
Why has fisheries management failed? The conventional management strategy is deeply anchored in biological population models. The single species fisheries approach is that population future is estimated through those models. A surplus yield model is used. Maximum Sustainable Yield assumes an equilibrium between fishing efforts and size of stock. However, stocks are very variable and size changes according to unpredictable environmental factors. Recruitment rate is independent from stock size, and fishing has no effect on recruitment. A more recent approach is to keep the minimum reproduction stock. The goal is to keep about 20 to 30% of reproductively active individuals of a non exploited stock. This rate is estimated by some as too low. The problem with single species models is that they ignore complex interactions between species. Overestimated quotas arise since there are many non selective fishing methods. This does no refute the previous chapter on “Captures and MSY”. It is important to see the downfalls of a management plan based on these models. It's also difficult to gather the biological data to base these models on. However these models can help get a rough idea of scale and stock size. However it is not sufficiently accurate to base a sustainable management plan.
Fisheries also fail when it comes to the application of the management plans. Even where the political climate can support the plan, there are not always enough ways to control and reinforce rules and regulations to keep it within the complex quotas, size, and material etc. Fisheries managers have lost their credibility since their approach has not included a margin of error, a buffer zone. MPAs can represent this buffer.
In the past, the main objective was to protect the stock. Today, the social, environmental and economical goals are added. Specific objectives depend on the type of fisheries, and political agendas. For commercial fisheries where most of the merchandise is exported, maximisation of profits is the number one priority. In this case, a small but very efficient flotilla is most appropriate. On the other hand for artisanal fisheries, where the goal is to provide income for as many people as possible, one must try to include as many people as possible in the share of resources.
The main problem in management is that of migratory species, or when different life stages are linked to different habitats. UNCLOS (United Convention of the Law of the Sea), a coastal country controls an EEZ (Exclusive Economic Zone) which stretches from the coast of the reef to 200 nautical miles. The country is responsible for the management, protection and exploitation of all stocks in the EEZ.
The main objectives of stock management are as follows:

- maximise catch for sustainable fishery and maximum socio-economic benefits
- base catches on biological references
- maintain minimum stock size
- target sustainable development

In general a management plan must include:

- the present management of the fisheries
- goals and objectives of the management plan
- management strategies
- rules and regulations laid in place to apply these different strategies
- flexibility to change with reference to monitoring

The manager will need a biological, economical, political, sociological, and legal approach in addition to skill in conflict resolution. Most of the time a unique management strategy is applied to a stock, for example the gradual increase of flotilla. However this is not highly recommended because of variations of stock. So different strategies are applied to different subgroups of the same stock to compare them and then apply the best one. Rules and legislation can support and implement the chosen strategy. This must be chosen according to the most feasible solution (simple solutions with simple rules), so it can easily be reinforced.

17.2 Types of controls

17.2.1 Limitation of the number of fishing unity

Implementing fishing permits.
Who will get them? How many get distributed? A permit can be bought. Once bought the fishermen will want to get the most out of his investment, increase his fishing effort, and spend more time at sea. The permit can be exchanged between fishermen. This can be a risk, if it is between two vessels that are not the same. Transfer must be controlled. Permit must include size of vessel, and the gear used.

17.2.2 Limits on the type and efficiency of the gear

The number, size, and type of gear can limit the catch, additionally some gear can be forbidden. For example the number of hooks on a line can be limited, and scuba diving for lobsters can be forbidden. However these restrictions reduces the efficiency of a fishing vessel, and therefore profits for fishermen and their competitiveness compared to other regions. The economic point of view is that it is better to have fewer but more efficient boats. Ultimately this depends on the goals.

17.2.3 Closure

Specific closing period or area or both. An example could be a reproduction zone. This can be closed during the reproduction period. Rotation between closure and fishing zones/periods can also be a good strategy. This can be incorporated in protected area with multiple uses, for example tourism and fishing.

17.2.4 Minimum size and escape zones

Minimum mesh size and escape spaces restrict the size of the catch and allows them to enter fisheries at acceptable sizes. A problem is that there is so much by-catch in some nets that they block the mesh and small individuals are captured.

17.2.5 Release of females and pregnant females

This rule can only be applied to species where sexual differentiation is easy. For species where it is difficult, it is better to close during the reproduction period.

17.2.6 Quotas limited catch

A quota is defined for the totality of the stock. Fishermen hurry to catch as much as possible before the quota is reached and the fishing season closed. A consequence of this is high competition, short fishing season, high investment on new technology and little security (due to spending more time at sea during bad weather). Another method is to distribute quotas. Quotas can also be exchanged between fishermen.
The quota is based on anterior fishing years from fishermen's log books. They have a tendency not to record all of their catches. The environment also varies greatly between years and will influence stock size.

These rules need enforcement. However the best policy is education and sanctions must be regarded as a last resource measure. Public meetings, radio advertisements, newspaper articles, and posters can help to publicise new regulations and explain to the public the needs for such regulations. Education is the only long-term management strategy for sustainable development. It requires a change in the attitudes generation after generation.

17.3 How do MPAs help fisheries?

Fisheries try to maintain minimum stock for reproduction and MPAs can help this. Some important points to note include that:

- older fish have higher reproductive capacity
- most fish have a pelagic larvae phase that can transport them outside the MPA's boundaries
- migration of adults and juveniles i.e. the spill over effect can positively effect surrounding areas

MPAs on average increase the number of fish by 91%, with a 31% increase in size, and 23% the number of species after 2 year of protection. In St. Lucia in the Caribbean, one third of fishing zones are now no take zones. This was implemented in 1995. After 3 years the commercial fish stock outside the MPA has doubled.
Management techniques such as mesh size also help to protect the reproduction stock. Why do we need MPAs?
They help to resolve multiple species fisheries in particular. Different species have different life cycles. In general K selected species have a high life span, slow growth rate, and late reproduction. R selected species have the reverse. K species are very vulnerable to exploitation and can only support very low fishing intensity where as R species can take higher intensities. Ideally fishing rates for R and K must be different. However, fishing techniques are not selective enough to differentiate between both.

A second argument is the conservation of habitats. Exploitation causes degradation of habitats and loss of biodiversity. Modification of food webs through the removal of large predators affects non targeted species. There is a slow recovery of certain habitats and fauna such as invertebrates that can affect the bottom up relationships. Ideally an MPA should be a no take zone, but it can also be successful with regulated exploitation. However, a no take is easier to regulate and control and can be used as a control zone for monitoring.

17.4 How much should be protected and where?

In 1990 it was suggested to protect 20% of the continental plateau to ensure survival of 30% of the reproductive stock, in turn reducing recruitment problems. Today the estimate is 50%. For a better source effect (larvae spillover) use multiple small reserves can be used. Size also depends on social constraints and regulations. Information is needed but cannot be used as an excuse not to implement anything. MPA boundaries should be changeable to comply with results form monitoring programmes. There is a need to educate the fishermen and locals at the same time because they will usually not accept having 20 to 40% of their fishing area taken away from them. The same will arise for politicians and policy makers when election time comes around.

17.5 Conclusion

MPAs are not the solution to all problems. MPAs are very different from terrestrial PAs in the sense that there are no physical boundaries. This makes them difficult to define. You cannot keep organisms inside, and cannot close the park from degradation, pollution, disease, hydrological change, open system. This is why MPAs must be part of a larger management plan, which integrates all ecosystems and multiple uses.

17.6 Source

King, M., 1995. Fisheries biology, assessment and management. Ed, Blackwell Science Ltd, Fishing Books News. Oxford.

18 COASTAL MANAGEMENT

18.1 Introduction

The coast is a system situated between marine and terrestrial environments. It is a base for complex interactions and from a management point of view both environments must be incorporated as both influence the coastal zone. The transition zone can be very large, for example at estuaries and can support many human activities, from tourism to fisheries, aquaculture, factories, ports and energy production. The pressure on coastal systems increases with global populations and subsequent increases in demands on resources. With technological improvements, resources are being used increasingly unsustainably, not only environmentally but also economically and socially. The coastal populations, which are often the poorest may suffer the greatest consequence of the loss of those resources. The access to resources is not regulated and when it is, it is often not enforced. Markets are not able to give a fair value to these ecosystems due to increasing inflation. An increasing demand and supply leads to the belief that there are unlimited resources and free use since the sea belongs to everyone and has no limits. This can be regarded as an example of the 'Tragedy of the commons', with no one responsible for overall regulation. The strain on the marine and coastal environment is not only due to overexploitation but also from upstream, inland activities, or development on the coast.

18.2 Marine and coastal development: stakes

Anthropogenic activities have caused damage to the environment through pollution, bad management and loss of natural resources. They have also caused an increase in natural catastrophes such as floods (India), erosion, increasing level of the sea, public health declines and decreases in options/ alternatives for economical development. These have left the need for increased scientific expertise for management plans to prevent future problems. Sustainable use of marine and coastal resources is necessary to allow use by future generations.

18.3 Precautionary principle

At the Rio Conference in 1992it was officially stated that "Where there are serious threats or irreversible damages, the lack of scientific proof should not be used as an excuse to delay expensive but efficient measures to prevent environment degradation." This concept has been applied in the past for the protection of whales with the moratorium on whaling in 1985. This precautionary principle has been recognised internationally, for ex treaty on climate changes. Precautionary tools can include regulation systems for resource exploitation and national or international conventions.

18.4 Rules for efficient management

For efficient management it is necessary to identify stakeholders and clearly define their responsibilities, set out rules that match local socio-economic conditions, allow for the participation of primary stakeholders in decision making, create sanctions for violation of rulings, ensure conflicts are resolved and that the scheme is recognised by others. The favourable conditions for co-operation of institutions and success of agreements include
repeated interactions between all parties involved, information gathering on the behaviour of the participants, small group sizes for discussions and decision making and all stakeholders must benefit in a fair way from management plan.

18.5 Different options for regulations

Some of the options for regulatory management are outlined in the table below.

	Protecting the coast	Protecting oceans	Water pollution
Protected areas and limited access	Coastal reserves, restriction of use of coastal land	MPAs, restrictions, quotas, catch licences	Permits to extract material, agreements on used water outputs, quality of water
Private ownership	Concessions for wood cutting and right to management of communal forests	Fishing licences, individual quotas exchangeable	Permits for used water outputs, permits for sewage
Taxes and fees	Tax on industrial and tourist activities (on coast)	Access fees, tax of licensed boats	Water treatment
Fine	Fines and penalties for non respect of zonation	Fines, confiscation of materials and boats if regulations breached	Fees for illegal used water discard and infraction of regulations concerning toxic substances
Financial incentives	Loans for elaboration of new technologies, tax deductibility for environmental efforts, encouragement of reforestation	Incentive for investment in new, cleaner technologies including reduction of prices, tax exemption	Loans for use of new technologies, reduce taxes for efforts in environmental protection
Legal responsibilities	National or regional management plans	International convention on responsibilities and compensation funds	Insurance for responsibility in case of accident
Systems of loans	Reforestation	Tackling oil spills	Encourage industries to use “clean” technologies

18.6 Integrated coastal management

It is important to manage marine and coastal resources at the right geographical and political scale. If environmental effects spread over more than one country, each of these countries must participate in the management plan. On the other hand if impacts are on a local scale, management should only be delegated to local scale. The minimum unit for management is the ecosystem. However to ascertain the size of the area to manage, it is necessary to be aware of the relationships between different ecosystems which can be as wide as a region or a country. Integrated management of an ocean or a coast starts at the community level but economical interactions will call for an international or national approach. In the 70s, the notion of integrated coastal zone management (ICZM) appeared with the acknowledgement of the economical value of coast and the understanding of the links between different natural resources. This term is used to describe a continual and dynamic process that links governments, local communities, scientists, the economical sector and public interest in the preparation and development of the coastal ecosystem. The objectives of ICZM can include:

- maximising long term economic gain, whilst accruing sustainable social benefits for resource users
- finding practical answers for short term development such as diversification of activities in rural areas
- reinforcing plans at geographic and economic scales
- reducing conflicts between different users
- distributing wealth/ resources fairly between different users

ICZM’s goal is to regroup all stakeholders around a table to discuss the distribution of resources and their uses. It must transform an aggregation of industries at a national or international level into a dynamic and flexible network. This must then be organised to manage a number of potentially competitive uses. Often areas for action will be small, with a larger picture in mind. With UNCLOS (United Nations Conference on the Law of the Sea, 1994), the central regime for governance of the sea has established a new system for institutions. Under the convention, the number of sub-regimes can be identified, each corresponding to the objectives of the convention. The most important include:

- sustainable management of living resources is directed by the FAO (Food and Agriculture Organisation) and regional conventions etc.
- that marine pollution control is centralised by IMO (International Maritime Organisation) and other institutions based on this convention
- that the UNEP (United Nations Environment Programme) is responsible for the marine environment with a network of regional agreements and action plans
- scientific marine research and management of its services are centralised around the IOC (Intergovernmental Oceanographic Commission of UNESCO (United Nations Educational, Scientific and Cultural Organisation))

- development of mining of ocean floor is managed by ISA (International Seabed Authority).

UNCLOS has given a comprehensive framework, which puts the UN at the centre of governance of oceans.

18.7 Public participation

The recent emergence and practice of public participation is linked to general interest by social groups in the protection of the environment and its resources. This interest is combined with scepticism towards the ability of governments to resolve the problems of destruction of the environment and overexploitation. Additional rights which can insure success of public participation include:
- the right to know and have free access to information concerning natural resources
- the right to be consulted and participate in decision making concerning activities which may impact the environment
- access to legal tools to appeal to justice when their health or environment has or may be impacted

This practice is only starting to become operational at national levels and is not as yet integrated into decision making at the international level.

18.7.1 Case study: Indonesia

Coral reefs and associated marine life are one of the largest natural treasures of Indonesia. The Indonesian population live off these coral reefs, many are fishermen and some occasional fishermen when harvests are bad. The richness and biodiversity of these reefs make them a valuable tourist attraction and resource for scientists and students etc. However, health of these reefs is decreasing considerably, and only 29% of the reefs are considered in good health. There are 5 main threats:
- poison
- dynamite
- coral mining
- sedimentation and pollution
- overfishing

Private sectors of tourism have proven to have long term goals and should be included in decision making. They have economic power and can influence local peoples to help protect the reefs. Different sectors need different approaches. In general coastal management based on local scale, all users should be included in decision making. On the other hand, if there is one dominant actor then national regulations may be necessary. If there is only a small use of resources, with one principal threat a more direct approach than ICZM might be needed.

18.8 Local threats

If the threat is focussed on one specific site where Insiders and Outsiders are locals, then a small, local scale approach is most appropriate. This can take the form of community based management.

18.9 National and international threats

The main problems with ICZM are that it can be slowed down by too many participants and it can become an excuse for large national or international programmes with no positive outcome instead of small national projects with better results.

18.10 Case study: Philippines

Apo Island, in the province of Negro Oriental, symbolises an experiment of coastal management, which proved itself. The MPA model used included protection of reefs and fisheries all around the island and a small sanctuary. This increased stock, tourism, divers and scientists, which brought in additional income. The project was put in place through 5 steps:
1. Local community fieldworkers made contact with communities, created reunions and became familiar with the island and its environmental and socio-economic problems. This provided information for planning.

2. Continual education throughout the project was completed in an informal manner with small groups being taught marine ecology and management.
3. It is necessary to identify existing communities and during education realise problems and potential solutions. Logistics must be discussed so that they are close to traditional structures. Staff must be chosen to take charge of the education centre in the long term as a form of "community based marine management".
4. The project must be recognised and planned for the long-term
5. Continuous support must be given to the core group and its efforts, with the potential for new projects. Apo Island has become the formation centre for similar projects on other islands.

As a result of these steps, the reserve boundaries are delimited by buoys and managed by a local community of residents. At the ecological level there has been an increase in biodiversity that has spread throughout the islands.

18.11 Source

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Cesar, H., *et al.*, 1997. Indonesian Coral Reefs – An economic analysis of a precious but threatened resource. *Ambio*, vol.26, No6, pp.345-350

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19 PUBLIC SENSITISATION

Sensitisation and education are necessary steps for protection of the environment and resources at the local level. All age and demographic groups should be targeted. It is important to accentuate the fragility of ecosystems and the sustainable use of resources.

19.1 Why?

Many studies on mangroves and reefs of the Toliara region have been conducted by IHSM, however recently pressures have worsened and degradation of reefs has increased. This has lead to a change of focus from species, geomorphology and sedimentation etc. to use of resources, fisheries and socio-economic monitoring. Due to fast population growth and destruction of the marine environment, it is important to formulate a good management plan. In Toliara, during the 1970s there was a pop of 40,000. At the end of the 1990s this had increased to 140,000. Local populations of coastal villages have also doubled or tripled in that time.

19.2 Sensitisation, mobilisation, education (training)

It's necessary to educate people on the reproduction of species. So that fishing seasons can be implemented. Local communities need to be shown what they could gain from management. Education is therefore a useful tool for long-term management. Communities must be included in management plans, especially for protection of endemic species in Madagascar.

19.3 Sensitisation

Explain to the women the negative impacts of gleaning after teaching them the importance of reefs.
Educate men about methods of fishing and threats to different ecosystems.
Men should be educated on destructive fishing methods such as dynamite, poison, beach seining and small mesh nets etc.
Fishing cannot be stopped, but opinions and understanding can be changed
Other threats to be taught about include:

- coral mining
- disturbing coral heads for gleaning
- using mangroves
- colleting Terebralia and Pyrasus for coal
- using wood for pirogues
- using poison
- beach cleanliness (good for tourism)
- usage of toilets
- throwing garbage on beaches