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METHODOLOGIES FOR THE ASSESSMENT OF BIOLOGICAL DIVERSITY IN INLAND WATER ECOSYSTEMS

Note by the Executive Secretary

1. At its second meeting, the SBSTTA considered assessment of biological diversity and methodologies for future assessments. In its decision III/10, the Conference of the Parties instructed the SBSTTA further to review methodologies for assessment of biological diversity and make recommendations for their application to the fourth meeting of the Conference of the Parties.

2. The Conference of the Parties also noted, in its decision III/2, the recommendation of the SBSTTA that it adopt a thematic approach to its work. In its decision III/13, the Conference of the Parties requested the SBSTTA to provide advice to the fourth meeting of the COP on the status and trends of biological diversity in inland water ecosystems.

3. This Note, prepared by the Executive Secretary to assist the SBSTTA in its consideration of item 7.2 of the provisional agenda, therefore considers methodologies for the assessment of biological diversity within inland water ecosystems.

Methodologies for the assessment of biological diversity

4. General methodologies for the assessment of biological diversity were considered in some detail in documents UNEP/CBD/SBSTTA/2/2 and UNEP/CBD/COP/3/13. In particular, the annexes to these documents set out various techniques for assessing biological diversity. However, they mostly dealt implicitly if not explicitly with terrestrial ecosystems. It is therefore worth considering here some of the differences between inland water and terrestrial ecosystems and highlighting techniques of particular relevance to the former.

5. Major differences are:

- True aquatic ecosystems are generally buffered from direct human observation; monitoring techniques therefore have to depend heavily on various forms of indirect observation, using remote sampling, such as nets, traps and other collecting devices or remote sensing such as sonar. Limited direct observation is sometimes possible through use of snorkelling, scuba-diving and submersibles. This does not apply to surface-dwelling organisms such as waterfowl, which may in contrast often be some of the most straightforward of all wild animal groups to assess directly or through photography.

- In overall extent inland water ecosystems are far smaller than either terrestrial or marine ecosystems. They might thus be regarded as generally less problematic to monitor and assess. They are however highly variable in physical and chemical characteristics, certainly more so than the marine environment. Smaller inland water ecosystems (e.g. ponds and streams) also tend to be very highly dispersed Because they are not easily observed or sampled directly, there is a tendency to assume that particular inland water ecosystems are more uniform than they actually are.

- The vast majority of inland water ecosystems have been modified by mankind. This modification is often heavy and is almost certainly greater overall than modification to terrestrial or marine ecosystems. However it often takes a form which may not be easily and immediately identifiable (e.g. dissolved chemical inputs) so that assessment may be difficult carry out remotely. Moreover because adverse inputs may originate far from an affected area it is important that assessments are carried out across whole systems.

- Many inland water ecosytems, notably rivers and large lakes are transboundary in nature. Large rivers in particular may have parts in many different countries. Because of this, and the fact that activities in one part of a catchment area may have effects far distant (often in a different country), regional approaches to assessment may often be of greater importance than in purely terrestrial ecosystems.

The principal components of freshwater biological diversity

6. Aquatic organisms may be classified in a number of different ways. For the purposes of assessment the two most important approaches are by systematics (that is by taxonomic group) and by ecological zonation, the latter being chiefly a reflection of the size of the organism and the position it occupies within the freshwater ecosystem. These two approaches should be regarded as complementary. The former is necessary for the identification and monitoring of species, these being the most important individual components of biological diversity. The latter is necessary for an understanding of the ecological integrity of ecosystems. It is also important methodologically: survey and sampling techniques generally concentrate on one particular ecological zone which typically contains representatives of a number of different taxonomic groups.

7. Table 1 sets out the major freshwater groups taxonomically. Table 2 discusses the major ecological zones of inland waters.

Identification and monitoring techniques

8. The following paragraphs outline in a general way some of the methodologies and attendant problems in the identification and monitoring of the major groups of aquatic organisms.

9. Two major factors of importance in consideration of monitoring of aquatic ecosystems are: first, that data are usually limited; and second, that because information is very often obtained by sampling and because sampling techniques vary widely, it is difficult to ensure comparability in samples, which is essential for long-term monitoring and assessment.

Aquatic plants

10. The smallest, but in many cases the most important, components of aquatic flora are phytoplankton (see tables 1 and 2). Most of the dynamic features of lakes (e.g. clarity, trophic state (discussed below), animal plankton and fish production) depend to a large degree on phytoplankton. Sampling and measurement of phytoplankton is carried out using various samplers (tubes, bottles, plankton nets, fluorometers) and sometimes by remote sensing (see below). These techniques are the subject of an extensive specialist literature (see e.g. Vollenweider, 1969 - *IBP Handbook No. 12* and Wetzel and Likens 1991 *Limnological Analysis*).

11. Aquatic macrophytes are in general much less diverse than terrestrial macrophytes and are, as a group, reasonably well known taxonomically. However, many species show great morphological variation and may pose problems in identification. Emergents and floating species may sometimes be monitored by remote sensing. Submerged species require sampling.

Aquatic invertebrates

12. Many groups of aquatic invertebrates remain incompletely known, especially smaller organisms such as protozoa and nematodes. Most tropical systems remain very inadequately sampled. It has been asserted that freshwater insects (or those with a freshwater larval stage) are one of the few major groups which do not show a marked increase in diversity with decreasing latitude. However, it seems likely that this is based on insufficient knowledge of the invertebrate fauna of tropical inland aquatic ecosystems, especially rivers, as surveys in these routinely show a large percentage of undescribed fauna. In general, littoral areas (those in relatively shallow water) are far more diverse than deeper (profundal) areas, which have a relatively simple fauna of macroinvertebrates comprising mainly oligochaete worms, amphipods, insect larvae, and sphaerid and unionid clams (bivalve molluscs). Aquatic invertebrates cannot be monitored by remote sensing and require sampling in various ways. Quantitative sampling is particularly problematic and has not yet been satisfactorily resolved.

Fishes

13. Between 40 and 45% of the nearly 25,000 known fish species spend all, or a significant part of, their life in freshwater. Currently some 100 freshwater species (the great majority tropical) are newly described each year, and it is estimated that perhaps 15-20% of the global freshwater fish fauna has yet to be described, of which a significant proportion may well become extinct before they can be. The rate of description of new species appears to be limited by the number of taxonomists at work in the field, rather than the number of fish species awaiting discovery.

14. A wide range of techniques for monitoring fishes has been developed. The most important are summarised in Table 3 below.

Amphibians

15. After fishes, amphibians are taxonomically the least well-known group of aquatic vertebrates. A higher percentage of the total number of species has almost certainly been described than for freshwater fishes, but it seems certain that a signficant percentage in the tropics remains unknown. Monitoring of populations is generally problematic. Species which breed communally during a short breeding season may be monitored at this time; in other cases population densities may be estimated from counting calling males.

Crocodilians

16. Crocodilians are a small and taxonomically well-known group. In most parts of the world where crocodilians occur, relatively few species are found together and identification is not generally a problem. Monitoring may be carried out using standardised survey techniques, such as counting individuals at night (when reflected eye-shine is particularly prominent and animals tend to be active), by counting animals hauled out (basking) during the day, and for mound-nesting species by counting nests, which under some circumstances is possible from the air. Species which live in heavily vegetated areas (e.g. swamp forests, streams within forests) may be very difficult to monitor.

Chelonians

17. Freshwater chelonians are taxonomically relatively well-known, although in areas which have a high diversity of species (South-east Asia and North America), identification of particular species can be problematic. Monitoring of populations of most species is extremely problematic as they are typically cryptic and shy, spending much of their time hidden in mud or weeds. Some large, communally nesting species such as the South American River Turtles (*Podocnemis* spp.) and the Painted Terrapin (*Callagur borneoensis*) and Batagur (*Batagur baska*)of South-east Asia can be monitored at nesting beaches.

Aquatic mammals

18. Most mammals which inhabit inland waters are taxonomically well-known. Generally relatively few species occur in any one place, so that identification of species should not be problematic. However, as with chelonians, many aquatic mammals are elusive and cryptic and often occur at low density, so that monitoring of populations is very problematic. For some amphibious species, such as otters (subfamily Lutrinae), presence or absence and some indication of abundance can be obtained from terrestrial signs such as spraints. Censuses of beavers (*Castor* spp.) and muskrats (*Ondatra zibethicus* and *Neofiber alleni*) can be relatively easily undertaken by counting lodges or dens.

Waterbirds

19. Overall, waterbirds are probably the easiest group of inland aquatic organisms to monitor. They are taxonomically well-known and normally easily identified to species level. Many species are fairly straightforward to monitor, at least at some times of year. This applies most notably to those which form large aggregations while over-wintering or on passage, usually in wetland areas. Species which occur along rivers are generally more dispersed and may be less straightforward to monitor, but are still easier to assess than most other groups.

Monitoring of wetlands

20. Measurement of wetlands usually employs a range of methods originally developed for other aquatic and terrestrial systems. The main difficulty is getting representative samples in an environment that is spatially and temporally heterogeneous. The best solution is to employ stratified random sampling. In order to determine biomass, it is important to collect both above ground and below ground samples of aquatic macrophytes.

Assessment of inland aquatic ecosystems

21. Paragraphs 8 to 20 above have set out how identification and monitoring of particular groups of organisms in inland aquatic ecosystems may be undertaken.

22. Assessment of such ecosystems may be regarded as going further than this, constituting an examination of the state of, and trends in, such ecosystems, particularly with a view to the sustainability of human actions which affect them. As noted above, general methodologies for the assessment of biological diversity were considered in some detail in documents UNEP/CBD/SBSTTA/2/2 and UNEP/CBD/COP/3/13. SBSTTA recommendation II/1, which was endorsed in COP decision II/10, stressed that assessments should be: transparent; based on scientific principles; based initially on existing knowledge; focused; pragmatic; cost-effective; within a socio-economic context; and management- or policy-oriented.

23. Overall assessments should be made of the changing extent and quality of ecosystems. Because it is not possible to monitor and assess all components of biological diversity, it is clearly necessary to adopt other approaches. Three important techniques are the use of remote sensing, of indicators and of expert assessments. In some parts of the world, use of dispersed teams of non-professionals can greatly increase the amount of non-technical monitoring that can be carried out. In many cases a high priority is likely to be assessment of those components of biological diversity in inland water ecosystems which are consumptively used. As noted above, regional or transboundary assessments are likely to be of particular importance in consideration of many inland water ecosystems.

24. Recommendation II/1 also suggested that, in order to set priorities, assessments should be carried out using the framework of processes and categories of activities that are or are likely to have significant adverse impacts on biological diversity as set out in paragraphs 39-41 of document UNEP/CBD/SBSTTA/2/3 and amended in paragraph 16 of SBSTTA recommendation II/1. This framework is set out in document UNEP/CBD/COP/3/12 and is appended to the present document as an annex.

Remote sensing

25. Remote sensing may be a very valuable tool in surveying and assessing the state of ecosystems such as large lakes. Different organisms such as blue-green algae, green algae, diatoms and submerged macrophytes, some of which may form dense layers or aggregations, have distinctive reflectance patterns for different wavelengths of radiation, such as infra-red and visible light. Turbid water and some pollutants also produce distinct patterns. Occurrence of these, which can be highly variable in space and time and which can provide a great deal of information on the state of an ecosystem, can be mapped and monitored using various forms of remote sensing.

26. Similarly, because wetland plants tend to form large stands of one species, they may often be mapped by standard colour infrared aerial photography. In all cases of remote sensing it is essential that adequate ground-truthing is carried out.

Indicators

27. The use of indicators has been discussed at considerable length in documents UNEP/CBD/SBSTTA/2/4 and UNEP/CBD/COP/3/13, and will be further considered under item 7.3 of the provisional agenda of this meeting (see document UNEP/CBD/SBSTTA/3/9).

28. Much of the development of biological indicators has taken place in freshwater systems in temperate regions, notably Europe and North America. Presence, absence or relative abundance of a range of groups of organisms has been used to detect or assess changes in the ecological functioning or ecological "quality" of river and lake systems. However, because no two species respond to changes in their environment in the same way, extrapolation from indicator groups must always be used with care. Moreover, indicators based on assessments of combinations of organisms or groups of organisms tend to be limited in their application to fairly specific types of ecosystems in particular biogeographic regions.

Expert assessments (DELPHI approaches)

29. Where quantitative data are not easily or widely available, or where there is difficulty in interpreting these data unambiguously, use of expert assessment can give an extremely valuable insight into the status of ecosystems and development of management options. Consultation with a wide range of opinion and expertise can allow an informed consensus to emerge. It is important, however, that choice of expertise is not consciously or unconciously biased, and that different opinions are given equitable rating. Such approaches, often referred to as DELPHI approaches, work best when given a set of clear constraints, generally related to management options. These approaches are particularly relevant to many large inland water ecosystems, especially rivers, which are of importance to a very wide range of stakeholders, who may have widely diverging views on how best to manage the ecosystem.

Use of volunteers/amateur teams

30. In some countries, teams of volunteers or amateurs (often students or schoolchildren) can be of great help in monitoring dispersed ecosystems which cannot easily be monitored with remote sensing or by limited sampling. Streams and ponds are particularly appropriate for this treatment, which is exemplified in the “Streamwatch” scheme in the USA For data gathered by such efforts to be of value, it is important that great care is taken with the design of the scheme, and particularly in specifying clearly what kind of information should be gathered and how.

Key variables for assessment

31. The ultimate goal of assessment of inland water ecosystems should be to ensure that their ecosystem functioning (or long-term "health") is maintained. As with terrestrial ecosystems, it is difficult to make this concept truly operational, in part because these systems are so dynamic in nature and in part because the concept of health or integrity may be more societally than scientifically determined (at least other than in completely undisturbed or unmodified systems).

32. In many circumstances there is nevertheless broad agreement as to what constitutes a degraded aquatic ecosystem. Factors which may be assessed to give insight into this include:

∃ degree of cultural eutrophication: there is a wide body of literature concerned with diagnosis of, and remedial measures for, cultural eutrophication, which is widely accepted as one of the major factors adversely affecting biological diversity in inland aquatic ecosystems;

∃ degree of acidification: in industrialised parts of the world, acidification of wetlands through acid rain is believed to have had a major impact on biological diversity; this has also been the subject of extensive studies;

∃ prevalence of introduced species: accidental or deliberate introductions of a wide range of organisms have had severe impacts on the biological diversity of inland water ecosytems throughout the world; examples include the water hyacinth (*Eichhornia crassipes*) from South America and now a pantropical weed, and the Nile Perch (*Lates* sp.) introduced into Lake Victoria where it appears to have been the principal agent in the collapse of the cichlid fauna.

33. Other factors which should be assessed, but whose impact on biological diversity may be less directly measurable include:

- degree of channelisation in rivers: this alters flow regimes and destroys valuable littoral and riparian habitats;

- presence of dams, weirs and other obstacles: this affects migratory species (notably anadromous fishes) and alters flow regimes in rivers;

- amount of water abstraction: this alters flow regimes and water levels.

Assessment of sustainable use of inland water biological diversity

34. Paragraphs 41-45 of document UNEP/CBD/SBSTTA/3/7 outline the major components of inland water biological diversity which are consumptively used and note that, in general, fisheries are the most important aspect of this. Principles applicable to assessment of finfishes are equally applicable to assessment of other exploited inland water resources, such as crocodilians and amphibians.

Assessment of fisheries

35. Total inland water fishery production has two components: capture fisheries and aquaculture. National statistics collated by the FAO have separated these two sources since 1984. These data indicate that reported capture fishery production rose from 1984 to around 7 million metric tonnes in 1995[1]. Reported inland aquaculture production has been rising, to around 14.6 million metric tonnes in 1995, *i.e.* twice the production of capture fisheries. Most inland aquaculture production, and most of the recent increase in this sector, is attributable to China. (In this particular instance the dividing line between aquaculture and capture fisheries is indistinct; no husbandry is involved beyond release of hatchery stock, and the fishery operates as a capture fishery).

36. For the period 1991-1995 reported inland production has made up on average 7.5% of the world total capture production. Despite this relatively low figure, and without taking account of under-reporting of inland capture, inland production has special significance because:

- waste through discarded bycatch is large in marine fisheries but negligible inland;

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[1] FAO (1996), *The State of World Fisheries and Aquaculture*

- a greater proportion of the inland catch appears to be used for direct human consumption;

- most of the marine catch is landed by highly industrialised fleets from a small number of countries, whereas inland production exceeds marine landings in 25% of the 225 reporting countries, including 33 Low Income Food Deficit Countries;

- some countries are land-locked and have no internal source of fish other than freshwater fish, which may provide the main source of protein for the majority of the low-income population;

- inland fishery production is typically used for domestic consumption, and in principle subject to national level management, whereas marine production is more often traded internationally and supply is necessarily less secure;

- many more people have access to inland waters than to coastal marine waters;

- gears for subsistence fishing do not have to be technologically advanced (although such equipment is increasingly available) and costly to purchase, and often many sectors of the community are involved in inland capture fisheries.

Problems of assessment of freshwater fishery resources

37. Accurate assessment of inland fishery resources is highly problematic. The reported inland capture production is certainly an under-estimate because much of the catch is made far from recognised landing places where catches are monitored, and is consumed directly by fishers or marketed locally without ever being reported. The evidence suggests that actual capture fisheries catch may be twice the reported total, i.e. around 14 million metric tonnes per year.

38. It is also difficult rigorously to assess the condition of inland fish stocks because they appear able to respond rapidly to changing environmental conditions. However, there is a consensus that, regionally, most stocks are fully exploited and in some cases over-exploited.

39. There is, moreoever, increasing realisation that inland fisheries, like marine fisheries, cannot be effectively assessed or managed in the long-term by using traditional single-species stock assessments, but rather require integrated approaches. These should include not only multi-stock assessments, but should also take into account factors other than harvest which may impinge on the state of the species concerned. Unfortunately, these approaches often involve complex modelling of ecosystems and population dynamics, and are dependent on a constant flow of information from monitoring. Trade-offs, perhaps best exemplified in the concept of adaptive management, will always be necessary.

Recommendations

40. The SBSTTA may wish to consider recommending that the COP urge Parties to adopt an integrated approach in their assessment and management of inland water ecosystems, including associated terrestrial and inshore marine ecosystems.

41. The SBSTTA may also wish to consider recommending that, in view of the great economic importance of inland water fish species, and of the large gaps in taxonomic knowledge, the COP consider this as a specific focus of

the capacity-building in taxonomy recommended by the SBSTTA in its recommendation II/2 and endorsed by the COP in decision III/10.

42. The SBSTTA may also wish to consider recommending the following animal groups as particularly important in the assessment of inland water ecosystems:

∃ anadromous fishes
∃ aquatic mammals
∃ amphibians
∃ large freshwater chelonians, particularly those in the genera *Podocnemis, Batagur, Callagur, Orlitia, Kachuga*
∃ waterfowl as identified in the guidelines to Criteria for identifyig Wetlands of International Importance under the Ramsar Convention (see annex to document UNEP/CBD/SBSTTA/3/7).

43. The SBSTTA may wish to recommend that the COP advises Parties, and relevent international organisations, that issues of biological diversity and subsistence use of fisheries should be more fully addressed in fisheries reporting and management. In particular, the contribution indigenous species play in capture fisheries should be reported separately.

44. The SBSTTA may also wish to recommend to the COP that the transboundary nature of many inland water ecosystems be fully taken into account in assessments, and that it may be appropriate for relevant regional and international bodies to contribute as appropriate to such assessments.

45. The SBSTTA may wish to consider recommending to the COP that the usefulness of specific rapid assessment programmes for inland water ecosystems such as AquaRAP, currently under development by Conservation International, be considered by Parties. It may wish to consider recommending means by which methodologies for such programmes can be widely disseminated.

46. The SBSTTA may also wish to consider that as a priority, assessments should in the first instance be undertaken in inland aquatic systems which may be regarded as important in accordance with the terms of Annex I of the Convention.

47. The SBSTTA may also wish to consider stressing that assessments should be carried out with a view to implementing other Articles of the Convention, and in particular to addressing the threats to inland water ecosytems, within an appropriate framework such as that included in the Annex to the present document.

Table 1. The major freshwater groups (taxonomically organised)

General features	Significance in freshwaters
Viruses	
Microscopic; can reproduce only within the cells of other organisms, but can disperse and persist without host.	Cause disease in many aquatic organisms, and associated with water-borne disease in humans (*e.g.* hepatitis).
Bacteria	
Microscopic; can be numerically very abundant, *e.g.* 1,000,000 per cm^3, but less so than in soils. Recycle organic and inorganic substances. Most derive energy from inorganic chemical sources, or from organic materials.	Responsible for decay of dead material. Present on all submerged detritus where a food source for aquatic invertebrates. Many cause disease in aquatic organisms and humans.
Fungi	
Microscopic. Recycle organic substances; responsible for decay of dead material; tend to follow bacteria in decomposition processes. Able to break down cellulose plant cell walls and chitinous insect exoskeletons.	Present on all submerged detritus where a food source for aquatic invertebrates. Some cause disease in aquatic organisms and humans.
Algae	
Microscopic and macroscopic; include variety of unicellular and colonial photosynthetic organisms. All lack leaves and vascular tissues of higher plants. Green Algae (*Chlorophyta*) and Red Algae (*Rhodophyta*) include freshwater species; Stoneworts (*Charophyta*) mostly freshwater.	Responsible for most primary production (growth in biomass) in most aquatic ecosystems. Free-floating phytoplankton main producers in lakes and slow reaches of rivers; attached forms important in shallow parts of lakes and streams.
Plants	
Photosynthetic organisms; mostly higher plants that possess leaves and vascular tissues. Mosses, quillworts, ferns important in some habitats. Some free-floating surface species (*e.g.* Water Fern *Salvinia*, Duckweed *Lemna*); most are rooted forms restricted to water margins.	Provide a substrate for other organisms and food for many. Trees are ecologically important in providing shade and organic debris (leaves, fruit), structural elements (fallen trunks and branches) that enhance vertebrate diversity, in promoting bank stabilisation, and in restricting or modulating flood waters.

Invertebrates: protozoans	
Microscopic mobile single-celled organisms. Tend to be widely distributed through passive dispersal of resting stages. Attached and free-living forms; many are filter-feeders.	Found in virtually all freshwater habitats. Most abundant in waters rich in organic matter, bacteria or algae. Feed on detritus, or consume other microscopic organisms; many are parasitic on algae or vertebrates.
Invertebrates: rotifers	
Near-microscopic organisms; widely distributed; mostly attached filter-feeders, some predatory forms.	Important in plankton communities in lakes and may dominate animal plankton in rivers.
Invertebrates: flatworms	
	Mobile bottom-living predatory flatworms. Poorly known.
Invertebrates: nematodes	
Microscopic or near-microscopic roundworms.	May be parasitic, herbivorous or predatory. Typically inhabit bottom sediments. Poorly known; may be more diverse than recognised.
Invertebrates: annelid worms	
Two main groups in freshwaters; oligochaetes and leeches.	Oligochaetes are bottom-living worms that graze on sediments; leeches are mainly parasitic on vertebrate animals.
Invertebrates: molluscs	
Two main groups in freshwaters; Bivalvia (mussels etc) and Gastropoda (snails, etc). Very rich in species; tend to form local endemic species.	Snails are mobile grazers or predators; bivalves are attached bottom-living filter-feeders. Both groups have speciated profusely in certain freshwater systems. The larvae of bivalves are parasitic on fishes. Because of the feeding mode, bivalves can help maintain water quality but tend to be susceptible to pollution.
Invertebrates: crustaceans	
A very large Class of animals with a jointed exoskeleton often hardened with calcium carbonate.	Include larger bottom-living species such as shrimps, crayfish and crabs of lake margins, streams and estuaries. Also larger plankton: filter-feeding Cladocera and filter-feeding or predatory Copepoda.
Invertebrates: insects	
By far the largest Class of organisms known. Jointed	In rivers and streams, grazing and predatory

exoskeleton. The great majority of insects are terrestrial.	aquatic insects (especially larval stages of flying adults) dominate intermediate levels in food webs (between the microscopic producers, mainly algae, and fishes). Also important in lake communities. Fly larvae are numerically dominant in some situations (*e.g.* in Arctic streams or low-oxygen lake beds), and are vectors of human diseases (*e.g.* malaria, river blindness).
Vertebrates: fishes	
More than half of all vertebrate species are fishes. These are comprised of four main groups: hagfishes (marine), lampreys (freshwater or ascend rivers to spawn), sharks and rays (almost entirely marine, ray-finned 'typical' fishes (>8,500 species in freshwaters, or 40% of all fishes).	Fishes are the dominant organisms in terms of biomass, feeding ecology and significance to humans, in virtually all aquatic habitats including freshwaters. Certain water systems, particularly in the tropics, are extremely rich in species. Many species are restricted to single lakes or river basins. They are the basis of important fisheries in inland waters in tropical and temperate zones.
Vertebrates: amphibians	
Frogs, toads, newts, salamanders, caecilians. Require freshwater habitats.	Larvae of most species need water for development. Some frogs, salamanders and caecilians are entirely aquatic; generally in streams, small rivers and pools. Larvae are typically herbivorous grazers, adults are predatory.
Vertebrates: reptiles	
Turtles, crocodiles, lizards, snakes. All crocodilians and many turtles inhabit freshwaters but nest on land. Many lizards and snakes occur along water margins; a few snakes are highly aquatic.	Because of their large size, crocodiles can play an important role in aquatic systems, by nutrient enrichment and shaping habitat structure. They, as well as freshwater turtles and snakes are all predators or scavengers.
Vertebrates: birds	
Many birds, including waders and herons, are closely associated with wetlands and water margins. Relatively few, including divers, grebes and ducks, are restricted to river and lake systems.	Top predators

Vertebrates: mammals	
Relatively few groups are strictly aquatic (*e.g.* River Dolphins, platypus), several species are largely aquatic but emerge onto water margins (*e.g.* otters, desmans, otter shrews, water voles, water oppossum, hippopotamus).	Top predators, and grazers

Table 2. The major divisions of freshwater ecosystems:

Pelagic zone (open water)	Plankton	phytoplankton	Small, generally microscopic, suspendend organisms which float passively or swim weakly. Phytoplankton almost entirely algae; zooplankton from a range of groups, especially protozoa.
		zooplankton	
	Nekton		Larger actively swimming organisms within the open water or pelagic zone. Mostly fishes.
	Neuston		Organisms which inhabit the surface layer of water, including floating plants and surface-dwelling invertebrates.
		pleuston	Component of neuston comprising large floating assemblages of plants blown about by wind (e.g. Water Hyacinth *Eichhornia*).
Littoral (shallow water and shoreline) and benthic (bottom) zones	Attached macro-algae		Large algae attached to rocks and higher plants usually in the littoral zone.
	Aquatic macrophytes		Higher plants rooted in or anchored to the substrate, usually in littoral zone. Those which protrude above the water surface are termed emergents
	Aufwuchs		Very small, usually microscopic, attached community of algae, bacteria, fungi, protozoa and attached metazoa.
	Benthos	epibenthic fauna	Animals which live on the bottom
		infauna	Animals which burrow beneath the bottom
	Epiflora		Organisms which live within submerged vegetation

Table 3. Major techniques used in assessments of fishes

Habitat	Sampling Gear	Results and uses
Limnetic zone	Midwater trawls	Provides specimens; can be used for quantitative assessment and to provide information on vertical distribution
	Purse seines	Provides specimens; can be used for quantitative assessment and to provide information on vertical distribution
	Gillnets	Provides specimens; can provide information on vertical distribution
	Hydroacoustics	Can be used for quantitative assessment and to provide information on vertical distribution
	Underwater video	Behaviour and information on habitat use
Littoral zone	Gillnets	Provides specimens
	Electroshockers	Provides specimens
	Trapnets	Provides specimens
	Beach seines	Provides specimens; can be used for quantitative assessment
	Poisons (rotenone)	Provides specimens; can be used for quantitative assessment
	Underwater video	Can be used for quantitative assessment and to provide information on vertical distribution and behaviour
	Scuba	Can be used for quantitative assessment and to provide information on vertical distribution and behaviour

Profundal zone	Bottom trawls	Provides specimens; can be used for quantitative assessment and to provide information on vertical distribution
	Gillnets	Provides specimens; can provide information on vertical distribution
	Trapnets	Provides specimens; can provide information on vertical distribution
	Underwater video	Provides specimens; can be used for quantitative assessment and to provide information on vertical distribution
	Scuba	Provides specimens; can be used for some quantitative assessment and to provide information on vertical distribution
Lotic systems	Electroshockers	Provides specimens; can give some indication of abundance
	Poisons	Provides specimens; can give some indication of abundance
	Gillnets	Provides specimens
	Fyke/hoop nets	Provides specimens; can be used for quantitative assessment
	Scuba/snorkeling	Provides specimens; can be used for some quantitative assessment and to provide information on vertical distribution
	Hydroacoustics	Can be used for quantitative assessment and to provide information on vertical distribution

(table modified from Horne, A.J. and Goldman, C.R. 1994. *Limnology*. 2nd Edition, McGraw-Hill, Inc. New York).

Annex

(From paragraphs 39-41 of document UNEP/CBD/COP/3/12)

Proximate threats

The following factors may have a direct effect on biological diversity:

(a) Overharvest or overkill of wild species;

(b) Introduced species as competitors, predators, carriers of disease, or habitat disruptors;

(c) Habitat destruction or deterioration through conversion, fragmentation, or changing habitat quality;

(d) Pollution by toxins (e.g., heavy metals, radioactive contaminants), changing nutrient balances (e.g., eutrophication, acid rain), or physical contaminants (e.g., sedimentation and/or siltation); and

(e) Climate change, either locally or globally.

Categories of activities leading to these threats

The following categories of human activity may lead to the proximate threats listed above:

(a) unmanaged harvest of wild species for consumption;
(b) killing of wild species as pests or weeds;
(c) deliberate introduction of exotic species;
(d) accidental introduction of exotic species;
(e) conversion of land to settled agriculture;
(f) improper management of land;
(g) shifting cultivation on too short a cycle;
(h) overstocking by domestic livestock;
(i) accidental or deliberate burning, or change in natural fire regime;
(j) mining/dredging;
(k) dam construction;
(l) canalisation;
(m) road construction;
(n) urbanisation;
(o) overuse for recreational reasons;
(p) drainage of wetlands;
(q) burning of fossil fuels;
(r) use of potentially polluting chemicals in agriculture;
(s) use of potentially polluting chemicals in industrial processes;
(t) production of polluting chemicals as a by-product of industrial processes; and
(u) production of human effluent and other domestic waste products.

Ultimate causes of these threats

Within the context of human society, most of these threats can ultimately be attributed to six main factors:

(a) land tenure;
(b) population change
(c) cost-benefit imbalances;
(d) cultural factors;
(e) misdirected economic incentives; and
(f) national policy failure.
