Executive summary

Increased human activity leads to alterations in watercourses and their adjacent land areas. According to their needs, people use water systems for different purposes. Introduction of non-native organisms, overexploitation, technical encroachments, and pollution in aquatic ecosystems modify or even destroy the normal relationships between different links in the food chains and can lead to loss of ecosystems, species, populations and genotypes.

Priority Questions for Consideration by SBSTTA 3

Knowledge base

- Modalities to develop extensive taxonomic inventories of freshwater systems; to implement capacity-building, including professional, para-professional, and technical taxonomists and ecologists; and to make information widely accessible in electronic format.
- Ways and means to improve capacity and competence for individuals and institutions in all subjects related to developing and implementing management plans for sustainable exploitation of inland water resources.

Introduced non-native organisms

- Ways to develop more effective controls on trade in non-native species, especially illegal trade in ornamental species.
- How to remediate the problem that developing countries do not have the means to implement the inventory, monitoring, and risk assessment programs which are needed in relation to introduction of non-native species.

Exploitation

- Any management scheme which is to be sustainable depends on the active participation of all stakeholders, in particular the local communities. It is important to discuss modes of local participation and ways to minimize user conflicts.
- Many inland waters are shared between countries. This makes the development and implementation of management plans and harvest schemes difficult. Ways and means to improve management of biological resources in shared waters need to be discussed.
- Various approaches to increase biomass production in inland waters have been applied. Activities like aquaculture and cultivation of fish stocks may be detrimental to natural biodiversity. Codes of practice to increase sustainability of these activities should be developed.
- In many biomass harvest activities, large proportions of the catches are destroyed. It is therefore important to develop technologies that improve utilisation of resources, particularly based on energy sources and infrastructure available in poor countries.

Technical encroachments

- Bilateral and multinational financing institutions have the potential and responsibility to play a leading role in conveying the concept of ecologically sound development of freshwater resources. The ways and means to utilize these resources for conservation and restoration of freshwater biodiversity should be discussed.
- There is a need for an overriding long-term catchment based strategy for development of water resources. Modalities for the development of catchment based management plans may be considered, both within countries and for shared river systems.

Pollution

- The major forms of pollution negatively impacting freshwater biodiversity are: acid rain/acidification, eutrophication, toxic substances, radionucleotides and thermal pollution.
- The strategies to further develop international treaties to reduce emissions, and technologies to reduce waste production and emissions need to be discussed.
- Organic micropollutants is an increasing problem. Their effect on biodiversity and possible remedial actions should be discussed.

Recommendations

To be able to prioritize conservation actions, documentation of biodiversity of vulnerable localities is necessary. This forms the basis for the development of conservation plans for threatened and vulnerable water bodies and their catchments. Emphasize should be given to conservation plans regarding international waters (e.g. multinational agreements on the great East African lakes).

Introduced non-native organisms
General recommendations

- Encourage investment in native species to capitalize inventory, monitoring, and risk assessment programs, and decrease demand for introduced species.
- Develop the "Introducer pays" concept. This may be based on international standards for monitoring and risk assessment, so that any entity wishing to introduce a non-native species to a particular country contributes in proportion to the assessed risk of the introduction to the national infra-structure for inventories, risk assessment, and monitoring, enabling the host country to carry out its own risk assessment.
- Individual countries invest in national capacity building, directly or through loans or grants from international agencies, as a sign of commitment to economic growth and social development harmonized with the conservation and sustainable use of as much native biodiversity as possible.
- We recommend immediate funding of at least a small number of intensive inventories (1) to serve as models for developing and standardizing methodologies for inventories, monitoring, and risk assessment programs, (2) for developing protocols for capacity-building, and (3) for establishing the economic feasibility of such an approach.

Specific Recommendations

- The scientific community should begin deriving generalizations from existing data while still expanding the data base. Our present state of knowledge is that many, if not all, introductions are irreversible.
- When making decisions about deliberate introductions of non-native species, the concept that **there are empty niches that can be safely filled by the introduction of a non-native specie**s should be abandoned completely.
- Monitoring programs, using inventories of native species for reference, should be established to detect accidentally introduced species as quickly as possible.
- The economic value of native species should be developed as a means of decreasing local economic demand for introduced species.
- Risk assessments for deliberate introduction of non-native species should include a comparison of the economic potential of native species likely to be affected by the introduced species with the potential economic benefits of the species proposed for introduction.
- Approval for introductions should be made only when the economic benefits of the introduced species clearly outweigh the economic potential of native species **and** when there is likely to be minimal negative ecological impact by the introduced species.

Exploitation

- To promote sustainable use of freshwater resources, it is necessary to develop and implement management plans which are based on elements such as: biodiversity impacts, economic and social aspects, involvement of all stakeholders and local communities, monitoring programmes including target species and by-catches.
- It is essential to coordinate activities in border watercourses.
- The concept of community participation in exploitation and management should be strengthened.

- The international community should assist developing countries to achieve the capability to manage their resources for sustained biodiversity by strengthening and improving their awareness, research, and management capability.
- Aquaculture practices should involve environmental impact assessments, particularly taking into account effects on wild populations from escapes and diseases, habitat alteration, and eutrophication aspects, as well as investigating the use of local species.
- There is an urgent need for more studies on ecological functions and processes, to improve the understanding of effects of exploitation on non-target species and biodiversity.

Technical encroachments

- Water resources management plans should be developed for total catchments.
- Remedial measures should be incorporated already in the early planning phase.
- The maintenance of corridors of woodland and riparian vegetation along watercourses is of major importance for biodiversity. The riparian habitat is commonly species rich, it protects and enhances biological diversity and production in rivers and streams, and is of vital importance in its corridor function for migrating species.
- In order to provide the best possible conditions for fish and aquatic life in general, emphasis should be given to create flow regimes which is both flexible and as near as possible to the original regime.
- It is necessary to conserve unregulated parts of rivers and wetland systems as unique areas of original biodiversity as well as restoring appropriate parts of river and wetland systems for increasing of biodiversity and reinstatement of their functions.

Pollution

- The work on international agreements to decrease the emissions of acidifying substances, nitrogen oxides, ammonia, heavy metals and micropollutants connected with long range pollution must be intensified.
- In developing countries undergoing industrialization it is important that the environmental impacts of these emissions are estimated and considered in the planning process. Collaboration between scientists in developing and developed countries can help transfer experience from previously polluted to not yet polluted regions
- The concept of critical load should be modified and adapted to cater for differences in climate and biocommunities. The concept should be extended to also include parameters related to biodiversity.
- Mitigation actions, in the form of e.g. liming, should be directed towards areas which still have remnant populations of acid sensitive species. Liming of natural acid lakes must be avoided.
- Increased demand for documentation about the persistent organic micropollutants is needed.
- Export of DDT and other pesticides, which are banned in the developed countries, must be stopped.
- Heavy metal effluents from industrial activities (e.g. gold extraction) should be reduced to a minimum.
- There is a need for more knowledge on the long-term effects of low-level radiation, as well as on the transport and uptake of radionuclides in natural ecosystems
- Thermal pollution should be reduced to a minimum and warm water species should not be introduced into warm water effluents in cold water areas
- The following preventive actions are among those known to give positive effects in relation to several forms of pollution:
    - Maintenance and restoration of riparian protection (vegetation) belts including wetlands and intact flood plain vegetation, thereby increasing filtering of particles and self-purification capacity
    - Development and adoption of recycling systems for manure, sewage and wastewater at appropriate technological levels
    - Adoption of agricultural practices to reduce quantities and increase uptake efficiency for artificial fertilizers
    - Development and adoption of integrated watershed management plans, with participation of local communities
    - Minimize industrial waste by introduction of new technology (developed countries)

Working group reports

Background

The work under the Convention on Biological Diversity (CBD) has been organised so as to discuss issues relating to the various major ecosystems of the world. Biodiversity of freshwater ecosystems will be the major theme at the fourth Conference of the Parties (COP) in Slovakia, May 1998. This subject will also be given an indepth discussion at the third meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) in Montreal, Canada, 1-5 September 1997.

The **objectives** of this workshop were:
1. to develop the scientific basis to facilitate formulation of country positions on the issue of freshwater biodiversity in preparation for the third SBSTTA meeting, and
2. to develop a background paper to be presented to SBSTTA 3.

During the workshop, five major subjects were discussed in some detail by approximately 40 participants, mainly scientists, from 16 countries. The subjects were:
- general status of knowledge about biodiversity in fresh waters
- introduction of non-native organisms,
- exploitation of species populations,
- encroachments (*i.a.* hydropower development, canalization, irrigation), and
- pollution.

Four of the working group themes are based on the groups of factors which are generally accepted as major threats to biological diversity in inland waters.

The themes were treated by invited key note addresses, and discussed in four working groups, according to the major potential threats mentioned above. The general theme of knowledge status and gaps was discussed in each group. Each group presented their findings as a written statement and an oral presentation to the plenary. Based on this, the Secretariat (NINA and DN) has developed the present report.

The knowledge base

Diversitas has declared a lack of, and decline in, global taxonomic expertise the "taxonomic impediment" inhibiting progress towards documenting and saving the world's biodiversity. Concerning biodiversity in fresh waters, our knowledge base is quite good for some groups, e.g. fish and some macrophytes, in a few well-studied fresh water systems. Overall, however, our knowledge of the taxonomic diversity in freshwater systems globally is rudimentary. This is particularly so in several regions of high aquatic biodiversity, e.g. Africa. The workshop has identified three needs in this regard:

(1) develop extensive taxonomic inventories of as many freshwater systems as possible;
(2) capacity-building efforts aimed at overcoming the taxonomic impediment by creating and maintaining self-sufficient taxonomic infra-structures of professional para-professional, and technical taxonomists in as many countries as possible; and
(3) information obtained from these inventories, and from established collections in museums, etc., needs to be widely accessible in electronic format.

Although our understanding of ecosystem functions and biotic interactions in lakes is relatively good, we are still not in a position to reliably predict the impacts of e.g. introduction of non-native species or selective harvesting.

Working Group A: Introduction of non-native organisms

Participants: Dan Brooks (leader), Gunn Paulsen (secretary), Per-Arne Amundsen, Rita Daverdin, Wojciech Jurasz, Vyautas Kesminas, Jan Ivar Koksvik, Richard Ogutu-Ohwayo.

The threat to biodiversity from introduced non-native organisms is treated in Articles 8g and h of the Convention on Biological Diversity.

The status of knowledge pertaining to introductions

Ecosystem structure and function

Our knowledge base is quite good for some species' natural history and some aspects of community and ecosystems structure and function. Parallel to the taxonomic data base, we lack a sufficient overall bank of knowledge to permit accurate and consistent prediction and risk assessment. There is a need for more research in community ecology, emphasizing interactions such as inter-specific competition, parasitism and other potentially pathogenic associations.

Introduced species, if they persist, generally have a net negative impact on the ecosystem into which they are placed. These effects range from reduction in abundance of one or more native species (through direct or indirect action of the introduced species) to catastrophic collapse of complex and diverse ecosystems into simpler, less diverse and often less productive ecosystems. Because each ecosystem is historical unique, basing policy decisions on extrapolation from one ecosystem to another must always be done cautiously; in such cases, common evolutionary elements should be emphasized. In particular, the assumption that each ecosystem has a similar number of similar kinds of potential niches may lead to the erroneous conclusion that a given ecosystem has an empty niche that can be safely filled by an introduced species. Introduced species will almost always have an adverse effect on a local ecosystem. Their introduction, therefore, may be justified on humanitarian and economic grounds, but will rarely, if ever, be justified on the grounds that their introduction will enhance the existing ecosystem.

Of particular concern is a lack of consensus within the scientific community about the precise role of different elements of biodiversity (e.g., species richness, variation, community structure) in ecosystem function. It appears that (1) intact ecosystems are more resistant to introductions of non-native species and (2) the greatest negative impact on ecosystems comes from the deliberate introduction of non-native domestic species (e.g. carp, bass, trout), especially topline predators.

Vectors for introductions

The introduction of non-native species into ecosystems, or **dispersal**, is a widespread ecological and evolutionary phenomenon. Mega-diverse regions, such as Mexico, Costa Rica, and Brazil, owe their diversity in part to convergent dispersal of several different biotic influences. Evolutionary agents of dispersal include continental drift and other tectonic processes, watershed capture, biotic expansion and contraction, and rare dispersal events affecting single species. Humans represent a novel vector for dispersal. Unlike evolutionary dispersal, human introductions are not necessarily evolutionarily-based, affecting species from ecosystems that are not geographically adjacent or closely related. As a consequence, the effects of human introduced species need not be tempered by common evolutionary history, and thus may be difficult to predict.

Fresh water systems are particularly vulnerable to anthropogenic introductions because of the nature of the medium, which means that it is unlikely that the introduction of one species will affect only a single species within the new ecosystem; rather, we expect extensive impacts affecting multiple levels of trophic interactions. In addition, humans make extensive and diverse use of their fresh water systems. This increases the risk of accidental introductions by human activities, such as using freshwater systems for transport, and the creation of impoundments and new waterways.

Driving forces

The fundamental driving force behind both deliberate and accidental introductions is economics. Economic pressures stem from both population increases and from the aspirations of people to enhance their standard of living. Species are introduced deliberately for immediate economic gain, and that gain may outweigh negative impact on native species. Species are often introduced accidentally as a result of human economically-based activities, such as transporting goods using rivers and other fresh water systems. The increased globalization of trade, including tourism, increases the market for deliberate introductions and increases the risk of accidental introductions.

How to evaluate the balance between benefits and negative impacts

Introduced species are considered a problem by societies when they have a negative economic impact. Such impacts can be immediate (a reduction in some aspect of the economic production in a fresh water system by native biodiversity), or they can be indirect (damage to the integrity of the local ecosystem); indirect negative impacts may emerge rapidly or they may not manifest themselves for a long time. Introduced species are considered a problem by biologists, and sometimes by societies, when they have a negative impact on the ecosystem into which they are placed. In order to evaluate the balance between benefits and negative impacts resulting from species introductions, we must solicit input from all stakeholders, including people living in the areas that would be affected by any particular introduction, and concentrate on finding common ground for making decisions. We should have some idea of the economic potential of native species that may be affected adversely by the introduced species, in addition to assessing the economic potential of the introduced species. We should also have some idea of the long- and short-term effects on the quality of life for human beings living in an ecosystem that may be altered by the introduction of non-native species.

The relevance of the working group theme and potential strategies

Generality of the threat

According to the Global Biodiversity Assessment (GBA): "Freshwater ecosystems in all climatic zones seem to be especially sensitive to invasions and introductions." It also appears that many, if not most, successfully introduced species in freshwater ecosystems cannot be eradicated, and thus the introduction must be considered an irreversible act.

The threat of deliberate and accidental introductions of non-native species is probably greater today than in any time in human history, and will increase in the future. Many countries with developing economies are attracted to the economic benefits of certain introduced species, and most of these countries have rich native biodiversity that could be affected adversely by any introductions. A common theme is the introduction of topline predators (trout, bass, Nile perch) from their own ecosystems into new ones that have evolved in the absence of equivalent species. Accidental introductions of fouling organisms (water hyacinths, zebra mussels) are a major threat not only to the well-being of native species but also to local economies.

GMO’s/LMO’s (genetically/living modified organisms) may add a new dimension to the problem. Currently, GMO’s are mostly plants and micro-organisms, but there are some programs investigating genetically modified anadromous fish in Canada. At present, there are no plans to release any GMO’s into fresh water systems. Technological development is so rapid, however, that we need to take a position on the introduction of GMO’s before it becomes a problem. The convention provides obligations to parties [art. 8(g)] to assess and document possible negative impacts of the introduction of any GMO. We are concerned that even for a well-known organism, not enough is known about its natural history and evolutionary biology to make such an assessment possible. In addition, we believe that accidental releases of GMO's are a distinct threat, as all containment programs have at least some possibility of failure.

Monitoring and inventory methods

Monitoring programs should provide information for a varieties of activities related to conservation and sustainable use of biodiversity, including assessments of the ecological and economic impact of introduced species. Given the increasing threat of introductions, especially accidental ones, it is important to establish monitoring programs in as many countries as possible as soon as possible. Monitoring programs can also help distinguish between anthropogenic and natural introductions.

Monitoring programs are only as good as their underlying data bases and the ease with which comparative databases can be accessed easily, especially in electronic form. The types of data bases needed include two things. First, as complete as possible an inventory of each country's biodiversity, in order to recognize non-native species as soon as possible following their introduction. Second, information about the natural history of each native species and a data base tracking the distribution, abundance, and local impacts of introduced species, in order to make rapid and effective decisions about mitigation programs.

It is important to be proactive with respect to collecting and sharing taxonomic and ecological information, and in this regard it is important to (1) standardize monitoring methods as much as possible, and (2) encourage closer cooperation between taxonomists and ecologists. **Historical ecology** (Brooks and McLennan, 1991) is a research program that integrates taxonomic, ecological and behavioral information in a predictive evolutionary framework; some applications of historical ecology in biodiversity research have already been suggested (Brooks, Mayden, and McLennan, 1993). Other such collaborations are clearly possible, and clearly desirable.

Precautionary actions

We must show in as many cases as possible that native species have as much or greater economic value, especially sustained value, as would introduced species. At present, we do not have a good baseline of information about the possible value of most native species. The adaptability of any introduced species seems to be a prime determinant of its ultimate success, and thus its ultimate impact on a new ecosystem. Adaptability may not be simply a question of whether a species is a specialist or a generalist in its native ecosystem, but may be more a function of the way it functions in a novel ecosystem.

Special care should be taken with respect to risk assessment associated with the release of GMO's/LMO's, because such organisms may represent elements of biodiversity that have no counterparts in the natural biosphere. For these species, it is vitally important to consider not only the potential benefits claims for any given GMO, but also the riskiness of placing novel elements of biodiversity into any ecosystem.

Public awareness and education programs are essential complements to capacity-building. Such efforts should be conducted in cooperation with relevant stakeholders, including commercial, artisanal and sport fishing groups, representatives of the ornamental fish trade, ecotourism developers, and civic representatives of communities situated near freshwater systems.

Mitigating actions

We know of no cases in which programs to eradicate an introduced species have been successful. We should, therefore, accept that most introductions are irreversible events, and emphasize mitigation rather than eradication. The benefits to native species of mitigating actions against non-native species, as well as the costs of those actions, must be taken into account before economic resources as expended on any programs. We believe in most cases it will be a waste of money to try to eradicate an introduced species, but that in many cases it might be cost-effective to mitigate the spread and influence of a non-native species. In particular, we are concerned about programs that attempt to mitigate the impact of one non-native species by introducing one or more **additional** non-native species. We believe extreme care should be taken before such programs are initiated.

Developing sustainable benefits from native species in their native environments can serve as an effective mitigation program by reducing economic demand for introduced species. At the same time, such efforts may also help enhance the conservation status of rare native species. Such a case involves the requirement by Malawi that commerce in the ornamental fish trade involving rare haplochromine cichlids be based on the sale of hatchery-reared rather than wild-caught fish, thus removing pressure for harvesting small natural populations.

Some examples of mitigation and restoration efforts are:

- The impact of the water hyacinth in Lake Victoria is mitigated by three programs: (1) harvesting of the plant, (2) bio-control (the introduction of a non-native weevil), and (3) measures taken to reduce the level of eutrophication in the lake.
- The impact of the Nile perch in Lake Victoria is mitigated through increased harvesting of the fish by a growing local population.
- The ectoparasite on Atlantic salmon *Gyrodactylus salaris* has been introduced to Norway. As the parasite is species specific and do not survive for long independent of the host, rotenone treatment of the salmon inhabited parts of the rivers have been used. The point is to remove the host for a necessary period of time, for later reintroduction when the parasite has disappeared. Rotenone treatment causes, however, political and cultural conflicts in society, as well as negative ecological effects.
- Sea lampreys (*Petromyzon marinus*) was introduced to the North American Great Lakes, causing serious decline in the populations of several native fish species. Mitigation measures included decimation of spawning populations of sea lamprey in their spawning rivers, and release of hatchery reared salmonids less vulnerable to sea lamprey attacks.

Conservation measures

Intact ecosystems seem to be more resistant to introductions than disturbed ones, so it is important to save as many intact pieces of natural ecosystems as possible; that is, we need to conserve not only species but habitats and ecosystems functions. Conservation of natural ecosystems should provide natural mitigation against accidental introductions.

The value of native species should be enhanced by understanding their potential as economic resources. The economic value of native species may be manifested in different ways: for example, some species represent marketable resources, some enhance (or are necessary for) the survival of marketable species, some are essential for maintaining water quality, which itself has great economic value. Given this, it may be economically feasible and ecologically sound to re-introduce populations of native species that have become extinct in the recent past.

Public awareness and education programs are also beneficial to conservation programs, particularly in relation to creating public support for sustainable development and in capacity-building.

Priority questions

There is a need for more effective controls on trade in non-native species, especially illegal trade in ornamental species.

- How do we implement this? Do we need something like CITES but for non-native species?

- If we adopt an international organization like CITES, is there any way we can speed up the process, or will we get bogged down in bureaucracy?
- Should assessment for GMO's be international but for non-GMO's be up to individual countries? Should there be an effort to provide international standards?

Developing countries that are under tremendous economic pressure to introduce non-native species do not have the means to capitalize inventory, monitoring, and risk assessment programs. Consequently, they are often unable to make thorough cost-benefit analyses with respect to programs dealing with introduced species.

- How can developing countries capitalize inventory, monitoring, and risk assessment?

Recommendations

Below is a prioritized list of general and specific recommendations to solve the problems arising from the introduction of non-native species, emphasizing conservation and sustainable use of freshwater biodiversity.

General recommendations

Recommendations 1-4 concern ways to capitalize the necessary inventory, risk assessment, and monitoring programs, and capacity-building, necessary to achieve sustainable use and conservation of biodiversity resources.

1. **Encourage investment in native species to capitalize inventory, monitoring, and risk assessment programs, and decrease demand for introduced species, by developing a Biological Futures market.**

   The search for non-renewable resources involves a substantial element of risk. Not all oil or gold explorations succeed. Without such exploration, however, new deposits would ever be found. Investors thus spend capital on a variety of projects, hoping that the successes will return more money than the failures take away. Investors can fund studies on the economic potential of native species in the same way. Invest in studies of 1,000 species, 1 of which produces an effective bio-control agent, or of 1,000 species of aquatic plants, 1 of which produces an effective pharmaceutical, and the return is worth the risk. Additionally, it appears that the species that have the most negative impact on ecosystems are deliberately introduced domestic species. This is a way to reduce the demand for introductions of this type.

2. **Develop the "Introducer pays" concept: Below we list three possible ways in which this could be implemented.**

   a) Establish an international standards and review board for monitoring and risk assessment.

   This board could be funded by all stakeholders, governments, corporations, NGO's, private conservation agencies. The goal of such an organization would be to harmonize and stabilize policies and methods; all information gathered by this organization would be shared and accessible globally. If an international organization similar to CITES is established, this could be one of its functions. Any entity, that is not a subscribing member of the board, wishing to introduce a non-native species would be required to pay for a risk assessment done by the board, or for a review of its own risk assessment.

b) Any entity wishing to introduce a non-native species to a particular country contributes to the national infra-structure for inventories, risk assessment, and monitoring, and the host country carries out its own risk assessment.

c) Any entity wishing to introduce a non-native species to a particular country negotiates a contract, on a case by case basis, whereby it pays for the risk assessment and contributes to the national infrastructure for inventory and monitoring in proportion to the assessed risk of the introduction.

3. **Individual countries invest in national capacity building, directly or through loans or grants from international agencies, as a sign of commitment to economic growth and social development harmonized with the conservation and sustainable use of as much native biodiversity as possible.**

   Assessing the economic value of native species, monitoring the introduction, impact, and fates of introduced species, and performing risk assessments associated with all require, among other things, precisely the same taxonomic/ecological skills. Capacity-building in taxonomy and ecology, therefore, does not require multiple capacity-building programs, and is more cost-effective than it might appear. The goal of any capacity-building efforts should be a self-sufficient and sustainable infrastructure of professional, para-professional and technical taxonomists and ecologists. Agencies, such as the IMF and World Bank, that would be approached to support such proposals, must understand that the production of trained personnel is an economic development product, at least as much so as a bridge or a hydroelectric dam.

4. **We recommend immediate funding of at least a small number of intensive inventories (1) to serve as models for developing and standardizing methodologies for inventories, monitoring, and risk assessment programs, (2) for developing protocols for capacity-building, and (3) for establishing the economic feasibility of such an approach.**

   A substantial number of professional taxonomists from many countries now have extensive experience with planning for such inventories, including the training of, and collaboration with, parataxonomists and paraecologists, as a result of the All Taxa Biodiversity Inventory (ATBI) initiative in Costa Rica. In addition, such efforts would be consistent with the published recommendations of Systematics Agenda 2000, encompassing many more members of the taxosphere. The ATBI experience showed that a large proportion of the world's professional taxonomists are willing to participate in such projects in return for the opportunity to expand scientific knowledge and to contribute to the economic and social development of biodiverse countries in ways that conserve the world's biodiversity. Recruitment from the taxosphere will thus be highly cost-effective.

Specific Recommendations
(Recommendations 1-3 concern scientific research priorities):

1. The scientific community should begin deriving generalizations from existing data while at the same time striving to expand the data base. Our present state of knowledge is that many, if not all, introductions are irreversible.
2. Historical ecological studies should be used to form the basis for identifying common evolutionary elements between ecosystems, as a means for integrating taxonomic, ecological, and behavioral information into a common predictive evolutionary framework, and as one forum in which taxonomists and ecologists can collaborate easily.
3. When making decisions about deliberate introductions of non-native species, the concept that **there are empty niches that can be safely filled by the introduction of a non-native specie**s should be abandoned completely.

Recommendations 4-7 concern programmatic recommendations

4. Ecosystems should be maintained intact whenever possible, and that special caution be taken when considering the introduction of non-native domestic species.
5. Monitoring programs, using inventories of native species for reference, should be established to detect accidentally introduced species as quickly as possible.
6. Capacity building should emphasize creating and maintaining a self-sufficient infrastructure of professional, para-professional and technical taxonomists and ecologists to perform inventory, monitoring and risk assessment activities vital to conservation and sustainable use of the world's biodiversity.
7. Basic taxonomic and ecological information and principles should be introduced early in educational curricula, and public education and awareness programs should build on the educational base throughout life. This will build public awareness of the problems of introduced species, and public support for policies dealing with such introductions.

Recommendations 8-10 concern valuing native vs. introduced species

8. The economic value of native species should be developed as a means of decreasing local economic demand for introduced species.
9. Risk assessments for deliberate introduction of non-native species should include a comparison of the economic potential of native species likely to be affected by the introduced species with the potential economic benefits of the species proposed for introduction.
10. Approval for introductions should be made only when the economic benefits of the introduced species clearly outweigh the economic potential of native species **and** when there is likely to be minimal negative ecological impact by the introduced species.

References

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Working group B: Exploitation of species populations

Participants: Brian B. Rashidi (leader), Linda Hedlund (secretary), Anatoly Mamontov, Lazarus B. Nhwani, Toomas Saat, Adelaida Semesi, Asbjørn Vøllestad, Per Wramner.

The Convention on Biological Diversity stresses the issue of sustainable use of components of biological diversity particulary in Article 10.

The state of knowledge pertaining to exploitation

Ecosystem structure and function

Consequences of exploitation on target species are fairly well known, but there is much less knowledge available for effects on other parts of the ecosystem. This is partly due to the sectorial approach - fisheries are only interested in effects on fish, and not on other biota. We need monitoring not only of target species, but also to determine effects on other parts of the ecosystems.

The widely used models for yield calculations in fisheries management are single species models, often estimating "maximum sustainable yield, MSY". This concept should be abandoned, as the aim of maximum yield of single species in most cases leads to overexploitation. Present methods which include multiple stocks are appropriate for industrial or large-scale fisheries, and for big lakes or ecosystems, while they are not applicable for smaller fisheries, e.g. in smaller lakes and in river systems.

There is very limited knowledge on ecological interactions and processes, and this is a general, world-wide problem. For example lake Vänern in Sweden is a very well studied lake. The present knowledge only apply to species and food webs, not to processes. When a new species was proposed for exploitation, it was realised that not enough was known to determine the potential effects of the harvest on the ecosystem.

Criteria for sustainable exploitation

We need to have an ecosystem approach to management. An ecosystem approach tries to include all aspects of an ecosystem; water quality, trophic interactions, energy flow and other ecosystem functions, population structures, community structures, prey-predator interactions etc.

To achieve sustainable use, we also need to study human consumption patterns, and try to make better use of catches, not to spoil them. Handling of by-catches is also important. By-catches are usually not reported. They must be monitored and reported like other catches. This also applies to other by-catches than fish.

Use of fishing gear or methods that harm the ecosystem are not sustainable. Impact of gear and methods on the ecosystems have to be studied. Methods like dynamite fishing or poisoning should be stopped.

Exploitation in border lakes or rivers

There is often a political problem related to limited resources between nations. Both sides want to get more fish. There is a need for strong coordination structures for stock management and introductions etc. at border lakes or rivers. These should also include control and enforcement systems.

Measures to increase biomass production (cultivation, aquaculture)

Cultivation should generally be based on native species and stocks. However, re-stocking is an expensive way of keeping a fishery. It is much better to try to manage existing stocks for increased production. In this context, consideration of quality as well as biomass is important. For example, some fish species have much higher value than others.

Nutrient supply to oligotrophic water bodies usually increases fish production up to a certain level. However, eutrophication is a process which is difficult to control, and there is always a risk of an irreversible eutrophication process to a level when both water quality and fish production is reduced.

Concerning aquaculture, more knowledge is needed about ecosystems and the genetic and population structure of species. Among negative effects are habitat destruction or eutrophication, spread of diseases, and detrimental genetical effects on stocks, wild or captive.

Choice of species for cultivation is important. For example, in Malaysia, there are lots of indigenous species, but they are poorly known. It is easier to cultivate non-native, but better known, species. Aquaculture should mainly use indigenous species, and thus better knowledge is needed about local species.

Conservation status for freshwater biodiversity

There are several examples of lakes as national parks. Parts of lake Malawi is a freshwater national park with a conservation strategy, mainly to conserve species for the aquarium trade. However, there is a need for more knowledge about systems of non-destructive multiple use of protected areas within aquatic environments. There is a need for more freshwater biota conservation, as the situation in many areas is rapidly deteriorating.

The relevance of the working group theme and potential strategies

Exploitation as a threat to biodiversity

Exploitation of natural resources is a necessity for human life. As such, it can not be considered as a general threat to biodiversity. It is unsustainable harvest or over-exploitation that threatens biodiversity. It is important to note that not only fish, but also other taxa including plants, are harvested in freshwater systems.

Among destructive and unsustainable aspects of exploitation are un-controlled by-catches and fishing methods causing habitat destruction. By-catches should be avoided, but when they do occur, they must be recorded in fisheries statistics and utilised. Habitat destruction must also be avoided, through for example change in fishing method. Harvest must be more specific to targeted species, and the fishing gear has to be modified for this purpose. It is important to establish reserves, where harvest is not allowed. These areas serve as pools supplying the harvested areas, and may be important in stock and ecosystem monitoring.

The aquarium trade is different: it is very targeted for special species. To develop a sustainable aquarium trade, rearing methods for attractive species are needed. A sustainable trade may be based on local rearing, and only to allow trade in reared specimens.

Potential remedies for restocking must be carefully investigated before restocking is used as a management tool. The same apply for remedies for adding nutrients in low-productive systems.

Monitoring methods

We need better and more cost-effective monitoring methods. The monitoring systems must indicate the development of the ecosystem as well as certain species. The link between monitoring and research must be improved. Research is needed to improve monitoring methods, and monitoring data should be utilised in research. It is also important to standardise existing methods.

Governments must commit themselves to finance longterm monitoring programmes. Local people must be involved in the monitoring programmes, to understand and make use of the information generated.

Precautionary actions

Exploitation of inland fish resources usually has evolved without planning. Scientists and managers commonly become involved later, when things start to go wrong. The more large-scale activities, the more important it is with careful planning etc before activities start. However, in small inland water systems, even small scale exploitation may have devestating effects. Thus, any exploitation should in principle be based on a management plan. In the development of management plans it is important that all stakeholders are involved. Benefits from the utilisation to the local communities is also of utmost importance. The planning may not only consider the target resource, but should include all other aspects of the community and ecosystems involved.

Management needs to be adaptive. For example, there must be ways and means to close exploitation when needed. Enforcement and control must be strengthened. To achieve efficient enforcement and control, it is essential that local communities support and participate in the control system. Among the major reasons that the enforcement and control systems are not working is that rules and regulations are unrealistic and not understood and accepted by local communities. Thus local participation and awareness raising are important.

Conservation measures

Some conservation measures related to exploitation are:

- Vulnerable or threatened species must be identified. If these species are to be utilised, particularly cautious adaptive management schemes must be developed.
- Partnerships within the systems are important for conservation to be effective. Protected areas are not always a useful tool for conservation. For example, 25% of Tanzania's area is under protection. It is not feasible to increase this area, and protected areas are often only a solution in areas that are sparsely populated or inaccessible anyway.
- There is a need for trade regulations on ornamental species.
- Regional or country collaboration is needed for the conservation of shared waters, and shared resources.
- Biodiversity is a global heritage, and global efforts should be encouraged for conservation.

Priority questions

1. Capacity building

There is a general lack of capacity for management and management related research in developing countries. Thus, ways and means for capacity and competence development for individuals and institutions in all subjects related to developing and implementing management plans for sustainable exploitation of resources of inland water should be discussed.

2. Inventory, aquatic biota

There is a general lack of data on aquatic biodiversity, particularly in developing countries. Important data may also be stored in western museums and institutions. Thus, important questions are how to increase knowledge and how to restore data to the country of origin. Development of institutions for biodiversity data collection and storage (e.g. herbariums and museums), and of national and regional databases may be one important element.

A wider approach to studies on exploitation vs. biodiversity is needed. This involves both an ecosystem approach in the natural science aspects, and a multidisciplinary (including social sciences) approach to management plan development.

3. Local participation

Any management scheme which is to be sustainable depends on the active participation of all stakeholders, in particular the local communities. It is important to discuss modes of local participation and ways to minimize user conflicts.

4. Transboundary resources
Many inland waters are shared between countries. This makes the development and implementation of management plans and harvest schemes difficult. Ways and means to improve management of biological resources in shared waters need to be discussed.

5. Increase of biomass harvest
Various approaches to increase biomass production in inland waters have been applied. Activities like aquaculture and cultivation of fish stocks may be detrimental to natural biodiversity. Codes of practice to increase sustainability of these activities should be developed.

In many biomass harvest activities, large proportions of the catches are destroyed. It is therefore important to develop technologies that improve utilisation of resources, particularly based on energy sources and infrastructure available in poor countries.

Suggestions and recommendations.

1. Increasing awareness of biodiversity at all levels
It is necessary to ensure that knowledge about biodiversity at all levels, and its importance for the sustainable use of resources, is disseminated to the local communities, the managers, and the politicians. To do this it is necessary to increase competence in taxonomy and understanding of ecosystem functioning in the scientific community. Management related research also depends on close interaction between management institutions and researchers. Further, it is necessary to increase the level of understanding among local people. It is therefore necessary to develop and implement plans for the flow of information from science to management, and for public awareness raising.
There is a need for countries to broaden the basis for biodiversity valuation, and to include e.g. ecological, social, scientific and ethical values.

2. Management plans
To promote sustainable use of freshwater resources, it is necessary to develop and implement management plans, including:

- environmental impact assessments for all major projects, including new fisheries, industrial development, building, and aquaculture
- economic and social aspects
- involvement of all stakeholders and local communities
- regional monitoring programmes as part of the management plans (incl. sampling routines, data processing and presentation). Monitoring should include target species, by-catches where appropriate, and other components of biodiversity ensuring that the use is sustainable and ecosystem function maintained.
- interdisciplinary studies using standardised methods to support management planning.
- promote coordination of activities in border lakes/ rivers.

3. Community participation
Over-exploitation of biodiversity in freshwater is mainly a result of pressure from rapidly increasing populations in the developing world and irrational exploitation tendencies in the developed world, all of which have resulted in irresponsible utilisation of resources. Management strategies often have been planned without involvement of the people who harvest the resource. Hence they are not made responsible for any damage to the resource. It is recommended that resource users should be involved at all stages of resource management, beginning from planning, and they should be made aware of the benefits they

will derive from managing and exploiting the resources responsibly. The concept of community participation should therefore be strengthened.

4. Capacity building
Taking into account the high biodiversity in freshwater systems in tropical waters, and with the view that many of these countries have limited capacity and resources to make inventories and to protect biodiversity, it is recommended that the international community should assist these countries to achieve the capability to manage their resources for sustained biodiversity by strengthening and improving their awareness, research, management capability, technological transfer and intellectual property rights.

5. Maintaining freshwater productivity
By recognising that there is high freshwater biodiversity and that large populations surround many water bodies, it is recommended that special attention is given to the proper use of water and its biota for sustainable development, by ensuring that the productivity of the freshwaters is maintained by reducing pollution, blocking water flows or draining for other purposes.

6. Aquaculture
There will be a need to increase biomass production, and aquaculture is a possible solution. Aquaculture practices should involve environmental impact assessments, particularly taking into account effects on wild populations from escapes and diseases, habitat alteration, and eutrophication aspects, as well as investigating the use of local species.

7. Increase the knowledge base and dissemination
In order to promote development of freshwater bodies for biodiversity conservation and sustainable exploitation, it is necessary for countries to establish a strong knowledge base of their resources. It is recommended that countries undertake the following measures:

- thorough inventories of freshwater biodiversity (country studies)
- establish registers of freshwater bodies and distribution
- describe biodiversity that exist and create databases that are accessible for research and management
- promote development of systems for data exchange

8. Research
There is an urgent need for more studies on ecological functions and processes to generate knowledge for management and sustainable use of freshwater resources.
As an example, these are research priorities for fish-stock management:

- investigate the presence and role of natural rhythms and fluctuations in ecosystems
- reveal the structures of fish communities, and the trophic interactions as related to e.g. the ecosystem impact of exploitation
- investigate the evolution and establishment of local faunas
- investigate more thoroughly hybridisation in fishes, and its consequences.

Working group C: Technical encroachments on rivers, lakes and wetlands

Participants: Ján Šeffer (leader), Ove Hokstad (secretary), Angelo Antonio Agostinho, Peter Blomquist, Singharaj Bouathong, John Brittain, Liubov Nagorskaja.

The Convention on Biological Diversity points at this threat to biodiversity from technical encroachments in Article 7d, and in Article 14 stresses that proper EIAs should be performed to minimize adverse effects of projects on biological diversity. In this context, the following types of technical encroachments are discussed: water storage and dam construction, flood control and navigation, and drainage of wetlands and lakes.

The status of knowledge pertaining to technical encroachments

Water storage and construction of dams

Dam constructions leave a permanent impact on the natural water course. Large areas of terrestrial and wetland habitats are frequently inundated by dam construction, and the dam changes hydrology and biological systems in the water body.

Impoundment invariably modifies the hydrology of the downstream reach. In the simplest form, the discharge is redistributed in time. In other cases the annual discharge may either be increased if additional catchments are transferred to the reservoir or decreased if the downstream section is bypassed on account of a power facility. With the exception of peaking discharges, reservoirs generally reduce the short and long term variability and the frequency of major flood events is often reduced. Hydropower installations and irrigation needs often give rise to peaking discharges in which there is a rapid rise and fall in discharge, on a daily, weekly or seasonal basis. For many aquatic organisms, the rapid rate of change in discharge is often more deleterious than the high discharge itself.

Water temperatures are frequently modified as a result of dams. Many organisms depend on receiving certain environmental signals for successful completion of their life cycle. This may, for example, be the attainment of a particular water temperature necessary to initiate spawning in a warm-water fish species or to trigger emergence in a species of aquatic insect. The absence of such signals may lead to extinction.

Increased sedimentation in regulated streams may arise from dam construction activities, elimination of the flushing action of periods of high discharge, or reduced flow due to diversion. In addition to direct effects on biota, such as clogging respiratory surfaces and covering aquatic plants, sedimentation decreases substrate heterogeneity.

The chemical nature of the release water will invariably differ from the water flowing into the reservoir. For example, deleterious effects on the downstream community may occur due to decreased oxygen content of the reservoir release water, as most stream organisms are adapted to high oxygen levels.

Reservoirs are typically highly productive the first few years after impoundment, especially if nutrient-rich agricultural or grazing lands are inundated. Outflowing waters may therefore have greater concentrations of nutrients than waters entering the reservoir. This may result in increased aquatic vegetation, especially where flows are more or less constant. Simulated spring runoff and spates usually help to reduce the buildup of algal mats and excessive growth of mactophytes. In the long-term reservoirs may become more oligotrophic on account of decreased littoral production.

The construction of a reservoir on a river system constitutes a discontinuity not only in terms of the river continuum, but for many aquatic organisms impoundment represent a barrier to dispersal and reproduction. The dam itself is a physical barrier to upstream and in some cases downstream movement. This is especially important for migratory fish species.

Fish ladders or fish-lifts are often incorporated into dams to reduce such problems, but they are often ineffective. Conditions in the reservoir itself may also prevent or reduce the passage of migrating fish. For example the surface waters of stratified reservoirs may be too warm and the deeper water too low in oxygen for salmonids.

Below dams species diversity is nearly always reduced and the taxonomic composition of the downstream invertebrate community is greatly modified compared to natural streams. Increased flow constancy favors species more typical of slow flowing rivers. Rapid flow fluctuations eliminate accumulations of leaf litter and therefore most species utilizing this resource are reduced in such situations. However, reservoirs often provide an additional food source, the reservoir plankton, especially where water is released from the epilimnion. Nevertheless, entire groups of macroinvertebrates may be rare or completely absent below impoundments.

There is a wide range of mitigation strategies. For example weirs have been constructed as a remedial measure for many years. Their main purpose has been to create a suitable habitat for fish and maintain a certain water level in the river. Ducks and waders also benefit from the increase in food supply, particularly in the weir basin. Over a long period the benthos may undergo a succession towards life forms adapted to slow flowing waters, although major floods can "reset" the system.

Flood control and navigation

The main result of flood control and river management for navigation is a decrease in floodplain area and a loss of wetland ecosystems with their unique values and functions. These include groundwater recharge and flood storage, the elimination of nutrients from the water and soil, the processing of pollutants, and the production of biomass and oxygen.

River regulation for navigation has changed the natural character of rivers by:

- Shortening of rivers by removal of meanders. The loss of habitats of river banks and shallow water results from these encroachments. Spawning locations for fish are eliminated and isolated oxbows trap juveniles.
- Dredging of river beds for navigation has an adverse effect by lowering the water table in adjacent wetlands and causing their degradation. The gradual change of aquatic and wetland ecosystems into terrestrial ones causes the replacement of microorganisms, plants and animals typical adapted for life in water or saturated soil conditions. Loss of original biodiversity cannot be replaced by the spread of common, ubiquitous species to degraded habitats.
- Canalisation leads the water from old river bed into an artificial channel, resulting in a lowering of the water table from the former system and subsequent loss of water and wetland systems. The creation or breakdown of barriers created by canals can influence water quality and migration of species.

Drainage of wetlands and lakes

The problems of drainage of land covers entire river systems and we emphasize that the holistic view, looking at entire drainage areas of rivers should be in focus when solving the problems connected with drainage. Nevertheless, for the purpose of clarifying the problem, we have decided to distinguish between the effects of drainage of wetlands and the effects of lowering of lakes. By wetlands we mean all types of wetlands, also those adjacent to rivers.

Drainage of wetlands results, except in those cases when the entire ecosystem is lost, in reduction of system size. In many cases not only the size of the system diminishes but fragmentation into smaller units takes place. Due to the construction of drainage ditches the water runoff from the system speeds up and low water levels are reached earlier than in unaffected systems. With faster runoff a temporal discontinuity in the development of the system (ephemeral wetlands) often follows, affecting the survival of the flora and fauna. Among plants, drainage of wetlands often results in the loss of vegetation adapted to flooding and among animals loss of reproduction areas and juvenile development sites. Loss of wetlands, particularly along river systems, also results in destruction of natural corridors for migratory birds and mammals.

Lowering of lakes often results in entire lake ecosystems being transferred to wetland ecosystems, without pelagic and profundal zones. In other cases a new, smaller lake ecosystem is established after a few years, i.e. the ecosystem has been aged but not lost. Many lakes are drained to a point where they come close to changing into a wetland system. In these lakes, light penetration to larger bottom areas allows the littoral zone to expand, while the profundal zone diminishes. With the expansion of the littoral accumulation of organic matter in the lake basin and, particularly in north temperate lakes, loss of oxygen-demanding organisms, particularly fish, during periods of winter anoxia takes place.

Priority questions

- Bilateral and multinational financing institutions have the potential and responsibility to play a leading role in conveying the concept of ecologically sound development. The ways and means to achieve this for freshwater biodiversity should be discussed.
- There is a need for an overriding long-term catchment based strategy for development of water resources. Modalities for the development of catchment based management plans may be considered, both within countries and for shared river systems.

Recommendations

1. Water resources should be viewed in an overall perspective, balancing the needs of conservation and development.
2. Water resources management plans should be developed for total catchments.
3. Remedial measures, both in the river environment and in the surrounding catchment, can significantly reduce the impact and contribute towards a more sustainable development of water resources. Through integrated planning based on whole catchments, the extra costs involved in remedial measures constitute only a very small part of the total development costs. Such measures should be incorporated already in the early planning phase.
4. For dam constructions, complete remediation or restoration is not feasible unless the dam is removed and then only after a substantial period of time. In the case of river canalisation, however, complete restoration is strongly recommended.
5. The maintenance of corridors of woodland and riparian vegetation along watercourses is of major importance for biological production in rivers and streams, as well as being of vital importance for birds and game. Such boundary zones, or ecotones, are also areas of high biological diversity and have an important function in preventing erosion and reducing runoff from agriculture and industry.
6. In order to provide the best possible conditions for fish and aquatic life in general, emphasis should be given to create flow regimes which is both flexible and as near as possible to the original regime. This means that under certain conditions artificial floods should be created which promote or make possible fish migrations. Floods can also rejuvenate floodplain habitats.
7. To increase the possibility of adjusting the temperature regime in downstream reaches, dams should be constructed with both surface and deepwater release facilities, or even multi-level off-takes.
8. It is necessary to conserve unregulated parts of rivers and wetland systems as unique areas of original biodiversity as well as restoring appropriate parts of river and wetland systems for increasing of biodiversity and reinstatement of their functions. It is necessary to leave certain subsystems as refugia for native populations and for reproduction of migratory organisms.
9. It is necessary to apply mitigation measures in areas of conflicts of interest to decrease the loss of biodiversity
10. Certain lakes unaffected by water level regulation should be left within each catchment.

Working group D: Pollution of fresh water systems.

Participants: Tor Erik Brandrud (chairman), Heidi Hansen (secretary), Magnus Appelberg, Jan Herrmann, Trygve Hesthagen, Antanas Kontautas, Petter Larsson, Richard Ogutu-Ohwayo, Ann Kristin Schartau, Gunta Springe.

Various forms of pollution are among the major threats to biological diversity in inland waters. This is referred to in Article 7c of the Convention. In this context, the following types of pollutions have been discussed: acid rain/acidification, eutrophication, toxic substances, radionucleotides and thermal pollution.

The status of knowledge pertaining to pollution

At present, we have little knowledge on how a variety of the existing pollutants affect biodiversity. To handle this problem, there is a need for increased knowledge on the fundamental processes forming biodiversity including the interactions within and between species and the environment. Communities are complex systems, and we need to know how pollutants affects the structure and function of communities.

We have to develop a strategy for how to recognize the status and changes in biodiversity. Thus, there is a need for a) methods describing the present status, and b) methods used for detecting deviations from expected status.

Specifically, the following gaps of knowledge are important:

- The effects of pollutants on community structures and functions, and possible cascading effects within the community. In this respect, much may be learned from reanalysing existing data, in addition to rigorous testing of new pollutants.
- The effects of micropollutants on the species and community level, and concerning sub-lethal and synergistic effects of pollutants on biodiversity. This concerns particularly biologically active substances, pesticides and heavy metals.

Moreover, information of biodiversity is fragmented and often restricted to certain taxonomic groups, and to certain parts of the world.

Lack of standardised sampling methods makes existing data on biodiversity incomparable. Although environmental monitoring is fairly well developed in many countries, there is a gap between the present environmental monitoring and monitoring of biodiversity. There is a need to develop cost-effective parameters for monitoring status and trends of biodiversity

Acid rain.

During the last 30-40 years, acidification has led to substantial, regional loss and impoverishment of freshwater biodiversity in European and North American regions with predominately soft-water lakes and rivers. This situation probably applies also to other regions with acid-sensitive lakes and rivers. The acidic substances in precipitation are mainly nitrogen - and sulphur-compounds.

In southwestern Scandinavia, the decline of many species and bio-communities in soft-water lakes and rivers is well documented (e.g. atlantic salmon, brown trout, isoetid plant communities). For a number of other groups of organisms such as mayflies, chironomids and aquatic mosses, there has been an estimated loss of more than 50% of the original species in long-term acidified rivers or lakes. Four kinds of sensitive species can be distinguished, those affected by: **(i) low pH/labile Al** (fish, insect nymphs, crustaceans), **(ii) low pH/low Ca** (snails and bivalves, charophytes), **(iii) lack of HCO_3/alkalinity** (submerged plants more or less dependent on HCO_3 for inorganic carbon uptake), **(iv) indirect effects** (e.g. altered ecological conditions). The critical loads and short-term versus long-term effects vary between these groups, but serious negative effects are usually found at lake/river pH < 5.0-5.5.

The concept of critical loads and mapping of areas with exceedance of critical loads is well developed for conditions in Europe and North America. This system should be modified and adapted for use in other parts of the world to describe the need for emission cuts and to predict future problems. The latter applies especially to developing countries with increasing energy production from fossile fuels. The exceedance of critical load for surface waters has so far been related mainly to the status of different fish species. The concept should be extended to also include parameters related to biodiversity (e.g. critical loads for loss of 25% and 50% of original diversity in the most sensitive soft-water systems).

Acid precipitation is a transboundary problem and have to be solved by international agreements (cf. existing sulfur protocol for Europe). Acid deposition is rapidly increasing in developing countries, such as those of eastern and southern Asia, southern Africa and parts of South America. By 2020 emissions of sulphur is projected to be higher in Asia than in Europe and North America taken together. However, the effects of acid rain on tropical ecosystems is not well known.

Generally, the acidification problem is sufficiently well understood to implement additional measures for emission reductions.

Sulfur dioxide emissions and depositions have been reduced by approx. 40% in Europe and approx. 20% in North America since 1980, but still exceed the critical load for the most sensitive soft-water lakes and rivers. The critical loads are e.g. still exceeded in larger regions of southwestern Scandinavia, although the situation has improved.

The NO_x emissions is still unchanged or slightly increasing in developed countries (N America, Europe) due to the fact that international agreements on emission cuts so far has been less successful. In the developing countries, especially in southeastern Asia, the NO_x (and ammonia) emmissions are increasing more rapidly than those of SO_2.

Nitrogen may have both an acidifying, as well as a eutrophicating effect. Commonly, leaching of nitrate from the catchments can lead to blooms of soft-water benthic algae at very low N-concentrations, causing indirect, negative effects on freshwater biodiversity. A similar, but short-range eutrophication problem is seen in areas with high ammonia emissions.

Liming of acidified lakes and rivers is the only temporary mitigation action used on a large scale. In Scandinavia the environmental authorities are running a liming program amounting to a cost of approx. 3 billions NOK up to now. This is the most extensive environmental action in Northern Europe to preserve freshwater biodiversity. Approximately 11 000 lakes and rivers in Northern Europe are repeatedly limed, and annually ca 116 000 tons of lime are distributed only in Norway. The major aims of the liming programme are to restore the fish populations and the biodiversity in general within the acidified areas. At present, we see no alternatives to liming to mitigate the negative effects of acidification.

Management of catchment areas influences the acidification in rivers and lakes. For example, planting of conifer forest on Atlantic heathlands and various kinds of vulnerable grasslands and pastures contributes to acidification of water bodies.

Recommendations:

1. A lasting improvement in the acidification situation in sensitive parts of Europe and North America is dependent on further multilateral emission cuts.
2. In developing countries undergoing industrialization it is important that the environmental impacts of these emissions are estimated and considered in the planning process. Collaboration between scientists in developing and developed countries can help transfer experience from previously polluted to not yet polluted regions
3. The work on international agreements to decrease the emissions of nitrogen oxides and ammonia must be intensified.

4. The concept of critical load should be modified and adapted to cater for differences in climate and biocommunities. The concept should be extended to also include parameters related to biodiversity.
5. Mitigation actions, in the form of e.g. liming, should be directed towards areas which still have remnant populations of acid sensitive species. Liming of natural acid lakes must be avoided.
6. Soft water lakes are threatened and should be given priority in protection plans.

Eutrophication

River and lake eutrophication caused by excess phosphorus and nitrogen from agriculture and domestic and industrial effluents is a global problem of major concern.

Eutrophication has led to substantial loss of biodiversity on a regional scale in Europe, and the effects seem to be comparable in many other parts of the word. Eutrophication is a threat especially against (i) (ultra)oligotrophic soft water bodies sensitive to enrichment, and (ii) rare, species-rich habitats such as lime-rich chara-lakes and ponds/oxbow lakes on floodplains.

Eutrophication affects biodiversity indirectly by secondary effects of increased plant growth. Accelerated plant growth is seen as (i) increased phytoplankton production (including heavy algal blooms e.g. by blue-greens), (ii) increased filamentous (green)algae growth (periphyton), (iii) expansion of helophyte (reed) belts with *Phragmites, Typhae*, etc. into shallow areas (to 1.5-2 m depth), and (iv) expansion of submerged (elodeid) vegetation in shallow lakes. Critical limits for loss of biodiversity vary, because of complex interactions and cascade effects.

Heavy algal blooms lead to the following kinds of secondary effects: (i) reduced light penetration, with (complete) loss of submerged vegetation (if shallow areas are covered by reed belts), (ii) accumulation of organic material, habitat changes and anoxic conditions, loss of fish and bottom animals, (iii) unstable fish communities leads to change in zooplankton communities, (iv) altered phytoplankton communities (less edible species) leads to change in zooplankton communities. Many groups of organisms (especially plankton) have a higher species diversity in slightly enriched habitats, and might posses a high diversity even in fairly strongly polluted habitats (hypereutrophic lakes). However, the species composition changes considerably along the nutrient gradient, and there is a considerable loss of species when anoxic conditions are reached.

In Europe and North America, ammonia and phosphorus (but not nitrate) has generally decreased in most parts over the last 10 to 15 years, due e.g. to improved sewage treatment and substitution of phosphorus in detergents. However, still long-term effects of eutrophication prevail (especially in lakes), although improvements in biodiversity in some larger river systems (e.g. Rhine) have been achieved.

The eutrophication problem is substantially increasing in developing countries with increasing human populations, and is a major threat e.g. to the great lakes of East Africa.

The sources of nutrient load to waters are mainly local. The domestic sector and industry are the main contributors of phosphorus, agriculture is the main contributor of nitrogen. The following sources can further be distinguished:

- Sewage, increasing population
- Untreated wastewater from sewage, different kinds of industry and fish farming
- Agriculture runoff including erosion
- Forestry, e.g. runoff after clear-cutting
- Transboundary airborne pollution
- Leakage from rubbish dumps

We know enough about the process and effects of eutrophication to develop and implement action plans. Since the nutrients mainly come from local sources, the problem can only be solved on a local scale, involving local authorities and communities. In some cases, however, this is also a multilateral problem affecting international waters (e.g. the great lakes of East-Africa).

There is an array of efficient preventive measures which may be applied to reduce eutrophication. Self purification in natural waterways may also cause great improvements if the nutrient load is reduced to eutrophicated lakes. However, experiences with mitigation actions such as biomanipulation of lakes are mixed, and should not be recommended on a regional scale.

Recommendations:
The following preventive actions are among those known to give positive effects:

- Maintenance and restoration of riparian protection (vegetation) belts including wetlands and intact flood plain vegetation, thereby increasing filtering of particles and self-purification capacity
- Development and adoption of recycling systems for manure, sewage and wastewater at appropriate technological levels
- Adoption of agricultural practices to reduce quantities and increase uptake efficiency for artificial fertilizers
- Development and adoption of integrated watershed management plans, with participation of local communities
- Minimize industrial waste by introduction of new technology (developed countries)

To be able to prioritize conservation actions, documentation of biodiversity of vulnerable localities, is necessary. This forms the basis for the development of conservation plans for threatened and vulnerable water bodies and their catchments. Emphasize should be given to conservation plans regarding international waters (e.g. multinational agreements on the great East African lakes.

Toxic substances.

Inorganic toxines
Pollutions of a variety of inorganic substances are partly connected with long range transported pollution, either directly as a part of depositions or mobilised from the catchment area. This is a problem in Northern Europe and parts of North-America, and is an increasing problem in Asia connected with acidification. Heavy metal pollution is also a local problem connected with the metal processing industry and the metal mining (eg. copper mining in Africa and mercury pollution connected with the gold extraction in Brazil and other places). Mercury pollution seems to be an increasing problem in a large part of the World.

In addition heavy metals are a part of diffuse pollutions (e.g. lead in fuel and cadmium in fertilizer). The sublethal effects of low concentrations of heavy metals and effects on the community level are not well known. There are little knowledge about synergetic effects of different combinations of metals and also metals combined with other environmental stress.

Recommendations:

1. Heavy metals connected with long range pollution must be a part of the international negotiations on reduced emissions of acidic compounds.
2. Use of heavy metals (e.g. mercury) in industrial processes (e.g. gold extraction) should be reduced to a minimum. Development of less polluting processes is essential.

Organic micropollutions
New compounds are produced and brought into usage in accelerating speed. There are far from sufficient knowledge of the chemical composition of these compounds and their derivatives, the usage, and cycling in the ecosystem. Of special concern are hormone mimicking compounds that could affect the ontogenesis, fertility and behavior of organisms.

It is notable that chlorinated compounds (e.g. DDT and its derivatives), which are banned in the developed countries, are still exported to the developing countries.

Recommendations:

1. Increased demand for documentation about the persistent organic micropollutants is needed.
2. The environmental impact and co-impact of these compounds must be documented by methods which are more ecosystem relevant.
3. Export of DDT and other pesticides, which are banned in the developed countries, must be stopped.

Radionuclide contamination

Environmental contamination by radionuclides has occurred both locally and globally from fallout. Fallout from nuclear testing in the atmosphere has contaminated ecosystems worldwide. Many of the contaminants have long half-lives and thus are present long after the initial contamination. The contamination of areas in the vicinity of facilities for the production and testing of nuclear weapons as well as a result of accidents and uncontrolled discharges from nuclear power plants is, however, a much more serious threat to biodiversity. Terrestrial, freshwater and estuarine ecosystems are most severely affected. Some of this contamination has been spread globally by rivers and ocean currents, although contamination levels in the marine environment are generally low. High levels of contamination are lethal for most organisms, while lower levels can produce chromosome aberrations which result in genetic disorders and sometimes infertility. Radionuclides differ markedly in their ecosystem mobility as well as in their concentration in different body organs. The areas most severely affected by radionuclide contamination are the nuclear weapons sites and depositories for nuclear waste in the Pacific, North America and the former Soviet Union. Severe contamination over a wide area also occurred after the accident at the Chernobyl Nuclear Plant in 1986. There are a number of options for mitigation measures, ranging from chemical treatment of contaminated lakes to bans on the use of contaminated water for irrigation of food crops. However, certain of these measures may also entail negative effects on the environment.

Recommendations

1. Stringent safety systems and regulations should be enforced at nuclear power facilities.
2. Nuclear waste should be stored safely to prevent environmental contamination.
3. Sites of radionuclide contamination should be cleaned up.
4. There is a need for more knowledge on the long-term effects of low-level radiation, as well as on the transport and uptake of radionuclides in natural ecosystems

Thermal pollution

Significant elevation above ambient temperatures may occur in connection with industrial uses of water, such as power plant facilities, where river or coastal waters are used for cooling purposes. This often results in extinction of some species and a higher abundance of others. Warmer waters may also lead to the invasion of undesirable species which may cause changes in ecosystem function. In many cases warm water species are deliberately introduced by man. These alien species represent a potential threat to biodiversity in adjacent natural ecosystems.

Recommendations

1. Thermal pollution should be reduced to a minimum
2. Warm water species should not be introduced into warm water effluents in cold water areas