For Life on Earth

Institut de recherche pour le développement

Status of the freshwater/coastal/marine living resources with particular emphasis on threats and options in coastal areas

15-18 November 1999, Montpellier, France

International Workshop

IRD - Halieutique et Ecosystèmes Aquatiques
Halieutics and Aquatic Ecosystems Laboratory

Final report

UNEP
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on

STATUS OF THE FRESHWATER/COASTAL/MARINE LIVING RESOURCES WITH PARTICULAR EMPHASIS ON THREATS AND OPTIONS IN COASTAL AREAS

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G. VIDY

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An International Workshop

Institut Français pour le Développement

&

United Nations Environment Program

Convenors:

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DEIA & EW	IRD - HEA
Nairobi	Montpellier
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Nos plus vifs remerciements à Mme M.-C. Pascal pour son aide précieuse dans l'organisation de cet Atelier et dans la réalisation technique du rapport final.

ACRONYMS

CBD:	Convention on Biological Diversity
COP:	Conference of the Parties
DEIA & EW:	Division of Environmental Information, Assessment and Early Warning
EIA:	Environmental Impact Assessment
GBD:	Global Biodiversity Forum
ICAM:	Integrated Coastal area Management
ICZM:	Integrated Coastal Zone Management
IRD:	Institut de Recherche pour le Développement
IUCN:	The World Conservation Union
MFR:	Marine Fishery Reserve
MPA:	Marine Protected Area
SBSTTA:	Subsidiary Body on Scientific Technical and Technological Advice
SIDS:	Small Inland developing states
UNEP:	United Nations Environment Programme

Background

DEIA & EW background

This workshop was initiated by the UNEP Division of Environmental Information, Assessment and Early Warning (DEIA & EW). This division is a part of the United Nations Environmental Programme, as detailed in the organization chart below.

This meeting comes under several missions devoted to DEIA & EW:

Assessment and Reporting
Strategic oversight and Early Warning
Regional approach with collaborating centres
Environmental Observing
Inter-link scientific advisory processes
Integrated Global Observing Strategy partnership
Strategic oversight and Early Warning
Emerging environmental problems and potential crises
Strategic oversight of whole global observing and assessment system
Report on the state of the system

In consequence the following recommendations were assigned to this workshop:

1- Choose **suitable site criteria** and **select targeted sites or regions** that could be retained according to these criteria.

2- Address and clarify the **required supplementary scientific knowledge** in order to promote adequate **targeted research** programs.

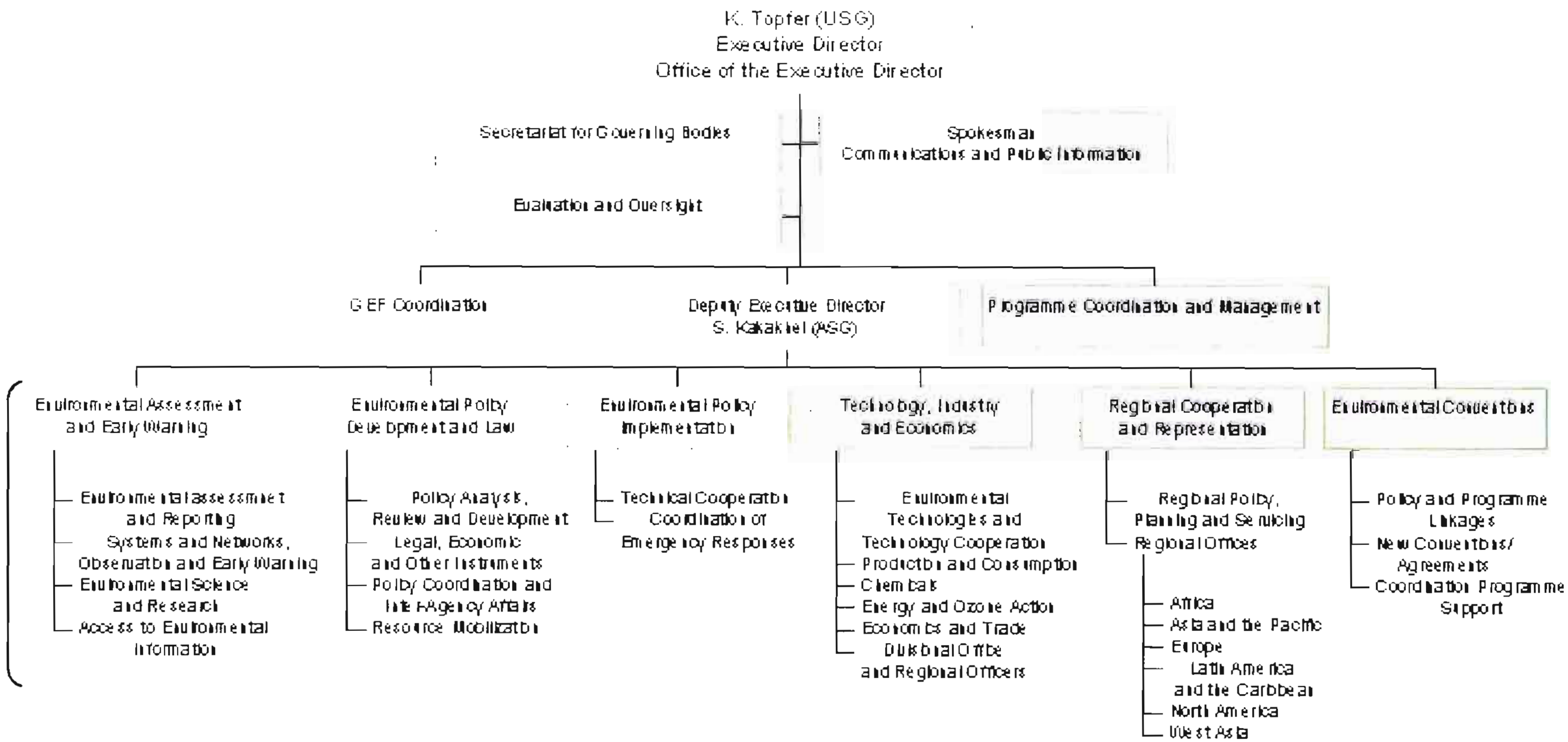
3- Propose ways **to improve or adapt the existing tools** and means to undertake and support the development of **new approaches and tools**, especially for **Rapid Biodiversity Assessment**, in **particular ecosystem approach** and **biological indicators**.

4- Set recommendations about **regional aquatic biodiversity databases**, about **Regional Workshops** to initiate those regional initiatives and/or syntheses and to link these databases in a **global network**.

5- Focus on the actions to be promoted for **Capacity-Building** through school and professional education, and public awareness aiming at long-lasting effects.

6- Propose criteria to select possible **regional focal point institutes or organizations** to host the regional database and, if possible, to constitute the regional reference center for Capacity-Building.

United Nations Environment Programme



Background from previous international meetings

Below is a summary of recent international meetings on biodiversity and their recommendations about the three major types of aquatic environment:

Major international meetings related to aquatic biodiversity

1972: The Convention on Wetlands, signed in Ramsar, Iran
1992: Convention on Biological Diversity (entered in force in 1993)
1992: Earth Summit in Rio de Janeiro, Chapter 17 of Agenda 21 on oceans
1995: 2nd Conference of the Parties to the Convention on Biological diversity + 3rd Global Biodiversity Forum (Jakarta, Indonesia)
Jakarta Mandate on Marine and Coastal Biological Diversity
1997: 8th Global Biodiversity Forum, held in Montreal together with the SBSTTA-3.
Workshops on inland water systems and incentives in the marine and coastal environment.
1998: 4th Conference of the Parties, Bratislava
1999: The 7th Conference of the Contracting Parties to the Ramsar Convention, San José, Costa Rica.
1999: 14th session of the Global Biodiversity Forum, together with the SBSTTA-4 (Montreal)

Marine, coastal and inland waters

<u>Decisions IV/5 and IV/4 of the COP/CBD Fourth Meeting in Bratislava:</u>

- Ecosystem approach
- Precautionary approach
- Development on a global basis of the scientific knowledge
- Development of collaborative networks
- Pilot-research and monitoring activities in particular on protected areas
  + rapid assessment methodologies, especially for SIDS

Marine and coastal area

<u>Decisions of the Jakarta Mandate (COP 4/CBD decision II/10):</u>

- Institute Integrated Coastal Management (ICAM), including community-based coastal resource management, and prevention and reduction of pollution from land-based sources
- Establish and maintain marine protected areas for conservation and sustainable use;
- Use fisheries and other living resources sustainably
- Ensure that mariculture operations are sustainable
- Prevent introduction of, and control or eradicate harmful alien species

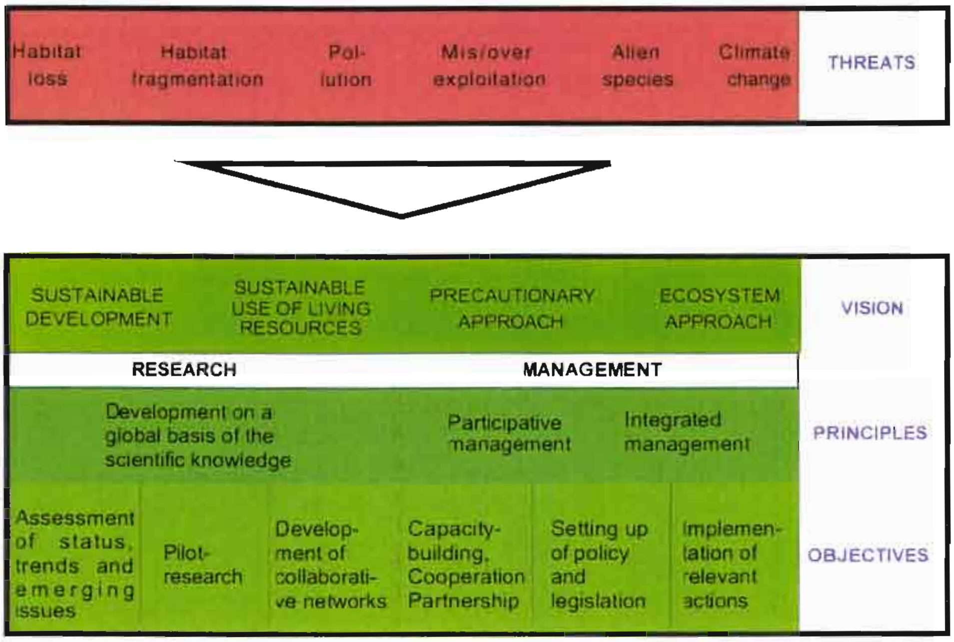
<u>Decisions of the UNEP 20th session report:</u>

- Participative management
- Sustainable development
- Rational use of living resources
- Assessment of the state of the environment, of trends and emerging issues
- New and expanded protected areas

Inland waters

Decisions of the COP/4 of the CBD - Bratislava :
- integrated watershed and rivers/drainage basins management
- investigations on the loss of biological diversity
- identification of measures and issues to address the threats
- cooperative activities and cross sectoral collaborations

All these recommendations do not take place at the same level. Some are quite practical (e.g.: monitoring on protected areas) while others are conceptual (e.g.: precautionary approach). They can be ordinated within the following conceptual framework:



The six objectives of this framework led to define a thematic structure of four major themes for the workshop:

ASSESSMENT OF STATUS, TRENDS AND EMERGING ISSUES
- Biodiversity Status
- Threats
- Trends
- Threatened areas

AQUATIC BIODIVERSITY ASSESSMENT: STRATEGIES, METHODS AND TOOLS
- Global methods
- Rapid assessment, indicators

OPTIONS FOR A BETTER CONSERVATION OF AQUATIC BIODIVERSITY
- Management
- Legal framework
- Valuation, economic issues
- Capacity building

METHODOLOGIES AND TOOLS TO MITIGATE THE LOSS OF BIODIVERSITY
- Monitoring, indicators
- Data management and processing
- Information flow, cooperations
- Protection and restoration measures

INTRODUCTION

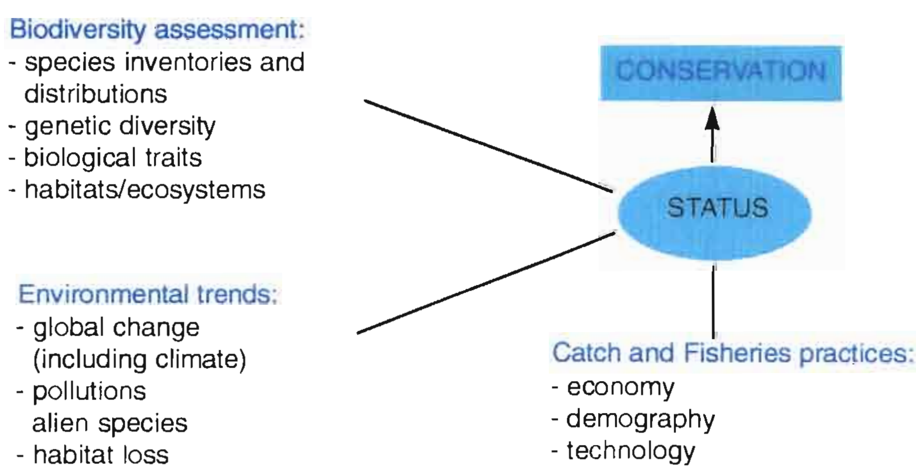
The definition of biodiversity considered along this workshop is the Convention on Biological Diversity one.

> "Biological diversity" means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
>
> Convention on Biological Diversity, Article 2

The definition of the CBD integrates all the aspects of biodiversity, from the genes to the ecosystem. This biodiversity can also be seen in terms of three basic components: composition, structure and function (Noss, 1990).

Current biodiversity is a dynamic equilibrium resulting from a balance between increase factors (speciation, immigration, introduction by men, genetic manipulations, behaviour) and decrease factors (different threats mentioned in detail below). As the concept of biodiversity has become more and more successful, there has been a drift from the concept of dynamic equilibrium (changing, far from thermodynamic equilibria, non reversible, realistic for biologists) to stationary and reversible equilibrium in people's mind.

Practically, when dealing with aquatic ecosystems, three main aspects must be considered: assessment of current biodiversity; environmental trends; catch and fisheries practices. Only an approach integrating these three components will step to an efficient conservation of biodiversity.



(C. Lévêque)

Assessment of current biodiversity

For a sounded assessment of biodiversity, inventories are required. They must be supplemented by an overview of biological traits insisting on behaviour, on the different life history stages and their corresponding habitats. The question of the different stages of a given species is a key question for conservation purposes.

The habitat has to be considered at different scales, corresponding to the successive requirements of an aquatic organism: shelter, access to food, reproduction, and colonisation. The habitats corresponding to these requirements are respectively: the home range, the ontogenic range, and the metapopulation level. Thus floodplains illustrate the close connection between these different scales and functions, all of them being linked to biodiversity.

Within these limits, the community ecology has proven the important role played by disturbance as well as that of the influence of predators on biodiversity through trophic cascades.

Environmental Trends

Soulé (1992) lists five levels of biodiversity (genes / population, species, communities, and ecosystem) and six major threats to biodiversity (loss of habitat, fragmentation of habitat, mis/over exploitation, spread of alien species and diseases, pollution and climate change).

This approach can be used to address the different aspects of preserving biodiversity in a given country or region:

	Genes/Populations	Species	Communities	Ecosystems
Habitat loss				
Habitat fragmentation				
Overexploitation				
Alien species				
Pollution				
Climate change				

A concern for a mitigation of these threats led to the concept of "ecosystem health" or ecosystem integrity:

> "A healthy ecosystem is one whose parameters do not vary outside predetermined limits from a predetermined level within a given period of time".
> "A harmful effect would then be defined as one that violates the conditions for a healthy ecosystem."
>
> *Report of the first meeting of experts on marine and coastal biological diversity*
> UNEP/CBD/JM/Expert/I/5

However the requirement of practical actions points out the necessity of shifting from such abstract concepts to operational tools. In that sense, new concepts will be operational only if they involve practical actions; if they refer to a given system; if they are clear about the social perception underlined and about expected outcomes. This demonstrates the necessity of taking the human factor into account for a better protection of biodiversity.

Fisheries practices

Although no case of overfishing leading to the extinction of a species has ever been documented (UNEP, 1995), -despite serious concerns about the sawfish Pristis sp. and several shark species- 69% of the oceans commercially targeted marine fish stocks are fished beyond ecologically safe limits. This over exploitation causes drastic decreases of local populations (e.g.: abalone off California, Northwest Atlantic barndoor skate, Banggai cardinalfish for aquarium trade; *in* Robert & Hawkins, 1999)

In inland waters, the introduction of alien species for fisheries purposes led to the extinction of dozens of species (e.g.: extinction of 142 haplochromines following the introduction of the Nile perch in Lake Victoria). Selective pressures due to exploitation in aquatic environments also lead to an erosion of the intraspecific diversity. Last, the reduction of the overall diversity is attested by the reduction of the average trophic level of fish catches (Pauly *et al.*, 1998), top carnivores becoming scarcer.

These different issues led to a new trend among fishery scientists, illustrated by the following provocative recommendation recently formulated by Pitcher & Pauly (1998): "the criterion of sustainability should be abandoned while ecosystem restoration should be considered as a new objective for the management of marine resources".

This document, based on the interventions of the participants to this workshop, aims at providing an overview of the current status and emerging issues in aquatic biodiversity, of the strategies and methods to assess this biodiversity, of policy options for a better conservation, and of methodologies and tools to mitigate its loss.

ASSESSMENT OF STATUS, TRENDS AND EMERGING ISSUES

Undertaking conservation of biodiversity in a strategic way requires to identify threats to aquatic ecosystems, most important geographic areas in which to develop projects, and opportunities to develop conservation policies or fieldwork. This is the aim of this section, through an ecosystem approach (COP-IV, Programme of work on marine and coastal biological diversity).

Specialists provided latest information and scientific developments about the main types of aquatic ecosystems: streams and lakes, wetlands, estuarine and coastal zones and large marine ecosystems.

Major threats on aquatic ecosystems and their consequences have been detailed elsewhere (e.g.; IUCN's category of threats to species, UNEP, 1995 ; Lévêque, 1997). Their respective impacts can be cumulative but have also been reported to be synergetic. Did recent studies point out particularly devastating combinations of threats, and is a ranking of combinations of relevance (from the less to the most impacting one) for the preservation of biodiversity?

This points out a certain need for further research on the nature and role of biodiversity. Although theoretical in nature and still much debated, this would be of major interest to underpin management and would lead to provision of sounded recommendations and arguments stronger than those of the precautionary principle when facing the decisions-makers.

Quantification of biodiversity under its different forms remains a major issue (Gaston 1996), where biological knowledge interferes with statistical science and where tight collaborations should be promoted.

Necessity of clear definitions, choices and methods

Many approaches dealing with biodiversity suffer from inconsistency in definitions and methods when they are to be implemented.

The notion of "assessment" is related to the perception of a problem, and therefore to "agreed" values and goals. This requires a community consultation in order to identify and agree about common values and goals prior to conservation actions.

Choices are also implicit in monitoring, this one being a collection of specific information for management purposes. From a conceptual point of view monitoring is not self-justified and autotelic, but is done in response to hypotheses derived from assessment activities. Monitoring is most effective if directed specifically at the goal and contained within a management (response) process, its results being used for confirming or altering management actions.

Placing assessment and monitoring within a management perspective leads to ask several critical questions:
- what are we trying to maintain or develop or restore and why?
- how are we going to maintain or develop or restore this?
- how are we going to determine if we have been successful or not?

Inland water ecosystems (streams, rivers, lakes and wetlands)

General features

Inland water faunas are characterised by a high level of endemicity, with genetically isolated populations. This result partly from the heritage of paleoenvironments, of glaciations and recolonisations from refuge places (e.g. lakes faunas). Inland waters are true islands for several animal groups including fish, macro-crustacea, molluscs, etc. Thus History is quite important to understand present stages of inland waters biodiversity, and long term changes were until recently considered as the dominant factor explaining biodiversity. Now, the role of behaviour is being pointed out as an alternative, with sympatric speciations occuring in lakes without isolation, but simply due to behavioural reproductive segregation. This is a major phenomenon in some places and for certain species (e.g.: Cichlids in Lake Victoria).

The present state of aquatic biodiversity, in a climatic and geomorphologic framework, is the result of past environmental changes that resulted in speciation and evolution. The future relies on global changes but also on human impacts at a regional or local scale: habitat changes, pollution, invasive species, overexploitation of natural resources.

Therefore dealing with freshwater biodiversity requires taking into account spatial and temporal variability, but also the complexity of interactions between faunas and their environment, and among faunas themselves.

Threats

Threats on inland aquatic systems are well known. They consist in physical modification (infilling, drainage), hydrological alteration (barrages, dams), biological invasion (alien plants and animals), over-exploitation (fishing, hunting, harvesting) and water pollution (nutrients, salt, toxins, metals).

In the case of wetlands, "Threat" was defined as a human-induced factor (e.g. water pollution, siltation, over-exploitation) that could change adversely the ecological character of an aquatic system. "Issues" were defined as underlying socio-economic and/or political factors (e.g. agricultural expansion, urbanisation, population pressure, sectoral structures) that could lead to adverse change in the ecological character of an aquatic system. "Assessment" was considered as the identification of the status of, and threats to, aquatic systems as a basis for the collection of more specific information through monitoring activities

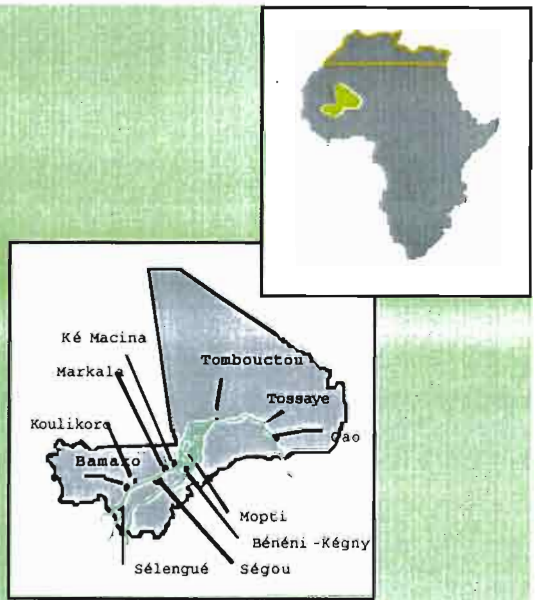
Issues are less recognised. They consist in management processes (sectorial divisions, planning structures, technical incompetence), in economic processes (subsidies and disincentives, greed and corruption, trade and competition), in population pressures (growth, expansion, short-term needs), and in cultural beliefs (taboos, tradition, religion).

(M. Finlayson)

CASE STUDY

The Central Delta of the Niger River (Mali)

R. Laë



For the last 20 years, the fish communities in the Central delta of the Niger river have been subjected to : (i) two drought periods in 1973 and 1984, (ii) a dramatic increase of fishing and, (iii) the building of an electric-power dam in 1984. At different levels, these various factors modified the biological cycle of the fish which were adapted to the former hydrological cycle of the Niger and the Bani rivers.

Impact of the drought

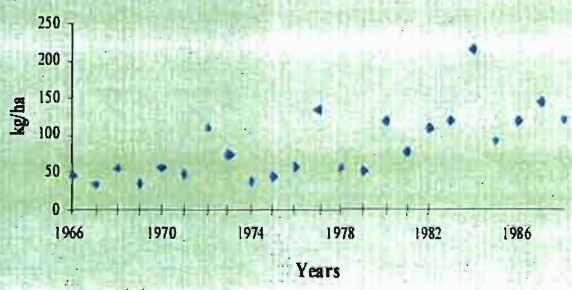
The Sahelian drought was responsible for a decrease in both flood duration and inundated area of floodplain which varied from 20.000 km^2 to 5.000 km^2.

Impact of dams

The building of dams disrupted the longitudinal migrations of fish but did not jeopardise species reproduction, spawning areas being located downstream these dams. A severe decline of fish catches was noted, correlated with the loss of water due to retention.

$$\text{Log(catches)}_n = 0.26 \log(\text{lost water})n + 0.18 \log(\text{lost water})_{n-1} + 9.82 \qquad r^2 = 0.92$$

However the total productivity per hectare of remaining area was not altered, but increased on the contrary.



Impact of the fishery

The demographic pressure (3% per year) doubled the number of fishermen in 20 years. Furthermore fishing efficiency increased a lot due to new fishing materials and gears. Large and medium mesh fishing nets were progressively abandoned. Last, the policy of the Malian authorities has been to insert the fishery into the market economy.

Impact on the fish community

The average catch length has been reduced significantly, and for most species there is a dominance of juveniles and young-of-the year now. Species reproducing in floodplains have almost disappeared from this system.

However, dams aiming at producing electricity create better flows during the dry season than those encountered before the sahelian drought. Consequently, the survival rate of spawners is increased, ensuring adequate reproductive success every year. This points out the necessity to distinguish between dams for electricity (with water discharge) and dams for water storage (with no remaining flow).

Conclusions

The Central Delta of the Niger River is a typical heterogeneous ecosystem in which fish species are able to tolerate serious environmental disturbances.

Unfavourable climatic conditions, high fishing effort and dams mainly affected large fishes and the migratory species. Droughts lessen the renewal rate of some species while fishing impacts mainly the age structure of stock.

Under new conditions of combined stresses, fish communities may reach a new stability; when environmental conditions are better, time of restoration have proven to be short.

Major issues

Indicators

The assessment of threats to inland water ecosystems requires the use of indicators of:
- long term, medium term and short terms (early warning) biological changes
- environmental changes in distribution, structure and functioning
- socio-economic changes

More generally, indicators should be part of monitoring programmes aiming at assessing the state of ecosystems (diagnosis) and trends in changes (degradation or rehabilitation).

They should be integrative and representative, costless and easy to manage. This would make them a major tool for decision-makers to assess the consequences of management options.

Hot spots

Biodiversity hot spots are geographic areas rich in species, or in high concentration of endemic species or taxa, and experiencing unusually rapid rates of habitat modifications or loss (Myers, 1988 ; Kottelat & Whitten, 1996).

About a dozen lakes in the world are more than 100 000 years old (e.g.: lake Victoria, lake Titicaca, lake Baïkal,...). Such lakes have exceptionally high faunal diversity and levels of endemicity, including species-flocks among fishes or amphibians (a "species-flock" is an aggregate of several species that are endemic to a circumscribed area and are each others' closest living relatives). There is a cichlid species flock of more than 500 endemic haplochromine species in Lake Victoria, and another one of more than 500 cichlid species in Lake Malawi. Ancient lakes are unique natural laboratories to study evolution at works for several groups of aquatic animals. They are currently major biodiversity hot spots and most of them are threatened by habitat alteration, trawl fisheries and the introduction of alien species. It is a world heritage to be preserved, both for their biological components and for the human technocultures associated with their use.

Estuarine and coastal ecosystems

General features

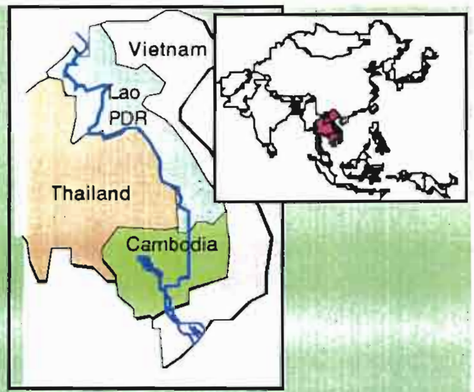
Estuaries are a rigorous environment, in close association with man. They exhibit the highest diversity in the tropics, and estuarine fisheries are developed and well studied. Three major zoogeographical zones can be defined: Indo-West Pacific, East Atlantic and West Atlantic. However there is a high degree of similarity between the species composition of the different regions:
66% of species in South East African estuaries are found in South East Asia
71% of species in Madagascar estuaries are found in South East Asia
95% of species in N. Australian estuaries are found in South East Asia
>50% of species in N. Australian estuaries are found in South East Africa

Biodiversity in estuaries is determined by the type of estuarine systems (closed, open, lagoon, coastal lake), by habitat diversity, by substrata, and by hydrological features (salinity, turbidity, tides, depth, and nature of adjacent sea). Generally, the more open the estuary, the higher the species diversity.

CASE STUDY

A biodiversity hot spot: The Lower Mekong

E. Baran



The Mekong River is the 10th longest in the world (4180 km), and the 3rd in discharges after the Amazon and the Brahmaputra. Its colossal high flows (maximum mean discharge amounts 54 times the minimum mean discharge) create large surfaces of wetlands in the rainy season (Scott 1989, Lacoursiere *et al.*, 1998):

Laos: 9700 km^2 (edges of the river, along 1700 km)

Cambodia: 35 000 km^2 (19% of the country)

Vietnam: 39 000 km^2 (> surface of Belgium)

Total: 83 700 km^2 (the surface of Ireland).

Biodiversity

- Considerable species richness of the fish fauna, with 1200 fish species for the whole Mekong and equally high diversity for molluscs (Rainboth 1996)
- High rate of endemic species, not quantified but attested by many authors, above all in the upland areas.
- Particular ecological patterns, 85-95% of the freshwater fish populations in the Mekong basin being migrant and following the inundation patterns to spawn and rear young fish (Pantulu 1986)
- Particular endemic and charismatic species, such as Pangasius gigas -the giant catfish- reaching 3 m and 300 kg, and migrating on thousand of kilometres from Phnom Penh to the province of Yunnan. Once quite common, today disappearing (about 70 individuals caught every year in Northern Thailand, several hundreds before). Also three dolphin species.

Social concerns

60 % of fish in the basin are from open water capture fisheries (Mekong Secretariat 1992). Proteins of aquatic origin make 80% of the diet of Cambodian populations, particularly around the Lake Tonle Sap (an inundation lake reaching 27 times the surface of the lake Leman, where more than 500 fish species are listed, and considered as the higher productive freshwater zone in the world - Rainboth 1996). Traditional fishing knowledge in this region is particularly rich and quickly disappearing.

Threats

Forty-three dams along the Mekong River or its tributaries are planned for the next years, including ten on the main stream - Mekong Secretariat 1992). Full implementation of the water resource management projects could lead to a loss of 92% of the high-water surface area of the inundation zone (Scott 1989). Water retention is a major concern for Vietnam threatened, not to mention other problems, by oversalinization in the delta.

The population increase (now 55 millions of people, projected to be 77 million in 2025), leads to habitat loss (loss of floodplains through water regulation) and habitat fragmentation For instance clearance of swamp forest around the Tonle Sap dramatically increases the siltation rate into this shallow lake (40 $mm.y^{-1}$ - Csavas *et al.*, 1994). Overexploitation is also regularly mentioned, including destructive methods (Hill & Hill, 1994 ; Roberts & Baird, 1995).

For any one type of estuary in a particular area, the information is now available to predict the species composition of its fish community under 'natural conditions'. Good information also exists to predict the effects of likely threats on different fish species within the community.

The background trends in estuarine and coastal systems are global warming (sea-level changes, rising water temperatures, strong storms), human population increase (mainly in the sub-tropics and tropics).

The rising of the sea level will modify depth and area of estuaries, and area and species of mangroves (however these effects can be considered as positive on mangrove surface in Australia for instance).

The rising of the water temperature will have effects on fauna living close to physiological limits.

The increase in severity of storms will cause a physical damage to mangroves and erosion of banks.

Threats

Threats on estuarine and coastal ecosystems have been listed below:

Dams, weirs and water abstraction

Obstruction may prevent movement or migration and result in changes in species composition.
Freshwater retention and reduction of flooding will change the salinity regime, resulting in hypersalinity, inland incursion of mangroves and changes in nursery function.
However the impact of dams will be different depending on the local pluviometry (oversalinization in case of low rainfalls, extension of the estuarine zone in cases of high pluviometry). The resulting impact may be good for certain estuarine fisheries.

Dredging

Massive disruption of substratum and disposal of spoil will modify and reduce the diversity of benthos and fish communities. Deeper channels may induce a change in fish populations towards larger species

Mangrove loss

The current loss of >1% p.a. for timber, aquaculture, development, oil etc. will allow increased erosion, surge protection, affect the physical structure of estuaries and the overall ecology of the system (species composition and community structure)

Effluents

They consist in persistent organochlorines, oils and hydrocarbons, trace metals and sewage. They might have direct toxic effects, xenobiotic activity or indirect effects on benthos and food chains. Eutrophication induces changes of communities and disappearance of many species.

Effects of fishing

Fishing impacts target species, but also non-target species, for instance through bycatch.
It can impact habitat (alteration, loss of nursery sites), reduce water quality, cause turbidity and effluents. One can also mention effects of fish removal on nursery functions and of removal of species on trophic structures.

Major issues

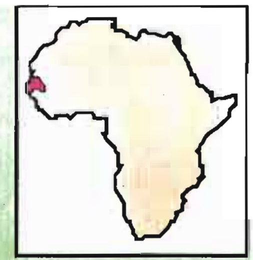
Estuarine biodiversity study sites

An approach of estuarine biodiversity study sites must take account successively of latitude, biogeographical regions, types of estuaries, health status and type of threat, and of the different biological communities. For such sites historical data sets are required. Sites where remediation is possible must be considered too.

Estuary health assessment

For an estuary health assessment, fish seem to be the most suitable group, because of large existing data sets, of detailed scientific knowledge, and of international recognition as robust indicator.
Thus fish species diversity is relatively high and many species have specific environmental requirements, hence make good indicators reflecting the overall health of the system. Fish species composition and diversity is a reflection of many small effects and subtle changes in water quality parameters, habitat, substratum, vegetation, flow patterns, fishing pressure,... Furthermore quantitative fish species compositions and diversity data are available from baseline and modified estuaries in all regions. As mobile aquatic animals, they allow for linkages with both freshwater and marine environments. Last, there is a community familiarity with fish and knowledge possessed by resource managers. High public interest and profile ensures political responses.

CASE STUDY



Threats on fish biodiversity in estuaries, rivers and lakes of Senegal

P.S. Diouf

The main causes of loss of fish biodiversity in the aquatic environments of Senegal are:

The rain deficit

- decrease of the surface of the flooded zone (the success of the reproduction of certain freshwater fish species depend on it)
- considerable increase of the salinity (up to 120-170‰); massive fish mortalities at certain seasons; alteration of the benthic malacofauna feeding some species of fish,...

Hydro-agricultural dams

- physical barrier to the migration of fish.
- for some fish stocks of the low estuary, their main spawning grounds have become unreachable, leading to a recruitment deficit.

Fertilisers, pesticides and herbicides

- proliferation of aquatic plants and seaweed.
- negative effects of insecticides on some species (Cichlidae) and notably the juvenile ecophases.

Overexploitation and bad fishing practices

- dramatic increase of fishermen efficiency, thanks to technological mutations these last decades (motorization of pirogues, long nylon nets,....).
- total fishing, blocking nets across the whole stream, use of several kilometres long beach seines with very small mesh size (catching mostly juveniles that are thrown away).

Irrelevance of policies and of their implementation

- laws regulating the Senegalese continental fishing are approximately 30 years old, but ecological, socio-economic and administrative environments have changed a lot, and they are now irrelevant.
- lack of human and financial resources in the administrations in charge of this sector.

Conclusion

When moderate, the increased salinity in non-dammed Senegalese estuaries paradoxically did not lead to a decrease of total species diversity. A huge number of freshwater species present 30 years ago has practically disappeared from these places. But the colonisation potential of marine species being clearly higher than that of continental species, they were replaced by marine species, and total species richness in these environments did not decrease. This points out the need for suitable indicators of biodiversity in changing environments.

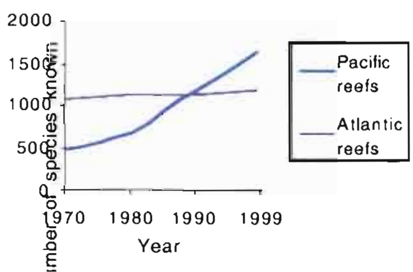
Marine ecosystems

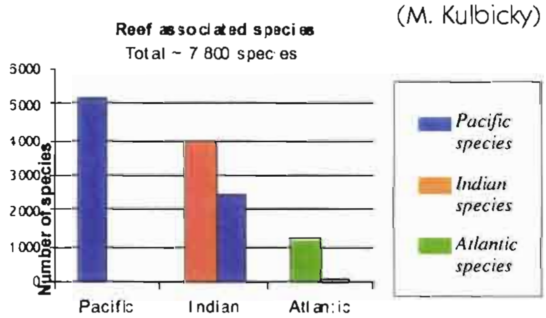
The wide diversity of issues related to marine ecosystems led to make choices. As Coral reefs biodiversity status and trends are to be taken into consideration by another UNEP workshop[1], it was chosen for the present workshop to focus on reef fishes and on large marine ecosystems.

General features

Reef ecosystems throughout the world are not similar in terms of knowledge on biodiversity. In the Pacific knowledge on marine fish biodiversity is still incomplete, and in most places species lists are still in a preliminary state.

(M. Kulbicky)





1 information management and decision support for marine biodiversity protection and human welfare: coral reef. Australian Institute of Marine Science, December 1999.

Species richness decreases from a biodiversity centre, between Indonesia and the Philippines, towards the East, and decreases as well as latitude increases. Another important factor in species diversity is island size, the larger islands having higher species richness. The combination of island size and distance to the biodiversity centre explain nearly 90% of the variance in species diversity.

Diversity = 570 + 92.5 logSurface - 0.076 Distance **$R^2 = 0.88$**

A consequence is that biodiversity may be more easily threatened in small islands in the Central Pacific than in islands of similar size or larger in the Western Pacific. However, the species distribution with respect to the distance to the biodiversity centre may be very different depending on the family considered.

The species composition of islands may shift quite drastically through time, with however no major change in the total number of species. In particular on small isolated islands, species may naturally disappear for some time and reappear later in relation with variations in the recruitment.

In most of islands, endemic species represent less than 5% of all species, with a few exceptions such as the Marquesas, Easter Island or New Caledonia. An important consequence of this low endemism is that if local extinction of some species is possible, complete extinction for reef or lagoonal species in the Pacific is probably unlikely in a near future.

Another feature is the existence of several biogeographical provinces that support distinct species groups, in particular the following ones: Hawaii, Polynesia, Micronesia, Western Pacific, Japan-Taiwan, Northern New Zealand, and New Caledonia.

The relationships between fish assemblages and the environmental parameters may change with biogeographical region or depending on the biotope considered. From a biodiversity standpoint this is important as it shows that one cannot extrapolate ecological results from one biogeographical region to another, or between different habitats of a given region, even if there is a high similarity in the species involved.

Threats

For Pacific reef and lagoon fish assemblages most of perturbations are of anthropogenic origin. Habitat destruction or modification probably is the most frequent and the most important one. Destructive fishing due to cyanide, explosives or in some areas extensive trawling is another major threat. Cyanide poisoning has received wide attention lately. Beyond its impact on the reefs this method is the sign of a profound degradation in customary regulation of fishing grounds, meaning that people are no longer concerned by the conservation of reefs and their resources.

Among the other types of perturbations is pollution of various nature such as industrial and city wastes, agricultural and forestry runoffs, open pit mining (especially important in the Western Pacific). Aquaculture, essentially shrimp farming may have also deleterious effects, mainly by its effect on shoreline and the input of nutrients as well as the increased risks of disease for wild populations. A more recent threat is the use of juveniles collected in the wild for rearing in aquaculture projects.

Species introduction is seldom a problem, however there are important exceptions (e.g. introduction of Lutjanus kasmira in the Hawaiian islands).

Major issues

A recent overview (Roberts & Hawkins 1999) provided criteria to identify marine species vulnerable to extirpation and extinction, according to their life history:

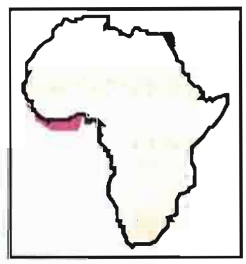
Population turnover
Longevity, slow growth rate, low natural mortality rate, low production biomass.

Reproduction
Low reproductive effort, semelparity, fishes old or large at sexual maturity; important sexual dimorphism; sex change occurring; spawning in aggregations at predictable locations.

Capacity for recovery
Regeneration from fragments does not occur; dispersal on short distance; poor competitive ability; poor colonising ability; low adult mobility; irregular/low recruitment.

Range and distribution
Nearshore horizontal distribution, narrow vertical depth range; small geographic range; high patchiness of population; high habitat specificity; high habitat vulnerability to destruction by people.

CASE STUDY



Large Marine Ecosystem of the Gulf of Guinea
K. Koranteng

In a large Marine Ecosystem such as that of the Gulf of Guinea, in West Africa, the living marine resources of the area depend on the upwellings which occurs seasonally.
Since the late 1960s, there have been dramatic changes in demersal shelf fishery catches, with decline of sardinellas, proliferation of triggerfish (making up to 60% of catches), increase of cuttlefish and recently, bloom of a bivalve. These changes remain poorly explained.

A recent work examined the structure and dynamics of these fish assemblages, together with related environmental parameters, during the last three decades.

Community structure is determined primarily by depth and type of sediment on the seabed, but the dynamics of the assemblages are influenced by physico-chemical parameters of the water masses.

Sea temperature was constantly rising during the 30 considered years, apart in the 1972-1982 period corresponding to the proliferation of triggerfish. This period was particular indeed in terms of temperature, salinity, and species composition.

The analyses show that temporal environmental changes (mainly natural) would lead to temporal changes in species assemblages whilst permanent change (e.g. habitat alteration or habitat loss) would lead to long-term or permanent change in species assemblages. The increased industrial trawling in coastal waters and environmental forcing appear to have singly or conjointly influenced the observed changes in the composition and relative importance of species in the assemblages.

Aquatic biotechnology: threats and issues

General features

Recent proliferation of aquaculture enterprises and related zootechnical developments modified the natural environment of aquatic animals wild stocks, via polluting effluents (organic matter), but also via spreading of aquatic pathogens, discharge of chemotherapeuticals and escapees belonging to alien species. However the genetic aspects of aquaculture is a major concern when dealing with biodiversity conservation.

Threats

Among freshwater species, crossings between two species gave birth to more than thirty popular hybrids. Fourteen of these hybrids are fertile.

Intergeneric hybridisation also occurred among marine fishes, for instance between specie of Sparidae and Dentex. Some of these hybrids, exhibiting huge growth rates and sizes, were also considered as fertile. These interspecific and even intergeneric hybrids deeply affect the notion of species.

Other genetic risks consist in the genetic erosion (loss of genetic variability in wild populations), genetic contamination (propagation of wild gene pools containing foreign genetic material) and genetic deterioration (accumulation of defective alleles induced by mutagens throughout generations).

In any case risk assessment in a natural context is almost impossible due to possibly unexpected capacities of released individuals, unpredictable interactions with other species, and uncontrollable becoming of these strains.

Major issues

An unidirectional gene flow from natural populations to farmed stocks should be the rule. Therefore management policies should incorporate:

- monitoring of genetic variability in populations that might be susceptible to greater genetic losses;
- reproduction control of farmed fishes and demand of complete sterility (lack of gonadal development, failure to produce fertile gametes or inability to mate) for all types capable of genetic contamination of wild fish populations
- checking for chronic mutagenic effects by using tests that may include the exposure of transgenic fish bearing known DNA sequences to be screened for damage.

However in the formulation of biosafety policy and regulations for living modified organisms, the characteristics of the organisms and of potentially accessible environments should be considered as more important considerations than the processes used to produce those organisms.

More generally speaking, the conference held in Bellagio (Italy) in April 1998 recommended to clearly assign national responsibilities for conservation and sustainable use of aquatic genetic resources among institutions and agencies. It also recommended to develop national curricula which integrate conservation and sustainable use of aquatic genetic resources into all levels of education.

Last, a concern for the protection and reward of knowledge, innovations and practices of indigenous and local communities and individuals is to be raised, together with intellectual property right regimes.

Summary of emerging themes

General features

* Present diversity is a reflection of evolution over a long time scale; we are looking at a "snapshot" in time.
* Estuaries are among the most impacted ecosystems because of close association with humans over long period. They are relatively low diversity habitats compared with the sea but have very high productivity and act as critical nursery areas.
* There are high levels of fish endemism in freshwater systems, and these ecosystems can be viewed as "islands" for several animal groups. These two features contrast to estuarine and marine systems
* Behaviour is now recognised as an agent in speciation.

Threats

* Human activities occur at different scales from local to global.
* Negative impacts of human activities on freshwater and coastal ecosystems are higher than those on marine ecosystems.
* Species introductions (e.g. Lates niloticus, Clarias gariepinus) can have a devastating effect on fish diversity.
* Fishing can alter not only the target species but also the biodiversity structure through direct and indirect effects.
* Release of genetically modified organisms into the wild is another major recent threat (sterile individuals reduce but do not eliminate threat).
* There is a lack of government support for long term studies on biodiversity trends in aquatic ecosystems.

Trends

* Dynamic equilibrium in terms of numbers of species has been altered by humans – in some cases an increase and in others a decrease.
* Habitat loss, alien species introductions, pollution and global climate change are major environmental trends affecting the conservation of biodiversity.
* Use of bioindicators at different levels (individual – ecosystem) and at different time scales (short-term -early warning-, medium and long term) are required to identify trends and inform decision-makers on the consequences of management options.
* Fish are a most suitable bioindicator group because of large existing data sets, scientific knowledge, international recognition as robust indicator, and likelihood of research outputs being used by managers
* Identification of sites (ecosystems) for targeted activities – goal is to create a network of biodiversity sites.

Emerging issues

* Ancient lakes have become an important tool to study fish speciation (species flocks) – these systems acting as natural laboratories.
* The need to better document the loss of species from tropical regions is an emerging issue.
* Another emerging issue is the selection and development of standard methods for biodiversity assessments and comparisons.
* The role of disturbances on biodiversity is a new focus, requiring the ability to distinguish natural from human induced changes.

* The role of dams in breaking biodiversity 'continuity' between freshwater and marine systems needs to be addressed. However the relative impacts of dams established for agriculture/industry versus those established for hydroelectric generation must be distinguished.
* Data management and information flow on an ecosystem and global basis also need to be addressed.
* Aquatic reserves are to play an important role in biodiversity conservation.
* Biodiversity conservation needs "tools" which can be rapidly used and the information conveyed to decision-makers in a user-friendly format. This does not replace the need for regular, long-term monitoring.
* However biodiversity should not be equated to ecological importance; for instance wetlands are ecologically important but often have low species diversity.
* Last, human dimensions is an important component of biodiversity; this covers human/nature relationships, loss of traditional knowledge, food security, population growth and needs, poverty and environmental degradation.

AQUATIC BIODIVERSITY ASSESSMENT: STRATEGIES, METHODS AND TOOLS

Most of the new theoretical and conceptual issues come from terrestrial ecology. Aquatic ecology suffers a lack of theoretical and conceptual formalization of the large amount of knowledge accumulated for many years. Nevertheless obvious differences, similarities exist between terrestrial and marine ecology concepts and approaches, which suggests that agenda of terrestrial biodiversity assessment should be looked at. It would be interesting to consider the recent advances in terrestrial ecology when studying aquatic ecology. Concepts like the well known one of keystone species are now enlarged by concepts of possible keystone ecophases or keystone guilds. Some of the tools in use in terrestrial biodiversity conservation, e.g. reserves, are now applying in marine conservation or restoration.

In 1997, IUCN required sustainability indicators drawn from population biology and life history parameters to be identified, and indices of level of impact to be developed. Indicator species reflect the quality and changes in environmental conditions as well as aspects of community composition. Changes in distributions, abundances and demographic characteristics (population, sex and age structure) of such species may indicate adverse changes in an ecosystem as a whole.

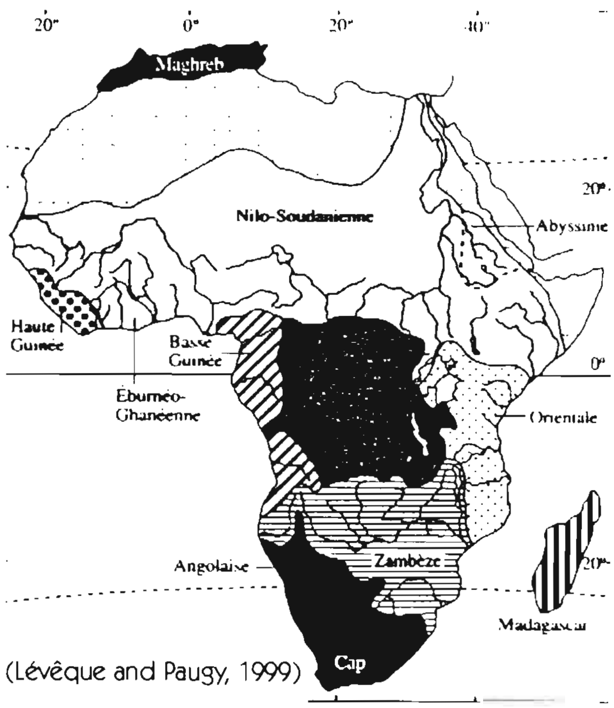
Black holes and information flow

Black holes and the ichtyo-region approach

The regions that were never studied, or where large time gap in information collecting exists, are considered as geographic black holes. Large parts of South America, Central Africa , (Congo, Angola, etc.), South East Asia, China (?) are the main geographic black holes identified during the workshop. It has been noticed that some "known" areas have changed dramatically since they were studied, and have at present time become "new black holes". This emphasize the need for the long time monitoring system.

Some habitat black holes have also been identified among seagrass habitats, rocky littoral habitats, deep sea, offshore water, coral reefs, mangrove ecosystems, wetland.

"The concept of ichtyofaunal provinces proved to be a useful tool for descriptive and comparative purposes (Skelton, 1988) even if it suffers limitation in its applications" (Lévêque, 1997). On the basis of the actual knowledge, it is possible to establish maps of what are or could be the main ichtyo-provinces and what is the "state of the art" in the different ones. It is possible to identify a dozen of ichtyo-provinces in Africa on the basis of similarity of fish fauna in different



(Lévêque and Paugy, 1999)

basins. Ichtyo-provinces give an idea of what can be the expected fauna in a given area. The ichtyo-province concept can help in identifying black holes and planning for sampling where knowledge is markedly weak. The Angolese region, for example, can be considered as a black hole because of the long lasting war, which prevents from any detailed study for a long time.

Ichtyo-provinces and ichtyo-regions are delimitated bio-geographical units of similar biodiversity based on species richness, endemism, taxonomic uniqueness and unusual ecological or evolutionary phenomena. Taking all these points into account leads to the concept of biological distinctiveness recently put forward by the WWF.

A further step inside the ichtyo-province concept is to identify the major habitat types. This can help in giving a status to particular habitat types like main rivers, wetland areas... Moreover, it helps in locating possible refuge zones that must be targeted as possible conservation sites. In other parts of the World, South America for example, the concept of refuge zone may not be applied with the same success depending of the history of fish communities and the geographical morphology of the area under concern. In marine communities, there may be more geographical continuities without obvious frontiers but functional similarities of the assemblages of equivalent fish species in sometimes very distant localities are observed.

Collecting and mapping the existing knowledge allow to identify the more studied regions, those which need further exploration and, finally, those without any information. This has been done (e.g. in Brazil) for different vertebrates and even for chemico-physical parameters. The ecoregion approach was applied in order to identify areas that need priority for conservation. Small areas such as very small coastal rivers may display a very high diversity. Even if biological diversity is not so high, high endemism may be the reason for conservation priority.

In the marine environment, the concept of large marine ecosystems (LME) has similarities with ichtyo-provinces that can be established for inland waters.

There are also "black holes" in the scientific knowledge on 1) Quantitative biodiversity (community structure, population demography, seasonal changes), 2) Life history, 3) Some particular groups of animals (Insects, mammals, sharks...). Attention has been drawn on the lack of knowledge on morphological identification of larvae, a useful information when dealing with nursery areas.

Non-exploited knowledge and information

An other way to fill the knowledge gaps either on inland water biodiversity or coastal and marine biodiversity within less known areas as well as threatened areas is to retrieve forgotten information. This is essential for establishing the state of the art and for further definition of goals and priorities.

Two steps can be distinguished when searching for existing information: firstly, identifying and localizing existing information, secondly, accessing and collecting that information. In fact, most of the existing information is not published, or more often published under a non-accessible form (gray literature, reports from surveys and expeditions...). This is a great waste of work and money, more often from public or international funding. Frequently, all these existing data might need reanalyzing (and evaluation).

Abundant existing information is often ignored. Examples given were those of the many publications in non-european languages and of the traditional/indigenous knowledge.

Some kind of intermediate level of publication should be proposed to help the diffusion of the knowledge not produced in the classical scientific format in order to make it available. This requires the setting up of scientific committees that could guaranty some level of confidence on the published data. These publications could be imagined on the model of some existing international organizations letters or newspapers and/or put on the web.

In some cases like economic crisis or armed conflicts, the existing information is threatened of disappearance. There is a urgent need of action towards the local scientific community in order to enhance its capability to keep the data "alive".

Distribution of existing information

Access to information is a key issue. A high priority should be given to knowledge availability and information flow. A lot of information is stored in museums and in locally published papers; local knowledge exists but remains neglected or unwritten. Making this information accessible at a global level and making use of it should be a priority. Mobilization of existing data is a key instrument for biodiversity strategies, through data base networks (Clearing House Mechanisms), meta-databases, management of these data.

Direct access to information free of charge should be promoted by establishing a network available to everyone at an international level.

Attention should be given to the establishment of a network of institutions and museums regarding the scientific collection of specimens as well as the maintenance of databases. A decentralized organization through a network of databases and museums would let each of the national museum contributes for its own relevant part. This is applied, for example, in the Brazilian network for conservation of biodiversity. Several institutions in North America, Canada, Europe and South America are now participating in this collaborative network.

It is important to avoid centralized systems that give little probability in long term success mainly because rapidly ageing in technology.

Ecological and Biological Indicators

Community structure

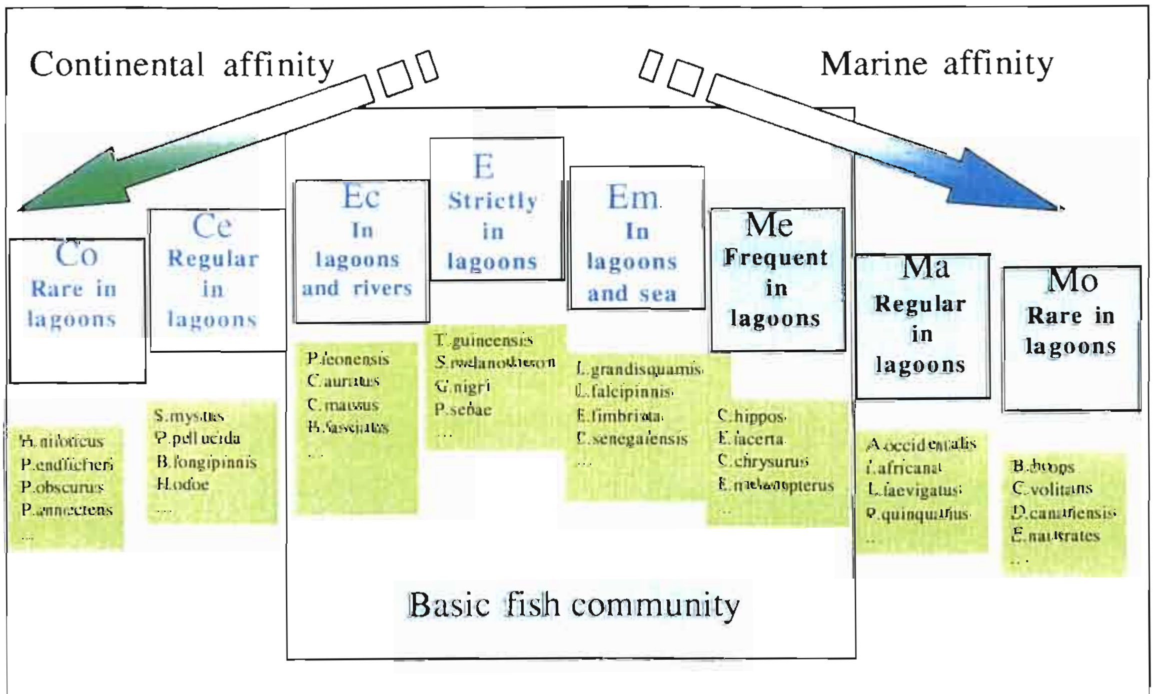
After being dominated by the role of spatial structures, such as Island Biogeography and Landscape Ecology, models in community ecology incorporated the influence of temporal variability. In maintaining populations below the carrying capacity of a habitat, and community far from equilibrium, disturbances have been considered as promoting biological diversity (Connell, 1978 ; Pickett & White, 1985).

Studies on species assemblages, based on various indices or multivariate approaches, intend to provide a tool to maintain self-sustaining communities and their dynamics in the long term. Another challenge is to identify the guilds and the functional groups of organism (important for function and structure). This leads to the concept of key/keystone guilds instead of key/keystone species (Brown & Heske, 1990). The last challenge is to rise an integrated theory of population and community ecology in an ecosystem approach.

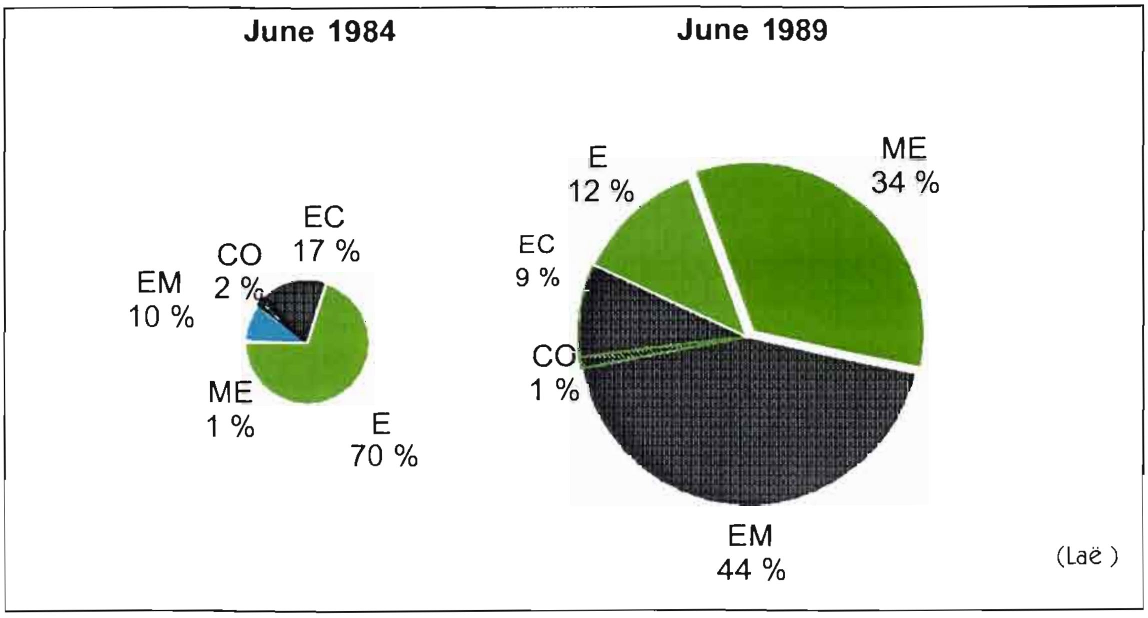
A largely accepted and ancient point of view is that species extinction would be impossible as far as marine species are under concern. A recent review of species disappearance and/or extinction of fish species at sea shows evidence for contemporary, but quite infrequent marine extinction (Robert and Hawkins, 1999). This could be a bias due to the insufficient amount and quality of data related to that topic. These extinctions occurred through many different causes like loss of ecosystem properties, loss or degradation of habitat, competition or predation by an introduced species, over-exploitation. Some cases arose from multiple causes. Species vulnerability may be due to biological properties: long living, slow growing, low reproduction effort, old age at reproduction... Causes may also come from ecological or behavioral characteristics especially weak dispersal abilities, high specialization, fluctuating recruitment, small colonization capabilities... Most of the threats resulting from human interaction with marine fish population certainly lie in the intra-specific loss of diversity. This could lead to less population resilience to stresses and to long term consequences in catches.

Community structure can be assessed in a more multi-dimensional approach. An example is given of a bio-ecological classification of fish species in west African estuaries (Albaret, 1999). Studies on fish communities from many West African estuarine systems were synthesized in so-called bio-ecological categories depending of the origin of the fish species, from marine to continental, the utilization they make of the estuarine environment, from temporary to permanent, the reproductive strategy, from sea spawners to estuarine spawners... (following figure). This allows the kind of results presented in the figure (figure p.27) where comparison of community structure in lake Togo, a Togolese lagoon, is made through these bio-ecological categories between two periods of time. During the first one, the lagoon is closed, during the second one, it is open to the sea. In that figure, the striking shift in the fish community structure, expressed by its relative composition in bio-ecological categories is clearly illustrated.

Ecological approach of the ecosystem shows that interaction strength between species is a key parameter when addressing management and conservation strategies. This leads to the concern on food web complexity and organization. Moreover, most of species do not have any detectable effect on the abundance of other species while a few of them have strong effects (keystones species).



(Albaret, 1999)



Trophic structure

Recent papers in the literature have shown the increasing success of trophodynamic models to assess the evolution of a community (mostly towards a lower average trophic level). However there are discussions about shifts in structure vs. shifts in total productivity, about the time lag for response according to generation time and the necessity to integrate migratory behaviour of upper trophic level predators (Silvert, 1994 ; Robinson & Ware, 1994).

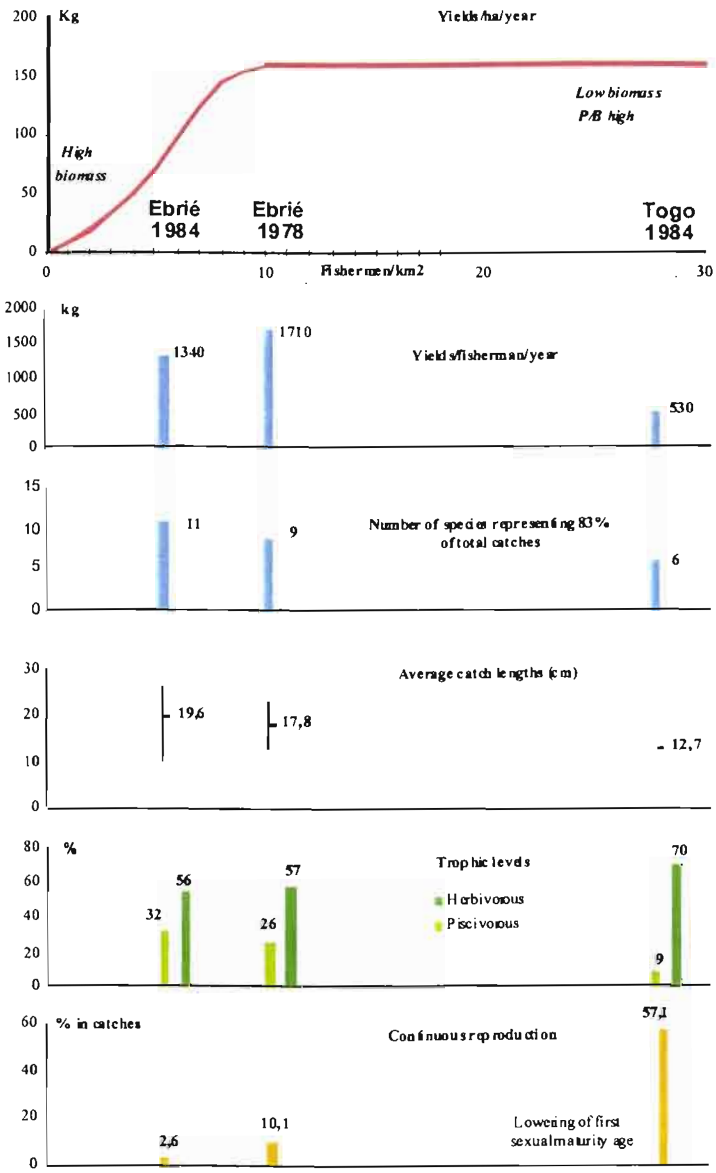
As fisheries are frequently multi-specific in tropical coastal region, one of the greatest effects could be on the overall structure of the community especially when fishing down the food web.

It has been reminded that the lowering of mean trophic level of a fish community under stressing conditions is a well known phenomenon. The general evolution is a decrease in the predators relative abundance and a correlative increase in the abundance of species belonging to the lowest levels, namely herbivorous species. A carefull and thorough study of that kind of fish community response could lead to suitable indicators of environmental change.

Reproductive strategies

In fish the age/size at maturity can change in response to environmental changes (Wootton, 1991) and the shape of the age-size maturation trajectory responds to selection. Can this criterion be fitted to evaluate the stress rate of a community and its exposure to diversity loss?

Evidence can be raised for a diversity of variation of the age at first maturity for a range of species when exposed to environmental perturbation (including fishing pressure). Some species are able to adapt generally through the diminution of their length at first maturity while most of other species cannot do so. Most of the species that are able to adapt belong to the lower food chain levels. This is why it is frequently linked to the lowering of the mean food chain level of the community decreases following the perturbation. The example of West African estuarine ecosystems showed that this could lead to a stabilization of the overall productivity in spite of high fishing pressure in opposition with the classical fishery theory concerning overexploitation (figure p. 28).



Response of fish communities to increasing fishing effort: the example of Ebrié and Togo lagoons
(Laë, 1997)

Fishing yields remain relatively constant even when fishing effort increases threefold beyond the point where the asymptote is reached. In that case, although fish landings are constant, fish biomass declines and CPUE decreases when the number of fishermen increases (from 1700 to 500 kg fisherman-1 year-1). The persistence of high yields can partly be explained by the rejuvenation of fish stocks in which the average length reduced from 19.6 to 12.7 cm. In the same time, the number of species representing 83% of total catches decreased from 11 to 6. The latter suggests an adaptive response of the community trophic level to overfishing by selection of phytophagous or detritivorous species. In terms of life history strategies, continuous reproduction as observed in some species is an important factor enabling these species to remain abundant when all the other species become less abundant when subjected to intensive fishing effort. Finally, continuous reproduction and lowering of the age at first sexual maturity leads to an increase in the number of reproductive cycles each year resulting in a rapid renewal of fish biomass.

The high mortality coefficient observed can be interpreted as an important reduction of the residual biomass. The response of fish communities to high fishing pressure is to reduce the number of species in selecting planktophagous or detritivorous species (Tilapia and Sarotherodon) and predators (Chrysichthys) and to favor species with high reproductive capacities, especially those which have several short-lived annual cohorts. The major adjustment is obtained by shortening trophic chains and this particular point tends to improve the P/B ratio in the fish communities.

Genetics

Molecular Ecology can be defined broadly as the application of molecular genetic markers to problems in Ecology and evolution, encompassing studies on the genetic relationships among individuals, population and species (Carvalho, 1998).

Molecular Ecology thus describes an approach, rather than a discipline, and necessarily incorporates expertises from diverse fields, but most notably from Molecular Biology, population and quantitative Genetics, Ecology, historical Biogeography and Systematics.

The erosion of genetic diversity has been considered as an indicator of loss of biodiversity in a given area. The recent and diversified technical developements provide useful tools in many issues related to conservation biology : Population structure, migration and gene flow, introgression, species identification, systematics, community diversity, stock assessment...

Examples from the literature have been presented to illustrate the interest of molecular ecology : Population structure in West-African tilapias, genetics and conservation of salmonids , of North-American desert fish and gene flow in mosquitos.

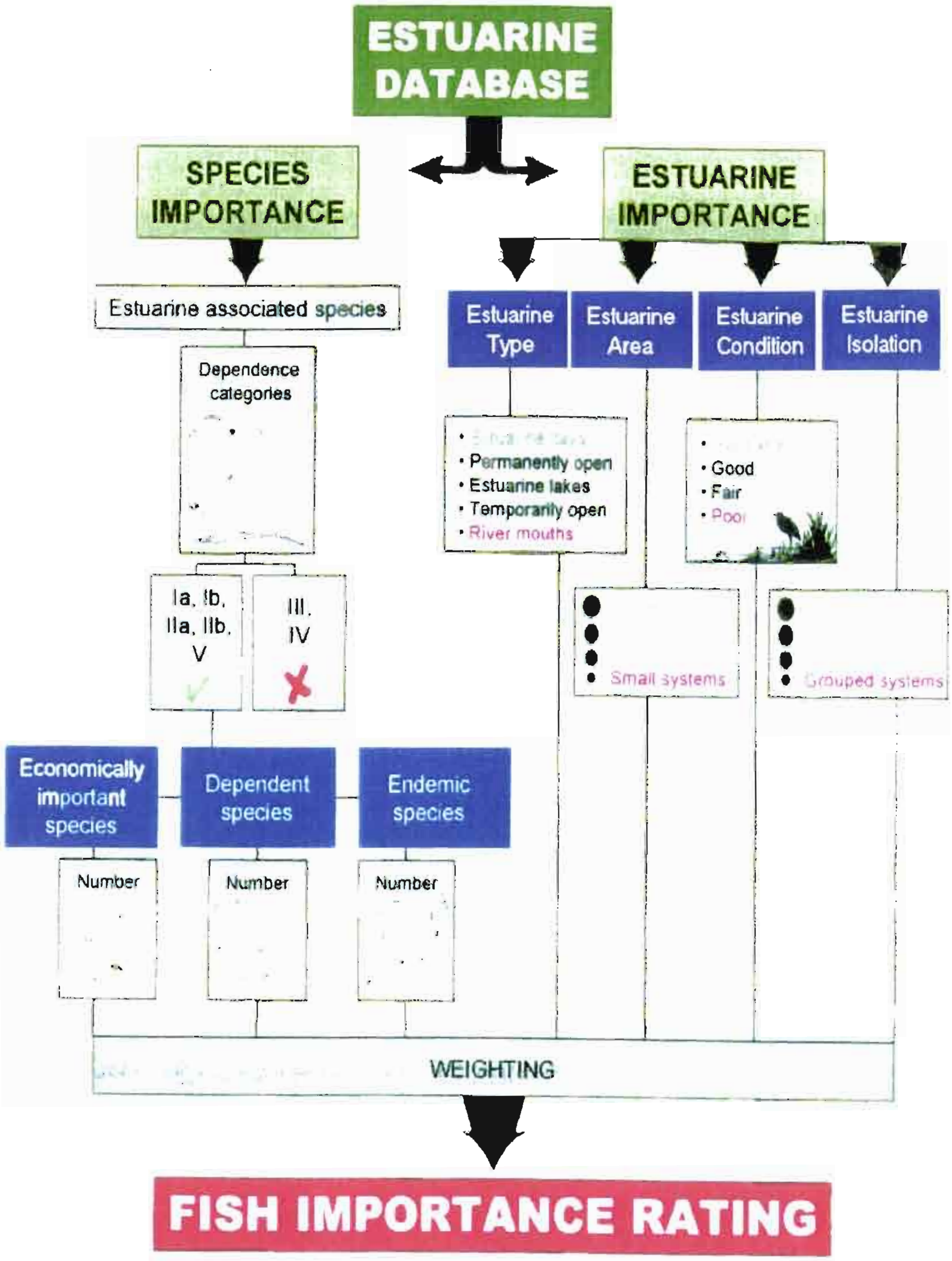
Ibi's and other possible indices

Although largely adopted in stream ecology, Indices of Biotic Integrity (IBIs) seems to have had, until now, low success in estuarine or coastal waters due to environmental variability and lack of reference situation (Deegan *et al.*, 1997). In the marine area these methods could be of interest for local communities such as in coral reefs or in closed areas, but remain problematic for most marine communities due to the open nature of this environment.

One of the major impediment to the use of this method in tropical ecosystems is the lack of the relevant knowledge in taxonomy. This is complicated by the diversity of the bio-geographical context. This implies to take a better account of the concept and definition of ichtyo-provinces. There is also a need for reference situations from high quality ecosystem whatever the type of IBI's in use : Species richness and composition, trophic structure and reproduction, population size, fish abundance and condition. IBI's could be a good tool for the survey of biodiversity in the tropical zone. Before reaching this, there is a urgent need for training researchers from the developing countries involved in these actions, especially in the field of taxonomy. The interest to invest either in the formation of taxonomists and the implementation of research programs or in the building of large museum needs further discussion.

In the case of coastal and estuarine communities, the complex relationship between fish assemblages and the multiple impacted environment strongly suggest that fish communities could be of interest as biological indicators. Fish offer the advantage to be present in almost all kind of aquatic ecosystems. Their response to environmental change is faster than for benthic , mainly sessile, organisms. Most of the fish species present different reactions to the stressing environment, depending of the life stage at which they are. The species as well as the developmental stages different answers to environmental changes is considered as one of the best advantages in using fishes for environmental survey. Difficulties come from the influence of different bio-geographical zones, the ability of fishes to swim away, the seasonality of their occurrence, their sensibility to pollutants and sampling selectivity. Fishes could be used either as biodiversity indicators, or environmental health indicators, or ecosystem importance indicators. These apparently contradictory arguments show that a lot of work remains to do in that field.

A tentative approach of South-African estuaries (figure p.30) was given as a good case study. This was conducted through a careful classification and a typology of estuaries, (functioning characteristics, size,



(Whitfield)

A fish importance rating (FIR) currently under development at the J.L.B. Smith Institute of Ichtyology, Grahamstown. This rating will result in a ranking of South African estuaries in which their importance to estuarine-associated fish species is prioritized.

geographical isolation...). This leads to the setting of an "health index" which can be used at the regional level. In this approach, fish are placed, for aquatic environment, at a level similar to birds in wetlands in the managers and the public consideration, especially when they represent an economic or recreational value. Such a similarity may be an opportunity to **formulate a convention on other aquatic environments similar to the Ramsar convention for wetlands.**

The strength of interactions between species in a community is recognized as the source of resilience, then there is a need for quantification of these interactions. This implies the setting of consistent, comparable and relevant metrics. Some of the possible metrics may be found in three main classes of indices:

- diversity and functional indices, (including strength of species interactions).
- aggregated indicators,(e.g. size spectra).
- new metrics (mean trophic level, food web structure, transfer efficiency,...).

Global rapid assessment methods

Rapid Assessment Methods embrace several of the previous approaches, but constitute a supplementary level of integration and are designed to be quickly efficient.

Standard methods for rapid evaluation of the number of species in a given area have long been used to define rich or depauperate areas (Anon., 1993)

Such an approach has been much developed for the aquatic environment and called AquaRAP. AquaRAP has become a concept where most of the recent international recommendations seem to be taken into account, and could serve as an example.

Automatic methods have also been developed, such as BIORAP. For terrestrial environment the principle is:

1- Acquisition of environmental data (topographic, climatic and other environmental data);
2- Spatial interpolation (of topography and climate);
3- Classification of environmental data;
4- Classification of biological data (a- classification of species based on point records, leading to a prediction of their spatial distributions; b- classification of assemblages of species forming functional units);
5- Prediction of the spatial distributions of species and assemblages. At the end this provides a map of potential location for a given endangered species.

In any case, these methods are basically built on scientific field studies whose results are generalized.

Reef Check is another type of rapid assessment field study involving volunteer divers (tourists and students). It was designed and implemented in 1997 to provide a quick view of the health of reefs over 300 sites in 31 countries and was said to have provided good results relatively to the investment. A similar survey entitled "East coast fish-watch project" focusing on fish was implemented in South Africa and involved SCUBA divers, anglers, aquarists and scientists together.

These methods could be developed for other biotopes (rivers, estuarine and coastal areas, mangroves...). Last, a rapid assessment method is the use of local traditional knowledge. This approach has proven to be successful in several cases (Johannes 1981, 1993, Emery 1997) and despite its limitations can provide information of interest at low cost. Its implementation should be recommended at least as a supplementary investigation method.

Example of the Aquatic Rapid Assessment Programme (AquaRAP)
(excerpt from the web site http://www.conservation.org/rap/aqua/default.htm)

AquaRAP is multinational, multidisciplinary program, devoted to identifying conservation priorities and sustainable management opportunities in freshwater ecosystems in Latin America.

The AquaRAP approach

AquaRAP is based on five key components:

1. A team of scientists in a variety of disciplines, including ichthyology, botany, entomology, macro-invertebrate zoology, limnology, and genetics.
2. A basin or watershed approach
3. A quick, first-cut assessment focused on conservation priorities based on:
   a. The heterogeneity of the habitats
   b. A preliminary survey of the organisms that characterize each of these habitats.
   c. The overall intactness of the habitats, and their capacity to support important biological resources and ecological processes.
4. Build-up of local scientific expertise and institutional capacity
5. Follow-up action
   a. Immediate in-country debriefing
   b. Electronic communication of main findings
   c. A written report
   d. Follow-up meetings

Site-Selection Criteria

1. Primary Criteria
   Habitat heterogeneity (number and types of habitats), habitat uniqueness, level of current threat, conservation potential and opportunity (in light of political and socio-economic factors), degree of fragility, other biological significance (ecological processes).
2. Secondary Criteria
   Endemism, productivity, diversity (species richness), human significance (economic and cultural values of the aquatic system), degree of intactness.
3. Tertiary Criteria
   Ability to generalize (from studies of particular habitats), degree of knowledge.

For a given site each category listed above is classified as high, medium, or low.

Teams of scientists study the biological, physical and, when possible, the anthropological aspects of watersheds, and categorize them on the basis of the 13 criteria listed above. The biological survey is rapid, often involving collection and preservation of specimens for identification, and genetic and bio-contamination analyses.

The activities sequence is next:
- geographical survey (cartography, aerial photography, satellite images, climatic information)
- review of existing information
- setting up of logistics
- collection of samples with multiple gears, in different groups (fish, insects, crustaceans, vegetation)
- identification, writing of reports, training of local scientists

Policy options for a better conservation of aquatic biodiversity

General features

The main challenge ecologists and stakeholders are dealing with is how to manage ever changing nature through the vision and needs of ever changing societies. Ecosystems as well as socio-systems are dynamic concepts. They coexist rather than compete. Both vary in time and space and that contribute to their heterogeneity. Complexity is an impediment to a clear understanding and action. There is a quite obvious dilemma between the need for a static, non-changing, quite definitive management and the ever changing nature of both natural resources and societies. This cannot be approached by static and definitive measures as policy makers and politicians usually do.

Policy cannot be formulated solely on the traditional bases of science. Control, replication and isolation of single causative variables are rarely possible in a multivariate complex system of humanity and nature. The power of science to analyze and predict is further hindered by the non-linear dynamics and the hierarchical, multi-scale operation of such large systems.

It is very important to distinguish the resilience concept from the biodiversity concept. Resilience as well as biodiversity contribute to maintain the integrity of systems. Resilience emerges from cross-scale interaction. Ecological resilience depends upon control of disturbance and regulation of renewal. Biodiversity is one of the factors which contribute to resilience of the ecosystem. Ecological resilience is produced by the abundance and diversity of a variety of factors and processes that operate at different scales. Policy determinations about large, complex systems cannot be made from the perspective of certainty, because society and nature change faster than we can comprehend. Interactions are increasing as human populations and uses expand globally, so policy must address the integrity of society and nature at the same time.

The processes are not linear. Natural systems rarely maintain a predictable course, "They erupt in episodes of transformation" (J. Sendzimir). They may flip between different stability domains. The dynamics of the systems include the probability for disturbance and catastrophes. An important point is that one where systems flip to a different state or not. System integrity has the capacity to absorb disruption and maintain the same kind of ecosystem. This lead to the important concept of resilience. The key issue to address here is to know the amount of disruption required to transform a system.

Disturbance and catastrophes are endogenous to the system. The flip and the disturbance are within its dynamics. The critical point is why the system would stay the same or becomes different when disturbed. Resilience deals with that question of why a system will reorganize as the same system or flip to another stability domain.

Management

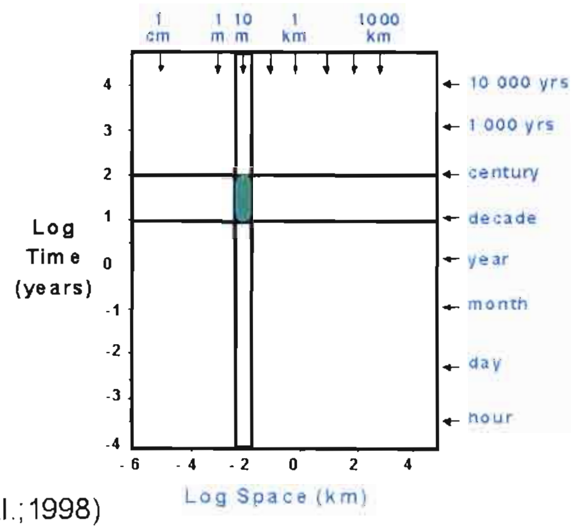
The ecosystem approach, as far as we wish it to be a practical one, must include the incorporation of trans-boundary and cross-sectorial elements for the conservation and sustainable use of biodiversity. This was emphasized by the "1998 ICLARM -FAO Bellagio Conference, 'Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources".

Ecological scaling, spatial and temporal, is essential. Space and time dimensions of the structure under study have to be considered as well as the space time scale of the processes that can interact on these processes. Different sets of processes dominate at different levels and generate different structure characteristic of each scale. The scale of a process is the spatial and temporal frequency of that process.

Ecological scaling

Scale is the spatial and temporal frequency of a process or structure.

A scale domain is bounded by the grain size of processes detected and the extent or span of processes attended.



(from Peterson et al.; 1998)

Controlling the level of disturbance can be achieved through control of disturbance frequency and intensity, landscape morphometry, habitat availability, cross-scale functional reinforcement, within-scale functional diversity. Example is given of landscape morphometry that can let the ecosystem be more resilient to flooding damage when one allows them to stay as they were formed by the floods.

Basic uncertainty emerging from nature is compounded by continuous and new sources of change created by society's attempts to learn and manage. **We need adaptive means to understand and implement that flexibly integrate theory and practice as we follow changes in nature and society**.

Policies conceived and applied as solutions have tended to freeze our capacity to adapt our understanding or our management activities. Policies should be formulated and applied as tests of hypotheses, therefore management actions become treatments in an experiment.

There is now a lot of experiences which have been made at different scales and levels, in different situations, with different ranges of participatory implications. The diversity of experiments offers the opportunity for everybody acting in the conservation of biodiversity and sustainable development to learn new approaches. This is particularly true for those who have responsibilities at a global level.

As well as the problems are dynamics, solutions must be.

Valuation, economic issues

From an economy point of view, despite the difficulty to assess the value of biodiversity, an attempt is necessary to set priorities and design policies. Most approaches to the valuation of non-traded goods and services are based on people's willingness to pay (WTP) and willingness to accept (WTA e.g., Pearce and Turner, 1990 ; Costanza *et al.*, 1997). Alternatives to this approach include the estimation of trade-offs with alternative activities which can be valued (for example what would be the opportunity cost of conserving biodiversity in rather than commercial exploitation (Hambrey, 1996), and damage schedule approaches (Knetsch, 1994 ; Chuenpagdee, 1996).

Most of decision makers do not want to place their objectives in the natural conservation agenda but the natural management in their own agenda

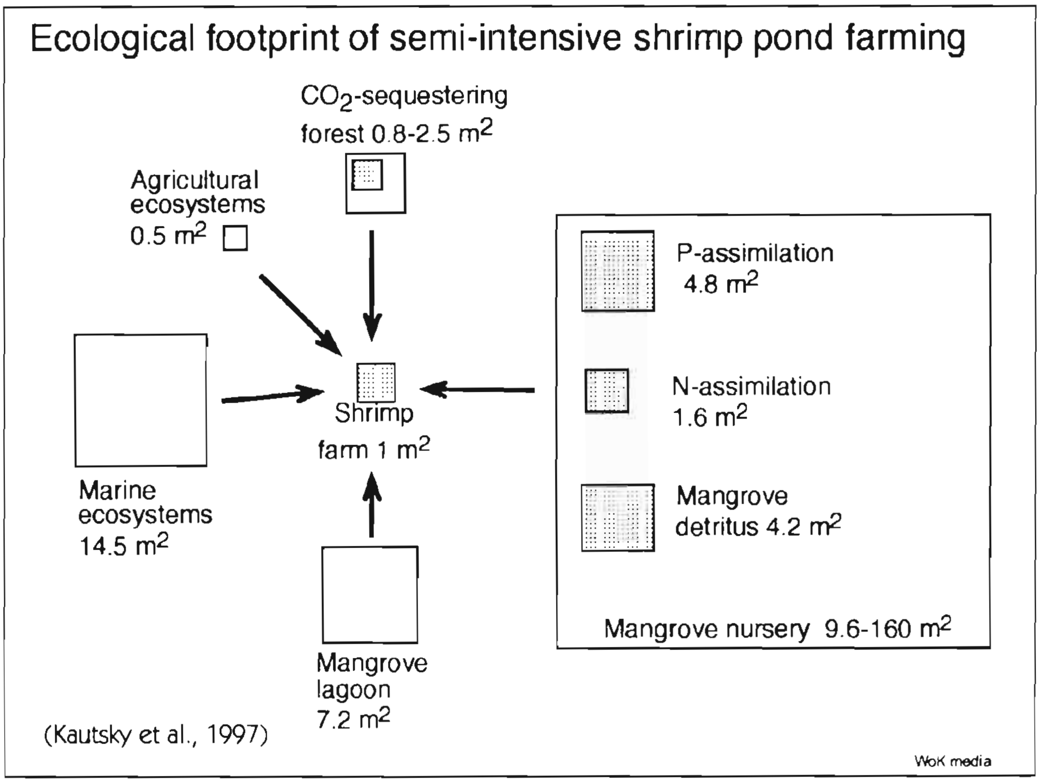
There is a great risk when ecosystem analysis are on incomplete ecological understanding . Economic valuation has the potential of highlighting this risk. The example given is the one of mangrove systems. Mangrove are one of the most productive aquatic ecosystems, as shows the fishermen density in the mangroves which is higher than in any other fishery system. This underlined the importance of the mangroves as a source of food and income. More than 50% of the world's mangroves have gone.

One of the many driving forces which leads to mangrove loss is under-valuation. Under appreciation of the economic value of this ecosystem and the goods and services that it generates and supports. Two main background forces drive this, the first one is the difficulty in assigning monetary value on these goods and services. Some goods and services would be harvested outside of the physical boundary of the mangrove. Many goods and services don't have a clear role or a clear value in the traditional market economy. The second force is the lack of ecological knowledge among valuators and decision makers which is partly due to the lack of interest. But more important is the inability among scientists, biologists as well as ecologists, to communicate knowledge and findings and to quantify this information in a way that is comprehensible by social scientists, by valuators and decision makers, etc

Identifying mangrove support to fisheries needs to have a clear view of the function of mangrove. Many fish and shellfish species utilize mangrove either as permanent or temporary habitat. An example of the second ones are the peneids shrimps which immigrated into mangrove habitat as larvae, post larvae and spend a few month in the mangrove system before to emigrate offshore in order to achieve their life cycle. This last type of species is usually harvested in the nearshore/offshore areas. Valuators needs to have a good knowledge on life history migrations of these species in order to value the fishery support from mangroves. One hectare of mangrove can support an average fishery of 162 kg of these shrimps (figure p.36).

Ecological footprinting was introduced as a means of demonstrating the spatial influence of human activities, whether at a large or small scale, on the surrounding environment. In this manner it may be possible to illustrate the cost of supporting such activities. It also raises the difficult concept of measuring the value of biodiversity to humans.

It has been stated that an unbiased valuation of biodiversity should also include the possible negative economic effects of biodiversity conservation.



Resource use practices

Adaptive management could be a suitable approach to the need of conserving biodiversity in the way of a new exploitation scheme integrative of sustainability and long lasting resilience of natural resources and ecosystem which shelters those resources. if one gets away from the idea that there is only one solution, only one reason why the system works as it does, then, one of the advantages of adaptive management is that one can come up with five maybe ten equally plausible hypotheses. There is not ONE solution, but 4 or 5 for every problem. People do not like this complexity. Uncertainty and surprise are inevitable, so structured learning is a very useful way to winnow uncertainty. Adaptive management offers a flexible framework to understand and act in the face of uncertainty.

Traditional knowledge

Keystone species are frequently socially selected, sacred, species in traditional societies. They are often associated with sacred landscapes. The value of that is in the linkage between the ecosystem and/or landscape management and the society.

Traditional management breaks down because of population increase and breakage of traditional social structures.

There are reasons to believe, on the basis of preliminary studies, that such an approach will give ample rewards for effective management of mangrove ecosystems with developmental concerns linked with the traditional societies associated with them.

Traditional societies tend to be much more holistic in their approach towards ecosystem/landscape management, but for disruptions caused by outside pressures on nature and natural resources.

Participatory strategies

After a period when protected areas were conceived as " places without people " (leading to conflicts between conservationists and local populations), the current trend is to allow human activity in protected area ("Joint management", Schelhas & Shaw, 1995 ; Kothari *et al.*, 1995). This reflects a new alliance between conservationists and local communities against the urban-industrial economy, and a search for a better balance among competing interests.

There is a need for integration of the ecological and the social approach as both nature and society are always changing. Societies are part of the ecosystem they exploit, man are one of the numerous species interacting in the global process of natural resource production.

Participatory methods might meet suffer from two basic impediments First, they reflect a certain point of view on nature, not necessarily shared. Second, the time scale of funding agencies is not that of the local population, and local involvement needs time (Lewis, 1996).

Can experience drawn from success stories allow to set appropriate time schedules for co-management projects?

It is also noteworthy that quantified evaluations in "successful stories" are particularly scarce despite their considerable interest in convincing decision-makers. This aspect of case studies should be better promoted, for instance through a workshop focusing on such quantified success stories

Education, capacity building and awareness

It is important to develop national curricula which integrate conservation and sustainable use of aquatic resources into all levels of education, and to ensure international sharing of knowledge and methods through the Clearing House Mechanism and other appropriate mechanism, including among local communities.

Capacity building should be an important activity and should be taken up on priority basis and should based on action-oriented research plan with participation of all actors right from the planning phase.

The implementation of biodiversity management and monitoring programs, data collation and management, and linkage with sustainable development options and opportunities provides a major investment in capacity and capability. The latter was considered a major priority.

Specific statements in relation to training included linkage and relationship to local situations and programs; difficulty of applying training when 'back-on-the-job'; provide technology transfer to local communities; provide technology transfer between technical sectors; assist the provision of 'in-country' training through well-equipped local institutions; provide training at sites appropriate to the trainees and the issues they will face in the future.

The involvement of local communities is often addressed on a 'top-down' basis, partly due to expediency, but that is only a short-term excuse. Greater direct linkage with local communities has been encouraged under previous discussions, but not elaborated in most instances.

Strategies to develop greater awareness by local communities could lead to 'biodiversity-technocrats' receiving support for the hitherto elusive goal of establishing and maintaining a 'global' network of long-term monitoring programs.

Legislation

Environmental legislation as well as underlying concepts are evolving quickly, therefore a future workshop on this particular topic seems to be of major interest. It would also be in agreement with recommendations of recent meetings on biodiversity (e.g.; Resolution VII.7 of Ramsar COP7).

Main Emerging issues

What could one do in order to provide for integrative landscape management involving community participation?

- Problem solving should involve multidisciplinary approach within and between natural and social sciences;
- Documenting traditional ecological knowledge both at process and systems levels with a view to utilizing it as one of the important basis for natural resource management strategy;
- Creation of appropriate institutional arrangements at different levels for ensuring community participation and also for involving other stakeholders;
- Alternative pathways for land use development, which aims at strengthening internal processes within human-managed ecosystems, rather than that emphasizes upon external energy subsidies should be explored.
- Integrate conservation and sustainable use of aquatic genetic resources into educational curricula;
- Assign national institutional responsibilities for conservation and sustainable use of aquatic genetic resources;
- Biosafety debate needs to be broadened to include alien aquatic species and genotypes not just genetically modified organisms;
- Develop policies and practices for sharing monetary and non-monetary benefits, e.g. for aquatic genetic resources found outside national jurisdictions;
- International liability provisions for damage to aquatic genetic resources;
- Economic valuation of natural resource and ecological services has the potential to illuminate the value of viable ecosystems; this may provide a financial incentive to their conservation and management;
- Capacity building should be an important activity and should be taken up on priority basis and should based on action-oriented research plan with participation of all actors right from the planning face;
- The destructive potential of any scale of natural resource exploitation should be carefully evaluated;
- Make scientific information available to local communities to create environmental awareness and to policy planners for action, in a language that they can understand and appreciate.

Policy dimension of biodiversity conservation

In the ultimate analysis, the objective is to develop strategies for sustainable livelihood concerns of the custodians of biodiversity as a short term strategy and a sustainable development plan on a long-term basis.

Long-term strategy

The emphasis should aim at evolving a loosely coupled landscape management strategy to reduce vulnerability of ecosystems to uncertainties in the environment/society that are inevitable. This approach necessarily will have to be based upon a flexible, information sensitive, smaller-scale operations that encourage heterogeneity that buffers the environmental ill-effects of human activity, both in space and time. Such an approach should aim at integrating conservation with sustainable development of the region concerned.

Short-term strategy

Realizing that much of the biodiversity is concentrated in the developing tropical world, it becomes necessary to have short objectives that are feasible in the context in which traditional societies operate – social, economic and cultural dimensions – and the societal perceptions of biodiversity in this context. Here traditional ecological knowledge and technologies have a role to play in providing an incremental pathway for sustainable livelihood where traditional societies, who have been the custodians of the biodiversity. Such an approach could then contribute to the long-term strategy for a loosely-coupled landscape management based on modern scientific inputs.

METHODOLOGIES AND TOOLS TO MITIGATE ADVERSE CHANGE IN A GLOBAL APPROACH OF BIODIVERSITY MANAGEMENT

There are many and varied techniques currently in use, being refined or developed. Many of the latter are sophisticated and possibly expensive, but that does not mean that all effective techniques are expensive – sophistication does not need to equate with expense.

Early Warning

Early Warning indicators can be defined as "the measurable biological, physical or chemical responses to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest" (Van Dam et al., 1999 ; Ramsar COP-7). An Early Warning indicator is only useful if the information is used within a management process. It implies a precautionary approach and intervention before harm occurs.

An Early Warning indicator should be: anticipatory, sensitive, broadly applicable, correlated to actual environmental effects, timely and cost-effective, regionally or nationally relevant, socially relevant, easy to measure, constant in space and time and non-destructive (Noss 1990, Ramsar COP-7).

Three broad categories of Early Warning systems have been defined:
- Rapid response toxicity tests (laboratory toxicity bioassays)
- Field Early Warning tests (used to measure responses or patterns in the field; e.g.: in situ toxicity assessment; phytoplankton monitoring; biomarkers from animals or plants collected in situ;...)
- rapid assessments (example detailed in § 3).

These categories for detecting adverse change in relation to water pollution can be detailed as follows:

<u>a. Rapid response toxicity tests</u>
- Laboratory-based toxicity assessments: It has been emphasized that it was much preferable to use local organisms, which is not usually the case because of the lack of sufficient taxonomy or ecological knowledge. So, "imported species" are often used.
- Sensitive whole organisms responses (e.g. growth, reproduction).
- Rapid turn-around of results.
- Predictive tests (e.g. for setting safe dilutions).
- Ecological relevance of these test has not generally been shown and should always been checked.

<u>b. Field Early Warning tests</u>
- Field-based measurements.
- Sensitive sub-lethal organism responses.
- Pre-emptive or preventative to avoid substantial impacts.
- Ecological relevance has not generally been shown.

<u>c. Rapid assessments</u>
- Can be standardized, rapid and cost-effective.
- Provide a 'first-pass' assessment of the ecological condition of a site.
- Can be used to identify 'hot-spots'.

- Output is coarse and generally only detects relatively severe impacts.
- Ecological relevance at the community level is very high.

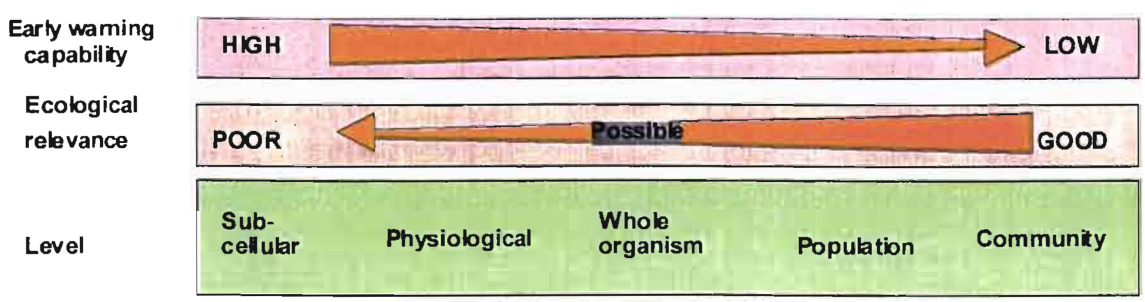
In aquatic ecosystems, several taxa have been considered for purposes of Early Warning:

- Phytoplankton monitoring (species composition and size assemblage shifts) is considered as of particular interest. Diatoms also seem to be relevant bioindicators of water quality changes, but the profusion of quantification methods and indices and the lack of systematised protocols are an impediment to their generalization. Systematics in tropical environments might be another one.
- Macrophytes are efficient to detect eutrophication, organic pollution, and for long term monitoring. However they do not meet the requirement of Early Warning indicators.
- Macroinvertebrates are a responsive tool for detection of environmental changes, but a major problem lies in their systematics. This is particularly noticeable in tropical regions where macroinvertebrates species diversity is huge and the ecological knowledge about species not as developed as required.
- Fish are considered as an interesting tool as they integrate adverse effects of multiple stresses on other components of aquatic systems such as plankton and macroinvertebrates on which they depend. Over the monitoring of diversity solely, that was proven to be insufficient, the most promising tool is the Index of Biological Integrity (IBI), but mainly for freshwater stream communities (see § 3).

To date the majority of Early Warning techniques have been developed to assess the impacts of chemicals on aquatic ecosystems, but relevant indicators for the other ecological changes still remain to be developed. As a matter of fact a genetic or toxicological study at the individual level can be of interest in terms of pollution threats; however it is not relevant for other threats such as channelization of streams, mangrove deforestation or bycatch the impacts of which are felt at the population, community or ecosystem level.

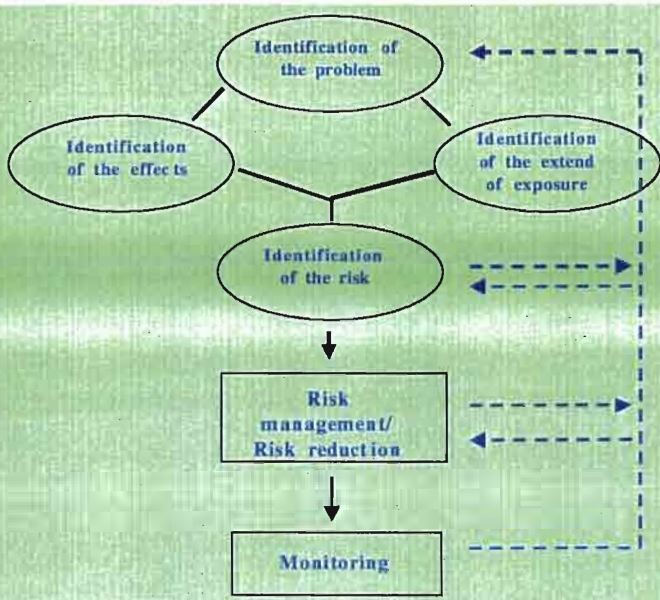
It has been emphasized during the workshop that Early Warning Systems have been mainly developed for pollution but not or seldom for other threats like exotic species. Nothing really exists for Early Warning Systems of habitat destruction which is also quite a difficult case. Time scales are very different according to the type of threats (days for pollution, years for habitat loss).

It has also been reminded that Early Warning Systems provide an indication that there is a problem but they do not solve the problem. Early Warning is only one aspect of a monitoring program.



Wetland risk assessment

M.Finlayson



(Van Dam *et al.*, 1999)

The Ramsar Wetland Convention has adopted the concept of 'Early Warning systems' and provided a 'wetland risk assessment' framework for their application. This emphasises a linkage to management processes.

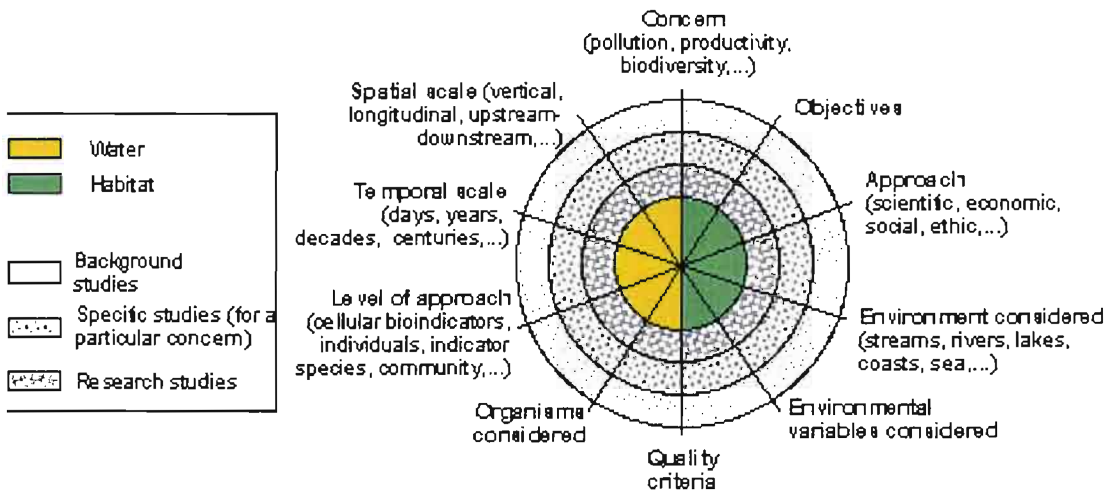
Following the Ramsar Convention the "Ecological character of a wetland is the sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions which maintain the wetland and its products, functions, and attributes." and "Change in ecological character is the impairment or imbalance in any biological, physical, or chemical components of the ecosystem, or in their interactions which maintain the wetland and its products, functions and attributes."

A framework has been presented for assessing likely change in wetlands using Early Warning indicators. It was underlined that wetland risk assessment is based on the assumption that 'adverse change' or 'harm' has been defined or agreed which is not often the case.

The risk assessment framework contains 6 sequential steps:

1. Identification of the problem, including what is being or should be protected.
   - Chemical : describe the chemical and its effect, what is likely to happen.
   - Invasive species : describe the species and its effect.
2. Identification of the effects, determine the seriousness of the problem.
   - Chemical : on-site ecotoxicological tests.
   - Invasive species : on-site mapping and observations.
3. Identification of the extent : determine how far the problem could spread.
   - Chemical : rate of input and dispersion into the environment.
   - Invasive species : rate of spread and habitat preference.
4. Identification of the risk : integrate the previous information on a large scale through GIS and/or relational databases in order to show spatial aspects and linkages.
5. Risk management and reduction : decisions to manage the problem.
   - Takes account of socio-economic, political and technological factors.
   - Who takes the responsibility, who does what?
6. Monitoring : verify the effectiveness of the management steps.
   - Hypothesis based : assumes that 'harm' has been defined.
   - Provides Early Warning of adverse 'harm'.

The figure (*Adapted from Meybeck, 1994*) shows the multiplicity of foci, approaches, factors, levels and scales included within the concept of Early Warning and lists the different steps to be considered when implementing an Early Warning system. To make it operational each step requires choices or options, often driven by the context. Furthermore, these options depend on the acuteness of the level of concern (monitoring, specific studies or research). Last, they are different whether the water or the habitat is considered.



Any Early Warning system is only related to some of the possible combinations listed here. Given this diversity, promotion of Early Warning systems necessarily requires contextualisation, and clear definition of choices (in terms of concerns, objectives, quality criteria and scales). From an applied point of view, this makes the implementation of Early Warning systems a corollary of the identification of "hot spots".

Information flow

Considerable progress in the field of information flow comes from the Clearing House Mechanism and its achievements. The aim is to facilitate the building of national capacity for biodiversity data management and exchange, particularly in developing countries.

When considered from the basis, several questions arise from an overview of this topic:

- Assessment of available information

Assess the cryptic existing information, particularly biological data (e.g. in South East Asia where scientific surveys have been led for years but whose results remain unpublished)?

- Accessibility of the information

IPCC (Intergovernmental Panel on Climate Change) information network is considered as a good example.

Some NGOs in Africa work to make local scientific paper journals or publications available on Internet.

Last, considering Internet as a major communication tool is not relevant in most of developing countries where connections are not possible yet or prohibitive. Alternatives should be suggested, for instance, CD-ROMs of e-documents (those available on Internet) could be a good/realistic solution for isolated researchers

The information flow is not only a scientific concem, but is also of importance to managers and decision-makers. However it can be noted that communication between operating bodies is often lacking ("Each agency acts as if it is the only flower facing the sun"). This may be due, among others, to a frequent division of responsibilities between inland and marine/coastal fisheries management bodies (e.g. for Southeast Asia: World Bank 1991).

The BDM, (Biodiversity Data Management Project), a GEF funded project, was initiated by UNEP and the World Conservation Monitoring Centre (WCMC) to contribute to raise the profile of biodiversity information into the decision-making processes as required by the Convention on Biological Diversity (CBD). Focusing on developing countries and initially on the biodiversity data compiled in the country studies, it aims to mobilize these data as a key instrument in building enhanced national capacity for planning biodiversity strategies and actions for conservation and sustainable use.

Integration of information

Advances in GIS technology and applications can be applied to data collation and management, and also resource management. Practical and applied examples are available and being used to provide assessments and to formulate further questions. Such applied applications provide a justification for the investment in GIS.

Steps that could contribute towards the development of aquatic database creation include: regional workshops to involve key stakeholders; global networks at a meta-data level; identification of issues and questions; identification of beneficiaries; clarification of processes and uses; creation of a sustainable database; and elaboration and demonstration of applications.

The provision and adequacy of training in GIS operation and data collection was discussed. A balance between the provision of GIS capacity and the capability to make effective use of this was also considered. The latter incorporated concern over the processes being driven by technological capability rather than clear elaboration of priority needs.

Data integration and elaboration can assist with the clear identification of causes and effects, and enable intelligent choices for monitoring, including Early Waming and long-term trend analyses. These are both integral components of the 'management' process, but it is not always clear that the iterative mechanisms between management agencies, researchers and the community are effective.

Consideration has been given to methodological, technical and institutional implications of biodiversity management based on the use of information systems, databases and georeferenced databases at regional and global levels. At world and regional scales, species are represented by biogeographic zones, large marine ecosystems, ecoregions, ichthyoregions, and by habitats, communities, assemblages etc. at smaller scale. Inventorying biodiversity means surveying, cataloguing, quantifying and mapping such entities as well as others such as genes, individuals, populations. The framework proposed for monitoring biodiversity would consist of inventories carried out over time and space. It is aiming at predicting the behaviour of key variables and at improving management through options analysis and Early Warning of changes in biodiversity. Data and information are therefore required, as well as for identification of interactions between factors and for problems identification and solving.

Sustainable aquatic biodiversity is a concept which involves integrated and global approaches and requires information technology tools for data management such as Information Systems (IS), RDBMS

(Relational Databases Management Systems), OO-DBMS (Object-Oriented Databases Management Systems), GIS (Geographical Information Systems) etc. Complex data is the main feature of databases on aquatic biodiversity : they are composed of biological and ecological data on living resources, aquatic environment, surveys, economic activities, remotely sensed data, geo-referenced data at different scales, qualitative and quantitative information, data imported from external sources, etc. Quantitative information is essential as it derives from the integration of measurements and observations which allows identification of the nature, level and speed of changes in biodiversity. For understanding inter-annual changes and multi-annual trends, consistent long-term databases are therefore critical. Combining information on aquatic biodiversity from different sectors and sources implies also association of data in meta-databases which will allow to organize and maintain associated data for use in integrative tools and models on an ecosystem framework.

Regional databases on aquatic biodiversity should be created because of the broad scale of distribution of aquatic species, populations, assemblages and resources. Exploited marine species/resources are often shared among countries and their management across geographical and political boundaries requires regional or international bodies which mandate is to monitor the state of exploitation of the resources, the " health " of the aquatic ecosystems and to provide management advises. Data and information are essential for technical activities e.g. development of GIS applications, of Early Warning systems, organization of working groups and training sessions etc., on subjects of regional and international concerns.

Development of information systems (IS) which would include regional databases and GIS components on aquatic biodiversity is therefore needed. Such information systems would provide conceptual and computational " tool box " for storing, analyzing (e.g. multivariate statistical analysis) and viewing biodiversity data. Information systems on aquatic biodiversity should be specifically designed to transform satellite imagery, surveys and bioecological data into visual products (maps, charts, graphs, etc.) and statistical products that will aid in monitoring and managing biodiversity. Information systems and tools should be defined at the early stage of the biodiversity conservation programme but questions and issues raised by the end-users, with their own objectives and constraints, will provide guidance to their development. The main users are research institutions and governmental authorities, but in the broadest sense information systems would enhance communication between researchers, decision-makers and aquatic ecosystems users and provide quick access to information – e.g. through global networking (meta-databases) - on the status of aquatic biodiversity at regional and global scales.

Attention was drawn on the many examples of misuses of GIS, especially when the quality of the input data in use is problematic. Furthermore, current softwares require lots of learning investment.

Mitigation of genetic impact

Two of the main genetic threats on wild fish populations come from introduction of alien species and from aquaculture. In the last case, that threats is could also be linked with transgenic fish.

Introduction of alien species can occur either accidentally, during transportation, trade..., or intentionally for pest control, from tropical pet fish import, to improve productivity in aquaculture. Alien species contribute for almost 70% of the global fish production but significative ecosystemic effects of these introductions have been recorded in only 11% of the cases. 65% of these cases led to established populations.

Several possible genetics impacts can be recognized : Genetic erosion; Genetic contamination; Genetic deterioration. Reconciling biodiversity conservation with aquaculture was presented in terms of steps to prevent accidental introductions or escape of fertile species to the environment. Current policies to prevent such cases utilize risk and cost benefit analyses, and national registers of introductions. But consideration for the benefit may induced overlooking of the risk. More effective policy requires reproductive and physical containment of alien species.

As most of the problems come from the risk of gene transfer when possible mating with transgenic fish exists, a range of technical solutions can be proposed:

- Reproductive segregation. Obviously the best way but difficult to obtain when great number of transgenic fishes are produced.
- Physical confinement. Does not always prevent from accidental escaping.
- Climatic incompatibility. Species who do not survive when escaping.
- Metabolic inadequacy. Fish require some nutriment not existing in the wild (but no transgenic fish exhibit such characteristic).
- Sterile transgenic hybrids.

Transgenic processes (gene transfer) could be used for environmental protection including: transgenic fish to monitor for mutations; complement ecotoxicological phenotypic tests with genotypic tests; and conserve domestic stock through vaccination developed by transgenesis.

Parks and reserves

General considerations

Today, protected areas are widely considered as an efficient tool for preserving biodiversity, as well as productivity of certain zones. IUCN has defined different categories of protected areas corresponding to increasing degree of human presence and intervention (IUCN 1994).

> *Jakarta mandate on marine and coastal biological diversity*
>
> *Programme element 3, on Marine and Coastal Protected Areas, is composed of two operational objectives:*
>
> *- Operational objective 3.1: To facilitate research and monitoring activities related to the value and the effects of marine and coastal protected areas or similarly restricted management areas on sustainable use of marine and coastal living resources;*
>
> *- Operational objective 3.2: To develop criteria for the establishment of, and for management aspects of, marine and coastal protected areas.*

The recent trend has been to combine conservation and development aspects, with regard to local communities' needs.

When implementing or developing a reserve system in a given country, several questions have to be addressed: Objectives of the reserves; Number and size of reserves; Location; Practical design; Temporary or permanent protection; Social concerns.

Reserves to be implemented might have different and conflicting objectives:
- Maintain biodiversity (species richness and/or target populations and/or genetic pool)
- Maintain the functioning of a given system and/or ecological functions
- Maintain habitats and their natural dynamics including perturbations (overflows, high tides,...)
- Maintain productivity

Bohnsack (1996) listed the usual arguments in favour of Marine Fishery Reserves (MFRs) and documented advantages of such reserves in a reef environment:

Argument	Documented Advantages
MFRs increase the abundance (density) and average size of exploited species inside them	yes
MFRs protect biodiversity	yes, species richness specially for species vulnerable to fishing
MFRs maintain fishery sustainability	probably
MFRs provide migrants to surrounding areas	no direct evidence
MFRs enhance fecundity	difficult to answer " in principle, aquatic reserves can serve as protection against the directional changes in genetic variability that can result from traditional practises "
MFRs export larvae to surrounding areas	probably but no direct evidence
MFRs genetically protect stocks	no direct test
MFRs provide biological reference areas	permit to distinguish the effects of fishing from the human impact
MFRs do not protect highly migratory species	sometimes resident in protected areas

An array detailing the relative interest of the different types of reserves can be of interest when deciding to implement a new one:

	Conservation system				
Targets	Protected parks	Exploited reserves	Conservation in wild areas	Zoo parks	Restoration projects
Ecosystem					
Processes	3	2	2	2	2
Societies	1	3	2	1	2
Biogeographic assemblages	3	2	2	2	1
Endemic species	3	2	2	2	1
Local populations	3	2	2	2	1
Inter-species genetic variation					
Wild relatives of domesticates	3	2	2	1	1
Non-economic genetic variation	3	2	2	1	1
Total score	19	15	14	11	9

Modified after Soulé 1992

3	High interest
2	Moderate interest
1	Low interest

SLOSS: " Single Large reserve Or Several Small reserves" (?)

The question about the number/dimensions of reserves is controversial:

Determining optimum size and number of reserves requires an understanding of the home range and habitat requirements of the target species. The majority of fishes associated with reefs are relatively sedentary, remaining in a small area for most of their life. According to several studies (Brown, 1997 for Asia, and Shepherd & Brown, 1993 for Australia) small reserve can protect significant populations with a minimum viable size between 1-3 km^2. When colonization rates are high (species with high dispersal abilities), several small reserves seem to be also more efficient than a single one (Goodman, 1987). Although a single reserve may not protect all life stages of a species (i.e. coastal and estuarine species), other authors suggested that large areas may be needed to protect more mobile species. Moreover, in small areas genetic variability and vitality can be eroded by inbreeding and genetic drift (concept of minimum viable population MVP).

The size of reserves also has a psychological dimension: apparently when more than 20% of a fishing ground is being protected, local fishermen consider it as too restrictive to their activity; when less than 10% is protected, this does not seem to be significant to fishermen, and 10% seems to be a good compromise between restrictive access and consciousness of a protective measure (Kapetsky & Bartley, 1995).

Conserving small populations: Population and quantitative Genetics issues

The problem of conserving small populations in fragmented habitats using quantitative population genetics was presented as an option. However, it needed further development to be established as an active conservation mechanism.

An overview of theoretical and empirical results in quantitative Genetics provides some insight into the critical population size below which species begin to experience genetic problems that exacerbate the risk of extinction. Populations that regularly contain fewer than 100 reproductive individuals are extremely vulnerable to deleterious mutation accumulation. Security for long-term deleterious-mutation degradation requires a harmonic mean population size of at least 1,000 reproductive adults.

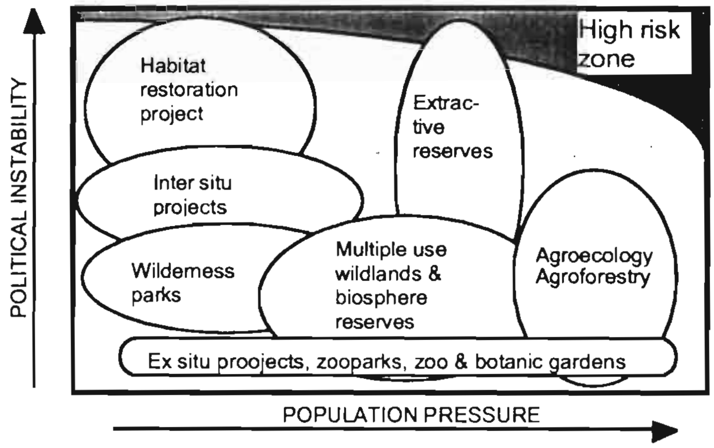
Current national and international policies are such that endangered species are usually only endowed with formal protection after their total census number has dwindled to several hundred or fewer individuals. Based on the aforementioned, such population sizes are two to three orders of magnitude below the point at which the genetic integrity of species begins to be at risk. Thus, on genetic grounds alone, there is a need for much higher standards in the protection of species.

Social issues

When formulating or designing a new reserve, the social concerns should be clearly formulated and objectives set. This could imply a deepening of prior sociological and economic researches (What are the resources/services/incomes expected to improve the welfare of local populations? How can they be evaluated? What is expected "improvement", from local populations' point of view?...).

Another concern is the socio-political context in which a new reserve shall be implemented. Soulé (1992) suggests the following framework, open to discussion:

Last, privately owned protected areas may avoid many of the constraints and difficulties of government-run areas or those on communal lands. In some countries, such areas make a significant and self-financing



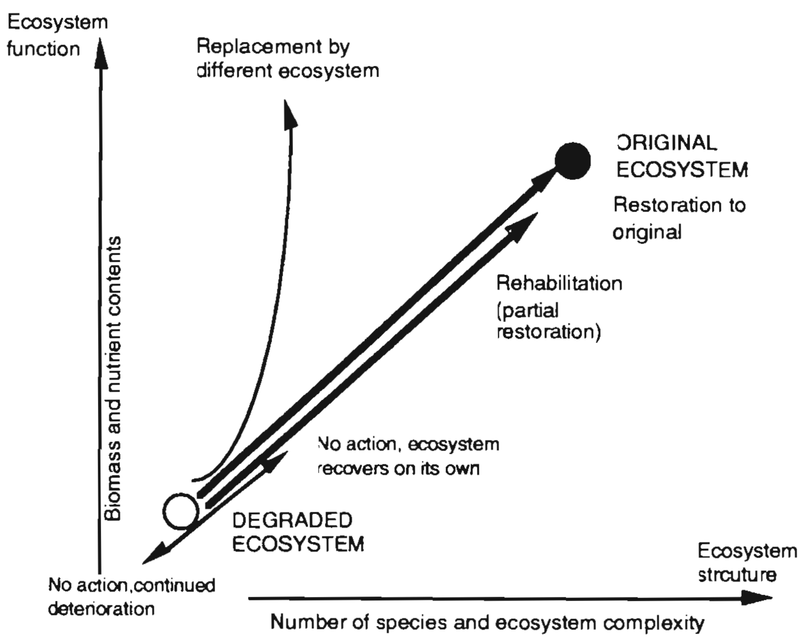
contribution to the maintenance of some biological resources and their diversity. According to a survey conducted in 1993 [...] of the 32 respondents, more than half reported making a profit (SBSTTA-4; Item 4.8 of the Provisional Agenda).

Is that trend significant/convincing enough to promote privately-owned reserves as an alternative to institutional ones?

Restoration

Restoration has been defined as " the return of an ecosystem to a close approximation of its condition prior to disturbance". In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are recreated. The goal is to emulate a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs (National Research Council, NRC).

Rehabilitation involves the repair - not the recreation - of damaged ecosystems, while restoration usually involves the reconstruction of a natural semi-natural ecosystem on degraded or modified land (Cairns, 1995 ; Le Floc'h & Aronson, 1995).



The goal of ecosystem restoration is to fully recover the species composition and ecological complexity of the original ecosystem. Rehabilitation seeks primarily to improve ecosystem function with only partial recovery of species diversity and ecological complexity (Source, Bradshaw 1990).

Concluding remark

The discussions and presentations targeted impacts of effects on aquatic environments with little attention to the underlying causes. The latter are generally driven by socio-economic and political forces and are often not addressed by biophysical scientists and their ilk. Yet, within this workshop we have apparently accepted that biodiversity conservation needs overt linking with sustainable use or development. This would seem to support efforts to jointly consider causes and effects when addressing impacts (change in ecological character as defined by the Ramsar Wetland Convention) on aquatic environments.

FINAL RECOMMENDATIONS

ASSESSMENT OF STATUS, TRENDS AND EMERGING ISSUES

Biodiversity status

All reference to Biodiversity makes use of the CBD definition :

"Biological diversity" means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Convention on Biological Diversity, Article 2

The following needs to be considered when operationalizing the definition:

- need to include the human dimension in the definition
- need of detailed definitions to operationalize it
- define biodiversity relatively to threats

Color : short term
Italic : long term, strategic
Color and Italic : short and long term

Identification of less known areas and actions to be undertaken

Geographic "black holes"

Recommendations :

- Provision of maps or tables showing poorly studied regions / regions where information is not easily available / regions where there exists a large time gap in information retrieval or gathering. Bioregionalization (e.g.: ichthyo-provinces) should be considered as a tool for the assessment of biodiversity. The concept of large marine ecosystems (LME) has similarities with ichtyo-provinces established for inland waters.
- Collation of major continental and international bioregionalization schemes

Habitats

Recommendations :

- Refer to Ramsar recommendations
- *Wetland habitats requiring priority attention due to a lack of information or the extent of degradation include: seagrasses, coral reefs, salt marshes and coastal flats, mangroves, arid-zone wetlands, peatlands rivers and streams*

Species / populations / communities

Recommendations:

- *Identify key species (from an ecological and/or social point of view) and the sensitivity of species, with the help of population turnover and ecosystem analysis, capacity for recovery as well as distribution ranges.*
- *Maintenance and development of ecological expertise.*

Genetics

Recommendation :

- *Promote studies to assess the genetic structure of populations, to establish phylogenetic relationships among taxa, and to reconstruct their phylogeographic histories.*

Taxonomy

Problem :

- Declining traditional taxonomic expertise

Recommendations :

- Reference to CBD recommendations
- *Development of taxonomic expertise particularly in the early life-history stages of aquatic organisms*
- Inclusion of taxonomic aspects in new projects from the beginning

Threats

Recommendation :

An integrated approach to study threats and their underlying causes should be encouraged, from a bio-physical as well as from a social point of view.

Trends and emerging issues

Problem :

- Global climate change, ozone depletion, habitat fragmentation degradation and loss, pollution, over/misexploitation, competition by alien and invasive species are major environmental trends affecting the conservation of biodiversity.

Recommendations :

- *Studies should account for the effects on biodiversity (including ecosystems and communities) by those phenomena occurring at large spatial and temporal scales*
- *Distinguish and quantify natural versus human-induced changes.*

Threatened areas

Problems :

- Estuaries, lagoons, mangroves and coral reefs are among the most impacted ecosystems because of close association with humans over long period.
- High levels of fish endemism in freshwater systems (compared to estuarine and marine systems) require special attention for conservation measures.

Recommendations :

- Identification of threatened sites for targeted activities and institution of long-term monitoring (ecosystems)
- *Creation of a network of biodiversity sites representative of bio-regions and systems. For example, use ancient lakes to study fish speciation (species flocks) – these systems also act as natural laboratories.*

AQUATIC BIODIVERSITY ASSESSMENT: STRATEGIES, METHODS AND TOOLS

Considering the need for 1) data collection on aquatic biodiversity 2) data acquisition for aquatic biodiversity data bases creation on regional bases, further regional workshops are recommended

These workshops 1) are aiming at strengthening studies on structuring and functioning of aquatic ecosystems at different space and time scales (community structure, life-history traits) using integrative/analytic tools/spatial analyses (GIS,...) 2)should provide the material for early warning systems and assessment bio- indicators

Global methods

Problem :

- What is meant by Early Warning Indicators

Recommendation :

- A new definition of Early warning indicators is suggested: the measurable biological, physical or chemical responses to a particular stressor, preceding the occurrence of potentially significant adverse effects on the system of interest (after Ramsar COP-7). Relevant social factors should be taken into account

Rapid assessment, indicators

Recommendations :

- Provide indicators of short term (early warning), medium term and long term changes to biodiversity.
- *Bioindicators from different levels (from species to ecosystems) should be used on a case by case basis to identify trends and inform decision makers on the consequences of management options.*
- *Fish, birds and macroinvertebrates are recommended as suitable bioindicator groups because of large existing data sets in some places, scientific knowledge, international recognition as robust indicators and likelihood of research outputs being used by managers*

POLICY OPTIONS FOR A BETTER CONSERVATION OF AQUATIC BIODIVERSITY

Management

Policy must provide effective direction in conserving biodiversity despite increasing uncertainty associated with unpredictable changes in nature and society. Adaptive management offers a flexible means to understand and manage the uncetain dynamics of society and nature. Resilience is a useful concept for examining all factors, including biodiversity, that help ecosystems and society maintain their integrity.

Recommendations :

- Multidisciplinary approach within and between natural and social sciences is required right from the beginning of project formulation and implementation
- *Use adaptive management where relevant as an interactive process involving collaboration of scientists, NGOs, government agencies and local communities*

Legal framework

Recommendation

Clearly assign national responsibilities for conservation and sustainable use of aquatic resources among national institutions and agencies

Bring national legislations in line with international conventions related to biodiversity, conservation and sustaible development

Valuation, economic issues

Problem :

To make rational choices among alternative uses of a given natural environment, it is important to identify and value the natural resources and ecological services generated by that environment.

Recommendations :

Develop appropriate tools and undertake economic valuations to illuminate the value of viable ecosystems and to provide financial incentives for conservation and management. This should be based on thorough ecological knowledge of the systems studied.
Apart from economic efficiency, sustainability of human activities and a social fairness of revenue distribution should constitute key components of the economic analysis

Capacity building

Recommendation :

- *Assist in the development of national curricula which integrate conservation and sustainable use of aquatic resources into all levels of education.*
- *Increase the capacity to understand biodiversity and sustainable use of aquatic resources through the involvement of stakeholders and users in research and monitoring.*
- Assist transfer of best available and most appropriate technology from the North to South countries by in-country training schemes to develop institutional and human capacities.
- *Training of local, national and perhaps regional expertise (taxonomy, early life-history stages, ...).*
- *Enhancement of existing institutes/organisations in representative/charismatic areas as regional centres for study and conservation of biodiversity, and aiming to gather and spread the existing information.*

METHODOLOGIES AND TOOLS TO MITIGATE

Monitoring, indicators

Recommendation

- Identify and compare the many existing techniques for mitigation, and those that are being tested or developed (e.g.; ecological footprint and transgenesis), and the management systems to use them effectively
- The ecological footprint concept can be used to make ecological services comprehensible to lay people and policy-makers by estimating the ecosystem area needed to support human activity.

Data management and processing

Similarities exist between terrestrial and marine ecology, which suggests that agenda of terrestrial biodiversity assessment should be looked at.

Recommendations :

- Make maximum use of existing database systems and promote the linking of information systems on the web through metadatabases.

- *Make full use of so far under-utilised knowledge and information such as :*
  1. *Scientific collections*
     Museums, private collections, etc.
  2. *Grey literature*
     Reports from surveys, expeditions, etc.
     Many publications in different languages.
  3. *Traditional / indigenous knowledge*
  4. *Information subject to possible loss*

Information flow, cooperations

Recommendations :

- Establish a network of institutions and museums regarding the scientific collection of specimens as well as the maintenance of databases.
- International organisations are requested to investigate the development of database directories.
- Consider several ways to propagate the same information (e.g. CD-ROMs supplementing Internet).
- Facilitation of access to environmental data and information.
- International organizations are requested to assist the capacity of developing countries institutions to access and effectively make use of relevant databases

Protection and restoration measures

The use of aquatic protected areas is recognised as a major tool for conservation of biodiversity and sustainable use of aquatic resources

Recommendations :

- *An adaptive approach that encourages the participation of stakeholders at all levels and scales should be explored as a tool for definition, management and monitoring of protected areas*
- *A participatory approach involving local communities should be a requirement for such reserves*
- A structured information exchange should be set up with links to existing networks and institutions
- *Protection is required over a range of temporal and spatial scales, to ensure the conservation or maintenance of different areas critical for the various life history stages for both sedentary and migratory species*
- *Habitats representative of major bio-regions should be promoted (see Ramsar definition)*

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A N N E X E S

1. Agenda

2. List of participants

3. Abstracts

UNEP-IRD Biodiversity Workshop

Agenda

C. Lévêque, Workshop President

Item 1: Context and introductory remarks

S. Diop, Item leader

Item 2: Assessment of biodiversity, threats, trends and emerging issues: an ecosystem approach

S. Blaber, Item leader

Item 3: Aquatic biodiversity assessment: Strategies, methods and tools

M. Goren, Item leader

Item 4: Policy options for a better conservation of aquatic biodiversity

P.S. Ramakrishnan, Item leader

Item 5: Methodologies and Tools to mitigate in a global approach of biodiversity management

M. Finlayson, Item leader

Item 6: Conclusion and recommendations regarding strategies, short term and long term actions, cooperation and required synergy among partners

President and Item leaders

Monday, 15 November 1999

9:00

Registration of participants

10:00

Voituriez B.
Welcoming and Opening speech

Organization team
Practical information

Coffee Break

11:00

Item 1

Organization team
Discussion and Adoption of the Agenda

Diop S.
UNEP Presentation / Jakarta Mandate / CBD

Lévêque C.
Introductive conference

13:00

Lunch

15:00

Item 2

Blaber S.
Assessment of Biodiversity, Threats, Trends and Emerging Issues: Estuarine Ecosystems

Kulbicky M.
Biodiversity of Lagoon and Reef fish of the Pacific Region: status and Threats

16:00

Coffee Break

16:15

Korenteng K.
Biodiversity Status and Threats on Demersal Fish Communities in Continental Shelf Waters on the Gulf of Guinea

Diouf P.S.
Multiple Threats on a river Basin: Senegal river (West Africa)

17:30

18:00

Cocktail IRD

Tuesday, 16 November 1999

9:00

Lévêque C.
Status and Threats on Great Lakes Biodiversity

Laë R.
Assessment of Biodiversity status and Threats. The example of climatic and anthropogenetic effects on fish diversity and fish yield in the Central Delta of the Niger River

Abban E.
Status and Threats on African rivers Biodiversity

10:45

Coffee Break

11:00

Finlayson M.
Status and Threats on Wetlands Biodiversity

Colombo L.
Negative impacts and positive effects that aquatic biotechnology may exert on Biodiversity conservation

Discussion

13:00

Lunch

15:00

Item 3

Cury P.
Marine Biodiversity: a fisheries perspective

Goren M.
Aquatic Biodiversity Assessment in Coastal and Inland Water Ecosystems

16:00

Coffee Break

16:15

Lévêque C.
Ichtyo-provinces as a tool

Buckup P.
Tools for evaluating Biodiversity in decision-making processes for conservation of fish species in the Neotropical Region

Vakily J.M.
FishBase, a Tool for Documenting and Exploring Fish Biodiversity

18:00

Wednesday, 17 November 1999

9:00

Laë R.

Aquatic Biodiversity assessment: strategies, methods and tools. The example of the West African lagoons

Teugels G.

An Index of Biotic Integrity (IBI) and biological monitoring for the assessment of fish Biodiversity in African Freshwaters

10:45

Coffee Break

11:00

Whitfield A.

Possible use of fishes as indicators of Biodiversity, environmental health and importance of estuaries

Agnèse J.F.

The role of Molecular Ecology in conserving populations

Discussion

13:00

Lunch

15:00

Item 4

Vakily J.M.

The 1998 ICLARM-FAO Bellagio Conference on Policies for Aquatic Genetic Resources

Sendzimir J.

Adaptive Practice for Resilient Aquatic Landscapes

16:00

Coffee Break

16:15

Ramakrishnan P.S.

Some issues on human dimensions of mangrove Biodiversity management

Ronnback P.

Economic value (valuation) of Biodiversity, focusing on capture fisheries supported directly and indirectly by mangrove ecosystems

Diouf P.S.

Presentation of the West African coastal zone management network

Hamerlynck O.

Development of the IUCN small-scale fisheries Programme

Discussion

18:00

Thursday, 18 November 1999

9:00

Item 5

Finlayson M.

Early warning systems for detecting adverse change in wetlands

Colombo L.

Possible ways of reconciling Biodiversity conservation with aquaculture productions

Agnèse J.F.

The problem of conserving small populations: Population and quantitative Genetics issues

10:45

Coffee Break

11:00

Ronnback P.

The Ecological footprint - a communicative tool for assessing resource use and development limitations in Aquaculture

Do Chi T.

Role of SIG as a tool for management of aquatic biodiversity

Discussion

13:00

Lunch

15:00

Item 6

Recommendations and Conclusion

16:30

2. LIST OF PARTICIPANTS

LIST OF PARTICIPANTS

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3. Abstracts

Status of riverine biodiversity and threats to them

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Human societies have identified structures, functioning units and processes as constituents of our environment. Fortunately, it is also recognised that the interrelationships among the components make up the functioning of our world. Thus a change in any component is likely to influence the environment to some extent. For example, water, one of the world's most demended materials is produced by one of nature's most primary processes, technically known as 'hydrological cycle' (Swaminathan, 1989). Swaminathan also indicated that forested watersheds provide high quality water.

Water produced by hydrological cycles contribute to the water component of various aquatic ecosystems including rivers. Rivers also contain aquatic flora and fauna which constitute their biological diversity which function in the medium of the physical components. Thus the maintenance of the diversity of flora and fauna and their productivity on a sustainable basis is related to the status of the physical component of rivers (Karr, 1999).

Different segments of society derive different benefits from rivers, thus, often, description of a river as good or healthy depends on who makes the assessment. For example, for domestic water producers, a river is good and healthy if enough pure or purifiable water is always available and to commercial fishers, rivers are healthy if there are enough fin-fish and shellfish to harvest. It is therefore usual that river components of no direct extractive value are trivialized. However, to protect all benefits of rivers including their biological diversity, a broader definition of river health is required – as prescribed by Senator E.S. Muskie (1972) as contribution to the amendment of the 1972 US Water Pollution Act (now called the Clean Water Act, Section 101 (a) 1).

Recognition of biodiversity as basis for life on earth, including that of human had been recorded more fundamentally by McNeely *et al.* (1990). In spite of the recognition of the significance biodiversity to human existence indicated above, acts of humans that constitute threats to biodiversity are constantly being committed.

Especially in the developing world, threats to riverine biodiversity are enacted through the following:

- Degradation and destruction of natural ecosystems structure and functioning (e.g. large scale clearing and burning of forests of watersheds, damming of river systems).
- Channelling of riverbeds or river catchment area degradation.
- Activities related to destructive fishing practices.
- Draining and refilling of parts of floodplains.
- Overexploitation of aquatic resource(s) e.g. fish.
- Industrialization further pollute the aquatic environment. For example – urbanisation, mining, and plantation developments.

Very often limited interest, lack of information and ignorance of consequences of acts may be the reasons for various acts of humans that constitute threats to riverine biodiversity. Society could obtain indicators of long-term changes in biodiversity structure and functioning through either rapid assessment or monitoring procedures. Of the two, monitoring is advocated.

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The role of Molecular Ecology in conserving populations

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Molecular Ecology can be defined broadly as the application of molecular genetic markers to problems in Ecology and evolution, encompassing studies on the genetic relationships among individuals, population and species (Carvalho, 1998).

Molecular Ecology thus describes an approach, rather than a discipline, and necessarily incorporates expertises from diverse fields, but most notably from Molecular Biology, population and quantitative Genetics, Ecology, historical Biogeography and Systematices.

Some people argue that for most endangered populations we need to focus on their Ecology and on the specifics of human threats (over exploitations, pollution etc.), rather than Genetics. In other words, that we should mainly be worrying about environmental effects and demographic stochasticity and less about diminishing genetic variability causing inbreeding depression or lack of adaptability.

This view is not correct in the long term and could be broadly correct inthe short-term. But, if we consider that even in the short term, a principal effect of most human activity is increasingly to fragment populations (XX), then questions about the genetic sub-structuring of the resulting populations cannot be avoided. Some human activities results also in populations collapse. Such populations have small effective sizes and the genetic aspect of their conservation must be studied.

Genetics input in Conservation Biology are numerous and some of them are briefly presented: Population structure, Migration and gene flow, Introgression and hybrid zones, Species identification, Systematics, Community diversity. Case histories from Fish like the Genetics and Conservation of Salmonid, Conservation Genetics of Marine Pelagic Fishes and Conservation Genetics of North American desert Fish, illustrated the utility of Molecular Ecology to Conservation Biology.

The problem of conserving small populations:

Population and quantitative Genetics issues

I) Maintenance of adaptative variation

II) The minimum effective size of an adaptively secure population

III) Population Bottlenecks and deleterious genes

IV) Conclusion

Assessment of biodiversity, threats, trends and emerging issues: estuarine ecosystems

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Although estuaries constitute a relatively small fraction of the earth's area, their economic value is disproportionately high. A recent review gave estuaries the highest total economic value per hectare. Despite this, estuaries and associated coastal waters are among the most modified and threatened of aquatic environments. Almost all have been strongly affected by man. Many activities including agriculture, industry and fishing together with environmental modifications have a variety of impacts on estuarine biota. Species diversity is influenced by the type of estuary (e.g. open, closed, coastal lake etc.) and its size, structure of the habitat (e.g. mangroves), substrata, hydrological features (e.g. salinity, turbidity) and the nature of the adjacent sea. Tropical estuaries have the highest species diversity, but within broad zoogeographic areas their faunas are similar. For instance, 66% of East African estuarine fish species occur in South East Asian estuaries. For any one type of estuary, information exists to predict the species composition of its fish community under 'natural' conditions. Good information also exists to be able to predict the effects of likely threats to different species. Any assessment of the threats to biodiversity must take account of background trends, whether 'natural' or affected by man. The most significant of these are firstly, global warming, resulting in sea-level changes, rising water temperatures and more storms; and secondly, human population increase. The rapid increase in population is mostly in the tropics and sub-tropics and is concentrated on the coast, placing natural resources under increasing pressure. Threats include the effects of industry, agriculture and fishing. Here, physical changes such as the construction of dams, dredging and destruction of mangroves have profound long-term effects. Likewise, effluents, including pesticides, hydrocarbons, trace metals and sewage have both long- and short-term effects. Fisheries impact not only target species, but also non-target species (bycatch); they affect the nursery function of estuaries by removing species, by changing the physical habitat, and by altering water quality.

Selection of sites for studying threats to estuaries must include latitude, biogeographical regions, types of estuaries, their health status and nature of threats, and the use of indicators. Sites for which historical data sets exist are necessary, as well as sites where remediation can realistically be attempted. Fish are the most suitable indicators for the following reasons: (a) scientific knowledge is greater than for other taxa; (b) large existing data sets; (c) quantitative species composition and diversity from baseline and modified estuaries in most regions; (d) international recognition as a robust indicator; (e) their use as indicators allows assessment of the state of linkages between estuaries and both freshwater and the sea; and (f) fish species diversity is relatively high and many species have specific environmental requirements – hence good indicators. Fish species composition and diversity is a reflection of overall health, affected by: water quality, habitat, substratum, vegetation, anthropogenic influences, changes to flow patterns and fishing. It integrates many small effects and subtle changes. The decision support for outputs is good because of community familiarity with fish, and knowledge possessed by resource managers. The high public interest in fish also ensures political responses.

Tools for evaluating biodiversity in decision-making processes for conservation of fish species in the Neotropical Region

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Knowledge about species diversity and their geographic distribution is an essential precondition for sound decisions in efforts to conserve biodiversity. However, such knowledge is available only for very few groups of organisms, such as birds and large mammals. For most aquatic animals living in freshwater there is very scanty information about their distributions and even their existence as individual species. Even this limited information is often unavailable for decision-makers involved with environmental conservation. Among vertebrates this is particularly true for the tropical areas of the New World, which are biogeographically encompassed by the Neotropical Region. While it is estimated that the South and Central American freshwater ichthyofauna may total 8,000 species (Schaefer, 1998), less than 5,600 have been formally described (Vari & Malabarba, 1998). Basic systematic research and comprehensive fieldwork will ultimately fill this knowledge gap, but a lot can be done to enhance the efforts of the scientific and conservation community by making available information on fish distributions on a large and multi-institutional scale. Because freshwater fishes are restricted in their geographic distributions by their historic association with particular river drainages, we cannot apply predictive models of distribution based on environmental factors. Instead, assessment of species richness and endemicity must rely on biological data derived from museum collections, as exemplified in a recent cross-disciplinary study (Kress, 1998).

Internet integration of museum collection databases is likely to provide the tools that will significantly help reduce the gaps of knowledge about Neotropical species distributions. The existing international network of scientific ichthyological collections dedicated to the Neotropical Region offers a model of successful international cooperation in this particular area. Initiatives such as the Inter-Institutional Database of Fish Biodiversity in the Neotropics – NEODAT (http://www.neodat.org) and the Brazilian Information System on Fish Biodiversity (http://www.ufrj.br/museu/vertebra/sibip.htm) are examples of successful cooperation that have already amassed almost half a million museum records of Neotropical fish samples on the Internet. On-line availability of these data now allows researchers to inventory available samples in a few minutes. Traditionally, this step in the production of systematic work used to consume several months. Most importantly, the associated on-line mapping tools allow for visual inspection of sampled locality distributions. This is precisely the kind of information that is often lacking in projects that aim to map priorities for conservation of aquatic biodiversity.

Museum record databases are also an important tool in assessing the conservation status of threatened or endangered species. Such risk assessment is highly dependent on availability of data on past distributions. Without such data, heavily impacted river drainages may be misdiagnosed as species-poor areas (which presumably do not require special attention), when in fact they may be undersampled areas or areas that previously sustained high levels of biodiversity and recently lost their ability to maintain viable populations of sensitive fishes.

In summary, comprehensive programs for conservation of aquatic environments should encourage and support initiatives to collect, improve and make available data from museum collections. The current level of computerization and cooperation among institutions holding significant Neotropical fish collections represents an ideal opportunity for developing and investing on an on-line information system about fish diversity in coastal streams of Central and South America.

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Avoidance and mitigation of genetic impacts on wild fish populations and measures for biodiversity conservation.

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The impressive acceleration recently imposed by man on the dynamics of several megaprocesses (demographic growth, technological innovation, resource consumption, transport and economy globalization) is prompting a shift in progress modelling and development programming from ecosystem domination towards sustainable ecosystem management in order to slow down, and eventually prevent, environmental degradation, biodiversity reduction and bioresource depletion. Aquatic ecosystems, however, are more difficult to manage than terrestrial ones owing to their three-dimensional nature, remoteness and vastness. Hence, the level of uncertainty about the effectiveness of alternative bioconservative management strategies is still very high and much research is needed to improve their predictive capacity.

The problem is that the time for this upgrading is really running short because the threats posed to aquatic biodiversity by the main impacting factors, namely fisheries, introduction of alien species and aquaculture, in addition to pollution and habitat destruction, are being rapidly magnified by their recent or present rate of expansion. In the 1990s, capture fisheries with their highly efficient sensing and seizing technologies have levelled off their global marine catch of target plus non-target species at about 127 Tg/year, a hardly sustainable yield. Introduction of alien species is already recognized as a major cause of biodiversity loss on land and may equally occur in aquatic ecosystems either accidentally, as a consequence of travel and trade booming, or deliberately for pest biocontrol, tropical pet fish export, or improvement of aquaculture. Since the mid-1980s, aquaculture has more than trebled its productions, reaching 34 Tg in 1996, and is expected to double them again by the year 2020. Debated issues raised by the unrestrained proliferation of aquaculture enterprises include the impacts on biodiversity exerted by the occupation of inland and coastal waters, the use of fish meal and fish oil in industrial feeds, the ecosystemic deterioration due to polluting effluents, health problems related to the spreading of aquatic pathogens and the discharge of chemotherapeuticals as well as the dispersal of escapees belonging to alien species, fertile interspecific hybrids, selected strains or genetically modified organisms.

Internationally approved codes of conduct for responsible fisheries, sustainable aquaculture and vigilance against exotic invaders are being translated into national codes of practice to cope with the most serious impacts by means of risk assessment and follow-up studies, the setting up and updating of databases, and the adoption of precautionary approaches and conservative regulations. Nevertheless, the proposed measures for a safer use of current technologies need be improved by a sharper focus on genetic risks, such as genetic erosion (loss of genetic variability in wild populations), genetic contamination (propagation of wild gene pools containing foreign genetic material) and genetic deterioration (accumulation of defective alleles induced by mutagens throughout generations). Management policies should incorporate: monitoring of genetic variability in populations that might be susceptible to greater genetic losses; avoidance of genetic contamination of wild fish populations by demanding complete sterility (lack of gonadal development, failure to produce fertile gametes or inability to mate) for all types of farmed fish capable of exerting genetic impacts; and checking for chronic mutagenic effects by using tests that may include the exposure of transgenic fish bearing known DNA sequences to be screened for damage.

Marine biodiversity: a fisheries perspective

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Extinction at sea can been viewed as anecdotal as only few marine species have been recorded to have disappeared. A new synthesis (Roberts and Hawkins, 1999) presents some evidence for contemporary marine extinction's that shows that a real threat to marine diversity exists. Characteristics that render marine species vulnerable to extirpation and extinction will be presented. But the most important threats for fisheries and human activities related to the exploitation of renewable marine resources are certainly the erosion of intraspecific diversity that can lead to lower long term sustainable catch, habitat destruction, and overexploitation such as fishing down the food web which can alter ecosystem functioning. Concepts that are applied in terrestrial ecology (keystone species, redundancy...) and their usefulness for marine ecology will be discussed. The role of new management tools such as MPAs will be briefly discussed as well as the increasing pressure now in fisheries to abandon the criterion of sustainability while ecosystem restoration should be considered as a new paradigm for fisheries management.

Framework and approaches for conservation of biodiversity and sustainable use of aquatic ecosystems

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A framework is proposed to meet the need for conservation of biodiversity from genes to ecosytems and for sustainable use of aquatic ecosystems. Management of aquatic biodiversity is based on global and regional approaches with particular emphasis on threatened coastal areas. The framework's goal should be to provide the scientific and technical information to elaborate strategies and global/regional approaches of aquatic biodiversity. This requires an understanding of the interactions between biology, evolution of biodiversity and ecosystems dynamics. The framework's main objectives should include:

- Provision of advanced, integrated approaches and tools for research on, and management of, aquatic biodiversity that will help in exploring and understanding the causes of changes in biodiversity and aid the communication,
- Definition and execution of cost-efficient monitoring and research programmes,
- Training to insure the continued development of this effort,
- Promotion of regional cooperation in research and support to aquatic biodiversity monitoring and management.

Consideration is given to methodological, technical and institutional implications of biodiversity management based on the use of information systems, databases and georeferenced databases at regional and global levels. At world and regional scales, species are represented by biogeographic zones, large marine ecosystems, ecoregions, ichthyoregions, and by habitats, communities, assemblages etc. at smaller scale. Inventorying biodiversity means surveying, cataloguing, quantifying and mapping such entities as well as others such as genes, individuals, populations. The framework proposed for monitoring biodiversity would consist of inventories carried out over time and space. It is aiming at predicting the behaviour of key variables and at improving management through options analysis and early warning of changes in biodiversity. Data and information are therefore required, as well as for identification of interactions between factors and for problems identification and solving.

Sustainable aquatic biodiversity is a concept which involves integrated and global approaches and requires information technology tools for data management such as Information Systems (IS), RDBMS (Relational Databases Management Systems), OO-DBMS (Object-Oriented Databases Management Systems), GIS (Geographical Information Systems) etc. Complex data is the main feature of databases on aquatic biodiversity : they are composed of biological and ecological data on living resources, aquatic environment, surveys, economic activites, remotely sensed data, georeferenced data at different scales, qualitative and quantitative information, data imported from external sources, etc. Quantitative information is essential as it derives from the integration of measurements and observations which allows identification of the nature, level and speed of changes in biodiversity. For understanding interannual changes and multiannual trends, consistent long-term databases are therefore critical. Combining information on aquatic biodiversity from different sectors and sources implies also association of data in meta-databases which will allow to organize and maintain associated data for use in integrative tools and models on an ecosystem framework.

Regional databases on aquatic biodiversity should be created because of the broad scale of distribution of aquatic species, populations, assemblages and resources. Exploited marine species/resources are often shared among countries and their management across geographical and political boundaries requires regional or international bodies which mandate is to monitor the state of exploitation of the resources, the " health " of the aquatic ecosystems and to provide management advices. Data and information are essential for technical activities e.g. development of GIS applications, of early warning systems, organization of working groups and training sessions etc., on subjects of regional and international concerns.

Development of information systems (IS) which would include regional databases and GIS components on aquatic biodiversity is therefore needed. Such information systems would provide conceptual and computational " tool box " for storing, analyzing (e.g. multivariate statistical analysis) and viewing biodiversity data. Information systems on aquatic biodiversity should be specifically designed to transform satellite imagery, surveys and bioecological data into visual products (maps, charts, graphs, etc.) and statistical products that will aid in monitoring and managing biodiversity. Information systems and tools should be defined at the early stage of the biodiversity conservation programme but questions and issues raised by the end-users, with their own objectives and constraints, will provide guidance to their development. The main users are research institutions and governmental authorities, but in the broadest sense information systems would enhance communication between researchers, decision-makers and aquatic ecosystems users and provide quick access to information – e.g. through global networking (meta-databases) - on the status of aquatic biodiversity at regional and global scales.

Regional and international collaboration are part of the framework envisaged. To insure the continued development, maintenance and use of information technology tools for conservation and management of aquatic biodiversity, short-term versus long-term constraints and benefits of such an approach were analyzed. They should be taken into account in programmes proposals and implementation as well as the related institutional aspects, human resources needs and training requirements.

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Early warning systems for detecting adverse change in wetlands

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Early warning systems are seemingly an attractive option for wetland policy makers and managers. However, in many instances they have not been well used or shown to be useful. This has occurred for a number of reasons, including the absence of a rigid framework for implementing appropriate indicators or tests. Thus, a wetland risk assessment framework is presented as a basis for applying early warning systems for wetland management. The risk assessment framework contains six steps:

- Identification of the problem
- Identification of the effects
- Identification of the extent of exposure
- Identification of the risk
- Risk management/reduction
- Monitoring

Early warning systems suitable for detecting water pollution in wetlands are described under the general headings of rapid response toxicity tests, field early warning tests, and rapid assessments. In dealing with these tests the issue of ecological relevance is raised in relation to the possible warning that can be provided by the test. This is particularly relevant for sites of high ecological value, e.g. those listed as internationally important, or those that provide many functions and benefits for people.

Aquatic biodiversity assessment in coastal and inland water ecosystems

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A good assessment of the biodiversity in an aquatic system is a prerequisite for any attempt to properly conserve or exploit the ecosystem.

Understanding of the theoretical and practical aspects which affect biodiversity is an important tool in assessing it in any ecosystem.

Biodiversity in an ecosystems is the end product of an evolutionary process that involves biotic and abiotic environmental factors. The comparative analysis of known aquatic systems enables us to identify various parameters which can help us in assessing the biodiversity of poorly known systems. Biodiversity in inland watersheds usually reflects the size of the system, complexity (structural and biotic), and its latitude. In coastal systems an additional parameter is the biogeographic region.

Prior to any further investment in studying or assessing biodiversity in aquatic systems it is essential to determine the state of art of the knowledge of aquatic biodiversity. Compilation of the huge amount of information, often disseminated in many scientific papers, databases, museums collections, theses, reports and unpublished information accumulated by scientists can provide us with an important tool for mapping the gaps in our knowledge and for selecting priorities.

Such a project will establish, for each aquatic taxonomic group, the number of species, genera and families known and estimated - worldwide, for each continent and for each watershed or coastal system. The project will also identify the relevant sources of information and will provide a directory of information sources such as literature, institutions, websites, etc.

Analysis of the information obtained from the project «determination of the state of the art», can assist the quick assessment of biodiversity in most aquatic systems on the basis of partial knowledge and extrapolation. It is possible to prepare a good assessment of the biodiversity in an ecosystem by synthesizing the following: partial data of the species stock, data of higher systematic levels, a study of key groups, comparisons with similar and better known ecosystems, indicator groups and general biogeographical knowledge and theories.

The availability of experts for the various taxonomic groups is a very important factor which should not be ignored when planing a strategy for regional or global aquatic biodiversity assessment. Training of young taxonomists should be part of the capacity building in undeveloped countries. In many projects the shortage of taxonomists for the various groups often presents a severe obstacle for both laboratory research and field sampling. The employment of non-expert scientists for these purposes makes the obtained information unreliable and consequently can lead the decision maker to the wrong decisions.

Selecting priorities is an important element in any strategy planned for global or regional aquatic biodiversity assessment. Such decisions have to be made considering the fragility, sensitivity and expected threats to the various aquatic systems. Most inland water systems in the world are far more fragile and threatened than most coastal systems.

Reducing the negative biodiversity impacts of fisheries and improving the management of west-african coastal wetlands

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Some worrying trends affecting the biodiversity and productivity in the west-african coastal wetlands are identified, especially those related to the uncontrolled development of so-called small-scale or artisanal fisheries. Positive experiences in participative resource management and ecosystem restoration are highlighted. The important role of protected areas both for conservation and for development of sustainable exploitation systems is emphasised. Information is provided on the status of some of the biodiversity and productivity hotspots on the West-African coast between Nouadhibou and Guinea Bissau. Prominence is given to sites on the Mauritanian coast but where appropriate regional links are highlighted. A number of tough conclusions are presented.

Biodiversity Status and Threats on Demersal Fish Communities in Continental Shelf Waters of the Gulf of Guinea

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The Gulf of Guinea is that part of West Africa with maritime waters defined by the Guinea Current Large Marine Ecosystem which extends from Bissagos Island in the north to Cape Lopez in the south. The living marine resources of the area depend on the upwelling of cold, nutrient rich, sub-thermocline water which occurs seasonally in the area and drives the biology of the shelf waters, near-shore processes like river discharge and contribution of nutrients from estuarine and lagoon ecosystems.

Since the late 1960s, there have been changes in the distribution and abundance of important fishery resources in this ecosystem. These include decline of sardinellas (*Sardinella aurita*), proliferation of triggerfish (Balistes capriscus), increase of cuttlefish (*Sepia* sp.) and recently, occurrence in huge quantities of a bivalve (*Chlamys opercularis*) in survey hauls. The relative importance of major species changed in every trawl survey conducted in the area. Balistes capriscus dominated the ecosystem for nearly 20 years. Studies of fish communities have shown that some of these changes may be due to changes in the structure of the fish community.

From surveys conducted in the region, it is apparent that generally the six assemblages described below are present on the shelf and inner slope of the region (Longhurst, 1969).

1. Sciaenid assemblage in shallow-waters and close to estuaries; sometimes very extensive e.g. off Côte d'Ivoire, east of Ghana, Nigeria and Togo-Benin. The important species of the group are of the families Brachydeuterus, Galeoides, Pseudotolithus and Arius.
2. Lutjanid assemblage with species of the families including Lethrinus, Lutjanus and Acanthurus, sometimes very prominent e.g. off Liberia or close to shore e.g. off Togo-Benin, or alternating with Sciaenid assemblage along shore; e.g. off Cameroon.
3. Sparid assemblages (shallow and deep elements) with species of the families Dentex, Pagelus, Balistes, Pseudupeneus, Epinephelus, Lagocephalus, and
4. Deep Shelf and Slope assemblages (Peristedion, Chlorophthalmus, Epigonus, Triglidae).

In this contribution, the structure of demersal species assemblages in the Gulf of Guinea are re-examined in order to contribute to the debate on the subject by throwing light on the dynamics of the assemblages during the last three decades. In addition, the study also seeks to isolate the factors that determine fish community structure in the study area and to assess the effects of environmental parameters on the structure and dynamics of the assemblages.

Using Two-way Indicator Analysis (TWIA) and Detrended Correspondence Analysis (DCA) it is shown that community structure is determined primarily by depth and type of sediment on the seabed and the dynamics of the assemblages are influenced by physico-chemical parameters of the water masses, which are periodically modified by the seasonal coastal upwelling that occurs in the study area. Changes in the status of the identified assemblages over a 25-year time period are examined in relation to observed changes in the marine environment (Koranteng and McGlade 1998). The analyses, including examination of patterns of diversity and species richness indices, show that temporal environmental changes (mainly natural) would lead to temporal changes in species assemblages whilst permanent change (e.g. habitat alteration or habitat loss) would lead to long-term or permanent change in species assemblages (Koranteng, 1998). Thus it appears that the increased industrial trawling in coastal waters and environmental forcing appear to have singly or conjointly influenced the observed changes in the composition and relative importance of species in the assemblages. Therefore, irresponsible fishing operations that lead to habitat alteration, and effects of other anthropogenic activities like oil exploration pose a threat to biodiversity in the Gulf of Guinea.

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Biodiversity of Lagoon and Reef fish of the Pacific Region : status an threats

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The Pacific is probably the region where fish diversity is the highest. At the moment there are approximately 4 800 reef and lagoon species recorded in this area and the total number of these species is certainly well over 5 000. These fish are distributed among 158 families, but 10 families make more than 30% of the total and one family, the Gobiidae, makes more than 12% by itself. The Pacific reef and lagoon fish fauna shares many species with the Indian Ocean since nearly two thirds of the species of the Indian Ocean are also known from the Pacific. On the opposite, very little is shared with the Atlantic. Endemism is very difficult to assess as the fish fauna of many islands in the Pacific is poorly known. However, «local» endemism is very low, with the exception of Hawaii, seldom exceeding 5%. «Regional» endemism is probably much higher, as there are several faunistic regions in the Pacific. Species richness (species / unit area) is a good indicator of diversity. Density and biomass of reef fish increase with species richness. Species richness is linked to local factors (coral cover, substratum, depth...) and regional factors (island size, island type, biogeographical region...). The type of relationship between species richness and local factors may vary greatly between regions. On the opposite, the organization of the fish assemblages (trophic structure, size, mobility, behavior...) is strongly dependent on local conditions, usually more so than on regional factors. Pacific reef and lagoon fishes are submitted to a number of threats which can be divided into four major components : habitat destruction, pollution, fishing and miscellaneous factors. Demographic increase is at the base of all the changes observed. Habitat destruction is mainly caused by destructive fishing (cyanide, explosives, trawling), changes in the coastal areas (mangrove and wet land drainage, coral grinding, dredging...), siltation due to bad land uses, and major ecological changes such as Acanthaster outbreaks or urchins proliferation's. As a large part of reef and lagoon fish are territorial or sedentary, such changes may have major impacts on the local diversity and consequently fish production. Pollution is probably the second major concern for fish diversity (industrial and city wastes, mining, forestry, agriculture and aquaculture). Other threats such as increased fishing, changes in fishing gear, global warming or introduction of foreign species are probably not as important at the moment. A shift is currently occurring in the quality of the catch (more herbivores and plankton feeders, smaller species) which can be related to a degradation in environmental conditions and increased fishing pressure. However, the probability of extinction of reef or lagoon fish is certainly much lower than in terrestrial systems because most species have a wide distribution. Fish is a fundamental part of Pacific cultures and the preservation of species diversity on reefs and lagoons is vital to most of the island countries in the Pacific. These countries however have major problems in facing the changes in their environment because they do not have the financial and human capacities to do so.

Aquatic biodiversity assessment: strategies, methods and tools. The example of the West African lagoons

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Limits of classical management of living resources by species or species group, is now acknowledged by the scientific community. For example, the current approach for fisheries management is based upon the utilisation of global, analytic and stock - recruitment models or even more empirical relationships between biotic and non biotic parameters. These models have proven to be difficult to apply and do not give attention to broader ecosystem aspects. There is no getting away from the ecosystem scale for taking in account natural and anthropogenetic impacts on fish communities. This approach was developed in the West African lagoons where the factors affecting yields are studied through the stability, species composition and size structure of the yields at high and low fishing intensities. Heavy fishing is followed by the development of a plateau phase resulting from a reorganisation of species assembly. In such a state, exploitation produces only a few dominant species for which average catch lengths are small, which are generally herbivorous and exhibit a continuous reproduction with sometimes a lowering of first sexual maturity, which permits them a faster turnover.

From this example, it is possible to define biological indicators of stress taking in account the dynamics of species and the interspecific relationships where the role of biodiversity is examined with hypothesises on the "bottom-up" control or the "top down" control and where the impact of environmental pressure on the variability and resilience of fish stocks is approached.

More generally, aquatic biodiversity assessment would be based on indices allowing to quantify the health and integrity of an ecosystem. These indices bring together environmental indices and habitat structure; ecological indices with references to diversity and functioning indices, size spectra and trophic levels.

Assesment of biodiversity status and threats. The example of climatic and anthropogenetic effects on fish diversity and fish yield in the Central Delta of the Niger River

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For last 20 years, the fish communities in the Central Delta of the Niger river have been subjected to: (i) two drought periods in 1973 and 1984, (ii) a dramatic increase of fishing and, (iii) the building of an electric-power dam in 1984. At different levels, these various factors modified the biological cycle of the fish which are adapted to the former hydrological cycles of the Niger and the Bani rivers. The Sahelian drought is responsible for a decrease in both flood duration and of the inundated area of floodplain which varies from 20 000 km^2 to 5 000 km^2. From 1968 to 1989, fish landings declined from 90 000 metric tons to 450 000 metric tons. During the same period, as fish catches fell, yields per hectare increased from 40 kg in 1968 to 120 kg in 1989. This phenomenon is linked to the decrease of the average age of the fish (69% of fish catches are under one year old) in response to the increased fishing mortality and natural mortality which is higher during the drought period. The increase in fish productivity is characterized by a depletion of species such as *Gymnarchus niloticus, Polypterus senegalus, Gnathonemus niger,* whose reproduction are linked to the floodplains and of species like *Citharinus citharus* and *Clarotes laticeps* which visit frequently flooded areas. Concurrently, families such as the Cichlidae or Clariidae, which are resistant to low oxygen concentration, increase. Species which are under one year old at first reproduction and have several spawning periods per year, are the more abundant in fish communities.

Summary of the introduction paper

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Biodiversity is defined in CBD as "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Thus, three hierarchical levels are currently accepted to describe biodiversity : the genetic, the specific and the ecosystem levels. Actually biological diversity is a dynamic process; biodiversity is the result of changes and interactions between the different levels.

However, biodiversity is not only a biological or ecological issue. It is also clearly a social issue, the interaction between human society and biological diversity. The question of biodiversity has been raised because of the human influences on biodiversity: poverty and environmental degradation, human/nature relationships, human population, growth and needs, trade, etc. The future of biodiversity depends on the management

Inland waters biodiversity and threats

Inland waters are true islands for several animal groups including fish, macrocrustacea, molluscs, etc. As a consequences, there is a high level of endemicity, populations are genetically isolated and species richness is the result of a dynamic equilibrium.

The present state of aquatic biodiversity in a climatic and geomorphological framework, is the result of past environmental changes that resulted in speciation and evolution. The future relies on global changes but also on human impacts at a regional or local scale: habitat changes, pollutions, invasive species, overexploitation of natural resources.

Status of biodiversity

Assessment of threats and trend

We have to deal with
- spatial and temporal variability
- complexity of interactions

To assess threats and trends we have to use
ı Indicators of long term, medium term, short terms (early warning) changes
ı Indicators of environmental changes in distribution, structure, functioning
ı Indicators of socio-economic changes

More generally, indicators are :
- part of a monitoring programme to assess :
state of the ecosystem (diagnosis)
trends in changes (degradation or rehabilitation)
- a major tool for decision makers to assess the consequences of management options
- they should be integrative and representative, costless and easy to manage.

Information flow

A lot of informations is stored in museums (Europe, N. America) and in papers published or not but not of easy access. A lot of local knowledge exist but unknown (not written).

High priority should be given to knowledge availability and flow :
- mobilize data as a key instrument for biodiversity strategies
-data base networks (Clearing House Mechanisms)

Conservation

Habitat

Fish stocks are highly variable and stock size is often driven more by environmental changes than by exploitation Fishing alter not only target species but also the ecosystems through direct and indirect effects (trophic cascades)

Conservation of species = conservation of their habitat

- Aquatic reserves as a conservation tool?
- Are aquatic reserves strategic tools in conservation ?
- No-take reserves can improve fisheries management:
  - protection of sedentary species (K-strategists)
  - protection of spawning sites and juvenile fish nurseries
  - protection of habitat and biota (damage caused by trawls to sea bottom..)

However :
  - constrained by changes occurring in their environment (pollution, exotic species, water abstraction)
  - little expertise for open water systems or rivers

- Conservation strategies

  They should promote both :

  Ecosystem level approach

  Precautionary principle

  Adaptive management

  Traditional knowledge

  Protected areas

  Training

  Regulation

- A few questions in relation with conservation:
  - who is in charge of conservation ?
  - who will pay for ?
  - Who will control it?

Moreover:
  - are decision makers willing to use scientific results?
  - are scientists in a position to give operational advises?

Conclusion

Priorities ?
  - mobilisation of informations already available ; information flow and accessibility. Clearing house mechanisms
  - Training capacity building, international and regional co-operative links ?
  - identify sites for targeted activities : network of biodiversity sites (pilot sites)
  - promote a "system approach" for conservation (ecosystems and sociosystems)
  - select or develop standard methods for assessments and comparisons.

Ancient lakes fish species flocks : a priority for conservation

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About a dozen lakes in the world are up to three order of magnitude older than most others. Such lakes which may be called "long-lived lakes" (some of them between 20 and 30 million of years) may have different origins, sizes and shapes, but in contrast to short-lived lakes (most of them being post-glacial lakes), they have exceptionnally high faunal diversity and levels of endemicity, including some of the most spectacular species-flocks among fishes. The longevity of ancient lakes may explain their unique endemic evolutionary radiations. However, longevity does'nt means stability and most of ancient lakes exhibited dramatic changes during their history.

The processes accounting for these radiations are a matter of debate among scientists, but there are more and more evidence that sympatric speciation may occur in isolated waterbodies. These species-flocks are sometimes considered to be a world heritage which is endangered and has to be preserve from destruction by human activities such as overfishing or introductions of aquatic species.

An important characteristic of ancient lakes biodiversity is the existence of " species-flocks ". An aggregate of several species should be identified as a flock only if its members are endemic to the geographically circumscribed area under consideration and are each others' closest living relatives.

According to our present knowledge, there is a cichlid species flock of more than 500 endemic haplochromine species in Lake Victoria, and another one of more than 500 cichlid species in Lake Malawi. In Lake Tanganyika evolution has led to the occurrence of species flocks within a few families: 7 Mastacembelid species, 6 species of the Bagrid Chrysichthys, 7 species of Synodontis and 4 species of the Centropomi, and 300 cichlids. The remarkable diversity of the large barbs (*genus Barbus*) in Lake Tana (Ethiopia) constitutes a potential species flock which has been discovered recently

In south America, 24 Orestias species (Cyprinodontidae) are presently recognised.

In Lake Baikal (Asia) ons should mention the the presence of sculpine fish (Cottotoidei) species flocks, comprising 29 species (11 genera) of sculpins totally endemic

There is also a number of invertebrates species flocks in ancient lakes and a high number of endemic species.

For many authors, ancient lakes are natural laboratories but their endemic fauna is particularly threatened by habitat alteration, trawl fisheries and the introduction of alien species. The documented disappearance of hundred Cichlid species from Lake Victoria resulted in international concern for the knowledge and preservation of this unique fish fauna. In the early 1980s the impact of the introduced Lates upon the indigenous fish fauna was considered an ecological and conservation It was later recognised, that predation by Lates may not be solely responsible for the depletion of haplochromine stocks, and that the haplochromine stock was already affected by fisheries before the establishment of Lates, and particularly by unregulated fishing or by trawling techniques.

Conclusion

Ancient lakes are unique natural laboratories to study evolution at works for several groups of aquatic animals. They are currently major biodiversity hotspots and most of the are threatened by human activities. It is a world heritage to be preserved.

The 1998 ICLARM-FAO Bellagio Conference on Policies for Aquatic Genetic Resources

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In December 1995, ICLARM convened, under the auspices of the System-wide Genetic Resources Programme (SGRP) of the Consultative Group on International Agricultural Research (CGIAR), a workshop about fish genetic resources (Pullin and Casal 1996). That workshop called for an international conference on policies for aquatic genetic resources. ICLARM and FAO held this international conference, 'Towards Policies for Conservation and Sustainable Use of Aquatic Genetic Resources', at the Rockefeller Foundation's Bellagio Conference and Study Center, Italy, in April 1998. International experts, invited in their personal capacities, presented in-depth reviews and discussed areas of concern and suggestions for action.

The reviews included: Fish Genetic Resources Conservation, Field Programs and Policy Development; Biotechnology, Genes and Genetically Modified Organisms (GMOs); Policies for Commercialization of Transgenic Fish; Policy Aspects of Genetic Resources for Fisheries; Preparation and Implementation of Policies for Aquatic Genetic Resources; Genetic Resources in Aquaculture, a Farmer's View; Intellectual Property Rights and Aquatic Genetic Resources; Conservation of African Fish Genetic Resources; Aquatic Genetic Resources in Asia and the Pacific; Aquatic Genetic Resources in Latin America; Fish Under Threat; Local Knowledge, Innovations and Practices Governing Aquatic Genetic Resources; Legal Regimes; Governance, Conservation and Sustainable Use of Aquatic Genetic Resources; Developing Sui Generis Options for Protection of Living Aquatic Resources of Indigenous Peoples; Institutional Factors and Aquatic Genetic Resources; Public Awareness; and Adaptive Biosafety Regimes for GMOs.

The conference agreed upon six 'Suggestions for Action', summarized here in no order of priority: integrate conservation and sustainable use of aquatic genetic resources into educational curricula, at all levels; clearly assign national institutional responsibilities for conservation and sustainable use of aquatic genetic resources; share knowledge and methods, through the Clearing House Mechanism and local mechanisms; broaden the biosafety debate to include alien aquatic species and genotypes, not just GMOs; adopt the ecosystem approach, including transboundary and cross-sectoral elements; and develop policies and practices for sharing monetary and non-monetary benefits. The conference also identified four 'Areas of Concern': international liability provisions for damage to aquatic genetic resources; protection of and rewards for local knowledge, innovations and practices; sharing benefits from aquatic genetic resources found outside national jurisdictions; and recognition that, for biosafety, the characteristics of living modified organisms are more important that the processes used.

The proceedings of this Bellagio Conference are published (Pullin *et al.*, 1999) as a source of reference for policymakers and other interested parties. It is hoped that this volume will contribute to the programs of the CBD on marine and coastal biodiversity (Jakarta Mandate) and inland aquatic biodiversity.

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FishBase, a Tool for Documenting and Exploring Fish Biodiversity

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Good resource management is ultimately the ability to maintain the health of exploited ecosystems, ensuring that their potential for biological productivity is maintained and its vulnerability to external factors is minimised. When assessing ecosystem health, biodiversity is only one aspect to be considered. However, changes in the biodiversity of exploited ecosystems over time might help to indicate whether their productivity and resilience are optimal. For this, as well as for assessing the status of species and populations and picking up warning signals where those are under threat, biodiversity must be documented in an appropriate format. Froese (1996) suggested that a 'unit' of biodiversity information must include four core elements: species name, date, source, and locality.

FishBase, a global database on the biology and ecology of finfish built through international collaboration and sharing of data (Froese and Pauly, 1998), has used this and other approaches to develop tools for biodiversity studies. Cooperation with European museums has enabled the numerous occurrence records in their fish collections to become progressively available in FishBase. Linked to the authoritative database on fish taxonomy in FishBase, such records facilitate investigations into the status (occurrence and distribution) of a species over time, irrespective of changes in nomenclature. Other links within FishBase permit retrieval of information on the biology and ecology of a given species, its use and status of threat. Overall, while not a substitute for on-the-spot surveys of current status, these tools give added value to existing data and can identify trends and potential threats and problems that might not be obvious from narrower, one--time studies.

FishBase has routines to explore biodiversity data including, among others: national fish checklists; occurrence records; biodiversity maps; introductions; trophic ecology; parameters for ecosystem modelling with Ecopath; and "key facts". The key facts are summary sheets of important biological parameters allowing, for example, analysis and comparison of representative length-frequency data sets of a given stock or population against generalised length-based indicators for that species (e.g. length at first maturity, optimum capture length, asymptotic length). The results facilitate rapid assessment of the status of an exploited fish population.

FishBase remains under continuous development so as to improve its coverage of all known finfish species and its utility as a tool for fish biodiversity assessment and management. All the data and tools in FishBase are under common ownership and are becoming available through the Internet (http://www.fishbase.org). All concerned with the development of FishBase welcome additional collaborators as well as critical feedback from its users.

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Some issues on human dimensions of mangrove biodiversity management

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Ecologists generally tend to view an ecosystem strictly in a biological sense, keeping the humans outside its structural/functionalboundaries. In this view of things, humans sitting outside the biological ecosystem boundary bring about ecosystem alterations through perturbations. The impact of human activities on the ecosystem and the effect of altered ecosystem properties on the humans are not viewed as an integrated whole, in the context of biodiversity influencing ecosystem function. However, contrary to the traditional ecologist's view point, if we take a view that humans form an integral component of the ecosystem function, and if we realize that this integrative view point becomes even more obvious at a landscape level, then the issues of management of biodiversity within the system would assume a different flavour. Indeed, this is the way in which many traditional/tribal societies perceive the immediate environment around them. The concept of village as an ecosystem, amongst «traditional societies» with all its ramifications involving agriculture, animal husbandry and the domestic sector enmeshed with the forest and forest-related activities such as hunting and gathering of food, fodder, fuelwood and medicine and forest farming are all examples of such an integration of humans within ecosystem boundaries, with implications for evaluating the role of biodiversity in ecosystem/landscape functions, in a broader context. This also implies that conserving this biodiversity is crucial for the survival of the local people. It is not only the mere presence of biodiversity and the functional role it has for the traditional humans that is significant here, but the manner in which they manipulate this biodiversity for ecosystem functional integrity, and through that for their own function within the landscape is interesting.

Whilst such an approach as related to terrestrial ecosystems has been a matter of intense research by this author during the last three decades, there are reasons to believe, on the basis of preliminary studies, that such an approach will give ample rewards for effective management of mangrove ecosystems of the tropics with developmental concerns linked with the traditional societies associated with them. In the Banni region of the Rann of Kutch, only a small patch of the relict Avicennia marina is protected as part of a «sacred grove», maintained for cultural/religious reasons. *Excoecaria agallocha*, locally called «Thillai» is a species worshipped by the local coastal population and other devotees coming to the temple town of Chidambaram in Tamil Nadu; the «Sundri» tree (*Heretiera* spp.) of the Sunderbans along the Bay of Bengal is another such a culturally valued species. Even wildlife like the Royal Bengal tiger (*Panthera tigris*) of the Sunderbans, associated with Goddess Durga in Hindu mythology, and crocodile (*Crocodilus palustris*) of Goan coast are also objects of worship. We have shown through our studies on terrestrial ecosystems that ecologically valued keystone species are often are also socially selected. Further, traditional societies tend to be much more holistic in their approach towards ecosystem/landscape management, but for disruptions caused by outside pressures on nature and natural resources. It is in this context, the whole issue of land use conversions that are occurring in the coastal regions, for a variety of developmental activities, including the recently initiated prawn culture industry along the Indian coastal regions need to be viewed.

In the ultimate analysis, linking up ecological processes with social selection processes provide an effective handle for rehabilitation of degraded ecosystems and biodiversity management with concerns for sustainable livelihood/development of traditional societies living along the coastal region. Mangrove ecosystem analysis, with this perspective in view, offers opportunities for biodiversity management with peoples' participation.

Seafood Production Supported by Mangroves: Illuminating the Need for Ecological Knowledge in Economic Valuation

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The biodiversity of mangrove ecosystems provides a wide range of natural resources and ecological services, which are vital to subsistence economies and provide a commercial base to local and national economies. During the last decades mangroves have experienced widespread deforestation, and as a consequence more than 50% of the world's mangroves have been removed. One major driving force behind this loss is the underestimation of the economic value of goods and services generated by this ecosystem. In part this trend of undervaluation is due to the difficulty involved in placing a monetary value on some goods and services. Lack of ecological knowledge among those performing the valuation is another important determinant.

The need for ecological knowledge is examplified by an economic analysis of capture fisheries production, which constitutes the major value of marketed products from unexploited mangrove ecosystems. The identification of commercial and subsistence fisheries supported directly or indirectly by mangroves calls for the recognition of: (1) the provision of mangrove nursery and feeding habitat; (2) the biophysical interactions in the coastal seascape biome; (3) the subsidy to total fisheries catch by shrimp trawlers; and (4) the aquaculture industry's dependency on inputs like seed, spawners and feed. The support from mangroves to fisheries show spatiotemporal variations between continents and regions, but also within individual mangrove systems, where riverine and fringe forests may be more important than basin forests. To clearly establish the relative importance of different types of mangroves more quantitative research is needed on the distribution pattern of fishery species, the functional role of mangroves as habitat and the biophysical interactions in the coastal seascape.

Productivity estimates are usually derived by correlating documented fisheries landings to mangrove cover. This method is straightforward, but limited by problems of auto-correlation and incomplete fishery statistics. By acknowledging the "mentally hidden" support functions, the annual productivity of capture fisheries supported by mangroves range from 1.3 to 12.0 ton/ha, which corresponds to a market value of US $2,000 to 13,300/ha. This highlights the life-support value of mangroves, and illuminates the lack of ecological knowledge and significant undervaluation in previous cost-benefit analyses aimed at discussing management alternatives for mangrove ecosystems. Most cost-benefit analyses have only recognized the mangrove habitat support to some commercial fisheries, and consequently their estimation of annual productivity and value of fisheries supported by mangroves range from 170 to 330 kg/ha and US $130 to $640/ha, respectively.

Economic valuation of natural resources and ecological services has the potential to illuminate the value of viable ecosystems, and may thus provide a financial incentive to their conservation and management. Thorough ecological knowledge of the ecosystem studied is, however, a prerequisite for a successful economic analysis. Furthermore, the assignment of economic values, whether quantitative or qualitative, requires a multi-disciplinary approach. It should also be emphasized that, apart from economic efficiency, the sustainability of human activities and the social fairness of revenue distribution constitute key components in the economic analysis.

The Ecological Footprint – a Communicative Tool for Assessing Resource Use and Development Limitations in Aquaculture

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The conversion of mangrove forests into shrimp aquaculture ponds constitutes the main threat to mangroves in many countries. Apart from mangrove habitat loss and fragmentation, the impacts of shrimp aquaculture on biodiversity include overfishing and bycatch problems in associated fisheries, introduction of exotic species and spead of diseases, and release of nutrients and pollutants into the environment. Ironically, the productivity and sustainability of these aquaculture systems are heavily dependent on viable mangrove ecosystems, which provide ecological services like water quality maintenance and buffer against natural disturbances, as well as resources like seed, spawners and feed from mangrove-associated fisheries. Failure to acknowledge this life-support function of mangroves is one explanation to the uncontrolled expansion and intensification of shrimp aquaculture, which has led to self-pollution and disease problems. The lifespan of most intensive shrimp ponds seldom exceeds 5-10 years, and 70% of previously productive ponds have been abandoned in Thailand.

To reduce the risk of resource constraints and impacts on biodiversity we need to shift to aquaculture production systems that use less resources and emit wastes that do not exceed the assimilative capacity of the environment. We also need to develop indicators or tools that enable decisionmakers to recognize and manage nature's life-support on which economic development and human welfare depends. One way of identifying the demands for natural resource and ecosystem services of aquaculture is to estimate the ecosystem area – the ecological footprint – functionally required to support the activity. The ecological footprint concept illuminates the non-priced "hidden" requirements for ecosystem support, and places the scale of human activities within an ecosystem framework. It also demonstrates that human activities, which at first glance may seem separate from nature, would not function without ecosystem support.

The ecological footprint has been estimated for a semi-intensive shrimp farm in Colombia. The spatial ecosystem support required to produce food inputs, nursery areas and clean water, as well as to process wastes was 35-190 times the surface area of the farm. The mangrove nursery area required to produce the shrimp larvae for stocking was the largest support system covering up to 160 times the pond area. The area of mangrove forest required to supply natural food inputs and filter the nitrogen and phosphorus load was 4.2 ha and 4.8 ha per ha semi-intensive shrimp pond, respectively. Feed pellets form a major input to a shrimp farm, and a marine area of 14.5 ha was needed to catch the fish, and an additional agricultural area of 0.5 ha for the vegetable ingredients used in feed pellet manufacturing. Finally, 7.2 ha was needed for providing clean lagoon water to the ponds, and 0.8-2.5 ha of forest area per ha shrimp pond area to sequester the carbon dioxide of fossil fuel burning at the farm.

Adaptive Practice for Resilient Aquatic Landscapes

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In this presentation I use theory and examples to address two questions. What are some of the factors that maintain the integrity of systems lying along land/aquatic interfaces? What are useful tools to maintain and promote that integrity? I briefly review a concept, ecological resilience, that embraces a number of factors that appear to support ecosystem integrity, including biodiversity. I then describe a process, Adaptive Environmental Assessment (AEA), that provides a flexible framework for exploring, understanding and acting (managing) to promote the integrity and resilience of land/aquatic interfaces. I conclude by giving some examples of AEA applications both in marine and fresh water systems.

What set of factors maintains ecosystem integrity? Resilience embraces species richness and biodiversity in a wider search to find how systems sustain their integrity in the face of disturbance. The resilience concept has been tested and developed in efforts to address resource management crises. Local problems, such as losses of biodiversity, were seen as problems at one scale but are increasingly recognized as crises that emerge from within-scale and cross-scale interactions. Therefore, the focus of resilience has grown to examine how within-scale and cross-scale interactions affect the integrities of natural and human systems. It offers the chance to look at species within a dynamic context of the multiple scales of operation of ecological and human processes.

Fortress tactics anchored in national parks have only protected biodiversity at small scales while allowing extirpation at large scales. One tradition of management practice starts with the idea that biodiversity must be protected at wider scales by expanding the land area in which ecological practices are pursued as part of everyday life. This means that in the buffer zones around bio-reserves ecological insight must become part of the foundation of such rural activities as agriculture, forestry, fishing and hunting. Extending the domain of sound ecological practice is not trivial. By what means can we integrate the understanding and practice of ecological science and rural economies and folkways?

Resource management problems have so often defied prediction that surprise rather than certainty has become a common theme for practitioners (managers) and theoreticians. Our understanding of this surprise has improved with our appreciation of resilience and the scales of ecological processes and landscape pattern. But how can we practically address this uncertainty while protecting biodiversity and resilience? I describe a process, Adaptive Environmental Assessment (AEA), that has developed over 30 years of experiments as a test of our abilities to integrate inquiry, understanding, and action in the face of surprising shifts in evolving resource systems. AEA has been applied to resource management problems such as tourism, fisheries, forestries, mining and agriculture. I discuss current experiments with AEA to address the interplay of ecological and economic processes in Europe and North America. I describe adaptive approaches to small scale experiments with stream erosion and biodiversity (Minnesota), medium scale experiments with flood protection, grazing practices and biodiversity of floodplains (Austria and Poland) and a large scale experiment with disturbance and estuarine bays (Florida).

An index of biotic integrity (IBI) and biological monitoring for the assessment of fish biodiversity in African freshwaters

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The Index of Biotic Integrity (IBI) is a multimetric index that rates the composition, structure and functional organisation of fish populations in a particular environment, compared to similar environments with high-quality ecosystems. A fundamental assumption in choosing fish as indicators of environmental degradation is their sensitivity to most forms of human disturbance.

The IBI metrics represent three major classes: species richness and composition metrics; trophic composition metrics; and metrics on the population size and the condition of individuals.

Developed in the eighties for small streams in the north-central part of the United States, the IBI has since been modified for use in other regions in the USA, where it became a legal index to officially demonstrate pollution; since a few years it is intensively studied in Western Europe.

In Africa only few studies have been made so far. These few applications, however, have demonstrated the ability of the IBI to identify a variety of forms of degradation (e.g. deforestation; mining). But in many parts of Africa the development of an IBI is seriously hindered by the lack of reliable basic information on fish taxonomy: this is especially true for West-Central and Central Africa, which still contain several poorly explored areas. As long as this basic information with correct species numbers, based on reliable identifications, is not available, the IBI will be incorrect. The training of African researchers in the field of systematics is therefore absolutely necessary and rather urgent. Until recently, research in this field has been an almost exclusive European speciality; due to other research priorities however, the study of African fish biodiversity is becoming rare in Europe and a transfer of knowledge is indispensable in order to guarantee the continuity of the research.

There is also an urgent need for continuous biological monitoring of African freshwaters. So far, extremely few studies are available. Recent studies on the effect of a dam on the fish population of a coastal river in West Africa, however, revealed considerable changes in the species composition and in the local catches; additionally, in the man-made lake and in the outlets, hybrids have been observed. The man-made lake studied is amongst the oldest on the African continent. It is obvious that in other dams, similar changes will be observed. Regular monitoring of the rivers is absolutely necessary in order to guarantee the sustainable use of the available stocks.