Fishes Under Threat: An Analysis of the Fishes in the 1996 IUCN Red List[1]

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ABSTRACT

Biological characteristics of threatened fishes contained in the 1996 IUCN Red List were analyzed using data in FishBase 98, a large database on finfish. The following trends or relationships were determined: (1) fishes that depend on freshwater at any stage of their life cycle are 10 times more likely to be threatened than marine and brackishwater fishes; (2) fishes that have a restricted latitudinal range such as occurring in only one country face a higher threat; (3) fishes that depend on wide feeding or spawning migrations are more likely to be threatened; (4) freshwater fishes that entrust the development of their eggs and larvae to the environment (nonguarders) are more threatened than bearers and guarders; (5) large, slow-growing and late-maturing fish are more threatened; (6) herbivorous freshwater fishes, and probably feeding specialists in general, are more at risk than opportunistic feeders; (7) there is a relationship between human population density and percentage of threatened fishes; (8) there is a relationship between number of threatened freshwater fishes and number of introduced fishes; (9) threatened fishes are often rare and poorly studied or discovered only recently. No relationship was found between the likelihood of threat and phylogenetic rank, climate zone, or human use.

Introduction

Fishes are the most specious group of vertebrates exploited by humans. They provide food and employment through commercial and traditional fisheries as well as recreation and enjoyment in sport fisheries and as ornamental species in aquaria and ponds. They are subjects of cultural importance in the arts, in religion and symbolism, and in science. Despite the economic value of these activities, fishes and especially freshwater fishes are probably the most threatened of all vertebrate groups (Bruton 1995). This serious situation is likely to worsen, as demand for protein and conflicts over the use of freshwater fishes continue to increase. These issues have been widely reviewed (see Andrews 1990; Nyman 1991; Beverton 1992; Kaufman 1992; Maitland 1994; Bruton 1995; Maclean and Jones 1995; Kottelat and Whitten 1997; McAllister et al. 1997). This paper attempts to quantify these mostly qualitative assessments of risk by analyzing the information on threatened fishes that is available in FishBase 98 (Froese and Pauly 1998), a large database containing biological information on more than 20 000 species of finfish (see also http://www.fishbase.org). The 1996 Red List (IUCN 1996) is a first attempt to apply objective and transparent criteria to the redlisting process (IUCN 1994). The list contains very few marine fishes and still has some inconsistencies, e.g., when threatened populations of nonthreatened species are listed. We therefore restricted our analysis to the exploration of major trends which were likely to be confirmed by future, more coherent Red Lists. We did not try to fit regression lines or to explore multiple regressions, leaving this approach to future analyses.

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Material and Methods

This study is based on information contained in the 1996 IUCN Red List of Threatened Animals (IUCN 1996), subsequently referred to as 'Red List'. The term 'redlisted' is used to refer to all fishes in that publication, independent of their status of threat. The term 'threatened' is used to refer only to the 637 fishes in the categories vulnerable (VU), endangered (EN), and critically endangered (CR) (see Table 1 and IUCN 1994). Biological information was taken from FishBase 98 and subsequently referred to as 'FishBase.' Some information was taken from FishBase 99 prior to its release. Hence, anyone wishing to repeat this analysis should use FishBase 99.

Table 1 shows the categories of threat assigned to the 1 128 fishes contained in the Red List. The Red List categories and the classification process are fully explained in IUCN (1996). Note that these assessments have been applied to less than 10% of the estimated 24 618 fish species (Nelson 1994).

One species (*Eurypegasus draconis*) has been listed twice in the Red List as data deficient (p. 205) and as vulnerable (p. 236), both for Madagascar. Because of its wide range (South Africa to southern Japan), we classified it here as data deficient (DD).

Results and Discussion

Nomenclature

Of the 1 128 scientific names of fishes listed in the Red List, 168 names (15%) were found to be invalid when compared with names in FishBase: four percent were considered misspellings and 11 percent were synonyms. Some of these discrepancies were due to unresolved taxonomic issues. For example, many of the cichlids of the African lakes are placed in the genus *Haplochromis* by some taxonomists (and in FishBase) whereas other taxonomists (and the Red List) have assigned them to the genera *Allochromis, Astatotilapia, Chetia, Enterochromis, Gaurochromis, Harpagochromis, Labrochromis, Lipochromis, Paralabidochromis, Prognathochromis, Psammochromis, Ptyochromis, Pyxichromis, Xystichromis* and *Yssichromis*. This case alone accounts for 71 of the discrepancies. Similarly, there are often conflicting views among taxonomists whether some of the populations of a species constitute subspecies or even different species. For example, Kottelat (1997) has discussed many cases of this for European freshwater fishes. Such cases accounted for 16 of the discrepancies. The remaining 28 synonyms were mainly cases where the Red List compilers had not followed recent revisions. Most of the 43 misspellings were of the 'slip of the pen' type. Others were common misspellings, such as *A. schrencki* instead of *A. schrenckii*.

Determining the correct spelling of a scientific name is not a trivial task and requires the consultation of the original description and a good understanding of the respective rules in the International Code of Zoological Nomenclature (ITZN 1985). This task is now greatly facilitated by Eschmeyer's (1998) authoritative *Catalog of Fishes*, which contains over 53 000 scientific names of fishes as originally published, with indication of the current status of their nomenclature.

Table 1. Number of finfish by category of threat, as contained in the 1996 IUCN Red List.

Category	Abbreviation	No. of species
Extinct	EX	75
Extinct in the wild	EW	10
Critically endangered	CR	130
Endangered	EN	125
Vulnerable	VU	382
Lower risk (conservation dependent)	LR (cd)	11
Lower risk (near threatened)	LR (nt)	93
Lower risk (least concern)	LR (lc)	92
Data deficient	DD	210
Total		1 128

Note: The term 'redlisted' is used in this study to refer to all 1 128 species in this table, whereas the term 'threatened' is used only for the 637 species in the categories VU, EN and CR.

*Threats at higher **taxonomic** levels*

Higher taxonomic levels, such as Family, Order and Class, group species that are thought to have evolved from one common ancestor. The higher the category, the more ancient is the common ancestor and the more distinct are its descendants from those in other groups at the same level. In the following, we explore the magnitude of genetic diversity at risk at the various taxonomic levels.

Threats at the Class level

The threatened fishes in the Red List belong to 93 Families, 30 Orders and 4 Classes (Eschmeyer 1998). The only Class that has not been listed is the hagfishes (Myxini) with 43 species in 6 genera (Nelson 1994). They are marine scavengers of the temperate zones of the world and are probably protected by their wide distribution. They may even benefit from high fishing pressure as they often feed on fishes entangled in gillnets or hooked on longlines. In contrast, 2 of the 41 extant species in the related Class of lampreys (Cephalaspidomorphi) are threatened, probably due to their dependence on freshwater. They are anadromous or landlocked.

Of the seven recent species within the Class of lobe-finned fishes (Sarcopterygii) the coelacanth *Latimeria chalumnae* is listed as endangered, making the monotypic Order Coelacanthiformes the highest ranking taxon among fishes that is "facing a very high risk of extinction in the near future" (IUCN 1996). The Australian lungfish *Neoceratodus forsteri* is not contained in the Red List, but is trade-restricted and listed in Appendix II of the CITES (1975) treaty. The southern African lungfish *Protopterus annectens bieni* is also considered vulnerable in South Africa (Skelton 1993).

Within the Class of sharks and rays (Elasmobranchii), 14 of about 800 species are threatened. However, this number might increase substantially in the near future due to the dramatic and unregulated increase in the fishery for shark fins, as evidenced in contributions presented at the International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management, held on 7-10 July 1997 in Sabah, Malaysia. The remaining species belonged to the large Class of ray-finned fishes, the Actinopterygii.

Threats at the Order level

McDowall (1969) referring to New Zealand birds, noted "... much more extinction amongst the old endemics than amongst most recent species", implying that–at least in the case of an island-ancient species were at higher risk of extinction than more recent species. When the 58 Orders of fishes are sorted into phylogenetic sequence, following Nelson (1994), only 3.6% of the species belonging to the more ancient half of Orders are seen as redlisted, compared to 5.0% of the species in the more modern half. This does not support an assumption that ancient fish are generally more threatened than modern fish. However, these numbers might change considerably as more species, especially sharks and rays, are assessed.

Table 2 shows Orders of fishes with numbers of threatened species, in phylogenetic sequence after Nelson (1994). The Orders with highest percentage of threatened species are sturgeons and paddlefishes (100%), coelacanths (100%), sawfishes (75%) and trout-perches, pirate perches and cavefishes (44%). The remaining Orders in Table 2 have less than 25% threatened species and 28 Orders do not yet contain any threatened fishes. Five of six Orders with more than 10% threatened species are ancient ones with relatively few extant species, possibly indicating that natural extinction processes are exaberated by anthropogenic threats.

Threats at the Family level

Of the 502 Families recognized in FishBase, 20% have members in the Red List. Among these are 10 Families in which 50% or more of their species are threatened. All of these Families have relatively few species (minimum = 1, maximum = 23, median = 2), stressing the danger of losing the genetic diversity of entire Families of vertebrates in the near future.

Most fish Families have 10 or less species (minimum = 1, maximum = 2 070, median = 10). If Families are sorted by species number and split into equal halves, only 22 Families in the half with fewer species have threatened member species, as opposed to 71 Families in the half with more species. Of the species belonging to the less species-rich Families, 3.3% are threatened, as compared with 2.6% of the

Table 2. Total number of species (after Nelson 1994) and threatened species and subspecies (IUCN 1996) by Order. Orders without threatened species are not included.

Order	Total no. of species	Threatened No.	Threatened %
Petromyzontiformes (lampreys)	41	2	4.9
Carchariniformes (ground sharks)	197	4	2.0
Lamniformes (mackerel sharks)	17	4	23.5
Hexanchiformes (frill and cow sharks)	5	1	20.0
Squaliformes (bramble, sleeper and dogfish sharks)	74	1	1.4
Pristiformes (sawfishes)	4	3	75.0
Rajiformes (skates and rays)	255	1	0.4
Myliobatiformes (eagle rays, stingrays and mantas)	143	1	0.6
Coelacanthiformes (coelacanths)	1	1	100.0
Acipenseriformes (sturgeons and paddlefishes)	25	26	100.0
Osteoglossiformes (bony tongues)	213	1	0.5
Clupeiformes (herrings)	358	5	1,4
Cypriniformes (carps)	2 423	179	7.4
Characiformes (characins)	1 273	1	0.01
Siluriformes (catfish)	2 268	32	1.4
Salmoniformes (salmons, pikes and smelts)	321	32	9.97
Percopsiformes (trout-perches, pirate perches and cavefishes)	9	4	44.4
Ophidiiformes (cusk eels)	298	2	0.7
Gadiformes (cods)	436	2	0.5
Batrachoidiformes (toadfishes)	64	4	6.2
Lophiiformes (anglerfishes)	253	1	0.4
Atheriniformes (silversides)	239	40	16.7
Beloniformes (needle fishes)	177	12	6.8
Cyprinodontiformes (rivulines, killifishes and live bearers)	671	57	8.5
Gasterosteiformes (sticklebacks and seamoths)	16	2	12.5
Syngnathiformes (pipefishes and seahorses)	257	28	10.9
Synbranchiformes (spiny eels)	78	1	1.3
Scorpaeniformes (scorpionfishes and flatheads)	1 156	8	0.7
Perciformes (perch-likes)	8 960	179	2.0
Pleuronectiformes (flatfishes)	552	2	3.6
Tetraodontiformes (puffers and filefishes)	329	2	0.6

more species-rich families. Considering that less than 10% of fish species have been assessed so far, we consider this difference as insignificant and conclude that species-richness of a Family does not seem to be a strong indicator of its likeliness to contain threatened species.

Recently discovered vs. long-known species

It has been said that the Earth is losing species before they have been discovered (e.g., Kottelat and Whitten 1997). To explore this suggestion, we looked at the percentage of threatened fishes in relation to their year of first description. As can be seen in Fig. 1, there is a steady increase in absolute numbers of threatened species, with 31 described before 1 800 and 246 described after 1950. In terms of percentage of threatened species, a similar trend is visible from 1800 onwards, with about 5% of newly described species being threatened. Thus it seems probable that some species will become extinct before scientists have a chance to describe them formally.

Knowledge *about **redlisted** fishes*

Conservation measures need to be based on sound knowledge of the species in question. FishBase records all references from which relevant information was extracted. The median number of references used per redlisted species is four (minimum = 1, maximum = 267, for *Gadus morhua*, listed as vulnerable for the Northwest Atlantic). More enlightening is an analysis of the type of information that is available for redlisted fishes. FishBase contains large, fairly exhaustive compilations of key information on various aspects of fish biology. As shown in Table 4, crucial information on food items, diet composition, predators, growth, maturity and spawning is missing for 85-95% of the redlisted fishes, indicating an urgent need to focus research on the life histories of this group.

Table 3. Total number of species (after Nelson 1994) and numbers of threatened species and subspecies (IUCN 1996) for Families with 50% or more threatened members; m = marine, a = anadromous, f = freshwater.

Family	Habitat	Total no. of species	Threatened	
			No.	%
Cetorhinidae (basking sharks)	m	2	1	50.0
Pristidae (sawfishes)	m	4	3	75.0
Latimeriidae (coelacanths)	m	1	1	100.0
Acipenseridae (sturgeons)	a	23	23	100.0
Polyodontidae (paddlefishes)	f	2	2	100.0
Diplomystidae (diplomystid catfishes)	f	2	1	50.0
Heteropneustidae (airsac catfishes)	f	2	1	50.0
Plecoglossidae (Ayu fish)	f	1	1	100.0
Amblyopsidae (cavefishes)	f	6	4	66.7
Adrianichthyidae (ricefishes)	f	11	10	90.9

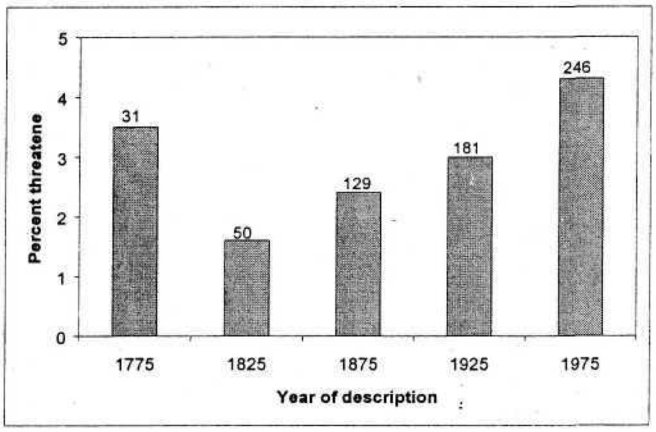

Fig. 1. Percentage of threatened species (IUCN 1996) by year of first description. Numbers above columns indicate number of threatened species described in the respective 50-year periods. See text for details.

Environment/salinity

Nelson (1994) estimated the total number of finfish species at 24 618. Of these, he classified 10 465 as 'species using freshwater' which 'would either not exist or whose range would be significantly reduced if freshwater habitats were denied to them.' This definition correlates with the 9 884 FishBase species in the categories 'primary freshwater', 'secondary freshwater', and 'diadromous species' (Table 5). Within these categories, 547 (5.5%) are threatened, compared with 90 (0.8%) of the remaining species that do not depend on freshwater. This comparison confirms the trends in Table 5, showing that fishes that depend on freshwater at any time of their lifecycle are about 10 times more likely to be threatened than marine species. This trend was confirmed by McDowall (1997) who found that it was mainly the freshwater phase that deter-

Table 4. Number and percentage of redlisted fish species for which key information is available in FishBase (Froese and Pauly 1998).

Type of information	Redlisted species	
	No.	%
Food items	137	12
Diet composition	52	5
Predators	66	6
Growth	95	9
Maturity	111	10
Spawning	167	15

Table 5. Numbers of total and threatened (IUCN 1996) species by salinity of habitat. The upper three categories include freshwater-dependent fishes exhibiting a higher level of threat.

Salinity	Species in FishBase	Threatened	
		Species	%
Primary freshwater	8 788	494	5.6
Secondary freshwater	465	24	5.2
Diadromous	631	29	4.6
Brackishwater/Marine	1 074	15	1.4
Marine	10 199	75	0.73
All species in FB 98	21 157	637	3.0

Note: FishBase (FB) (Froese and Pauly 1998) does not yet contain all of the estimated 25 000 species of finfish. See text for more information.

mined the status of threat for diadromous fishes. Lower extinction risk for marine species is also suggested by the fossil record, where the average duration of marine species is 3-8 times longer than that of freshwater fishes (McKinney 1998). The above assessment may, however, be biased by the fact that only 121 marine or brackishwater species have been assessed so far. Because of this low level of assessment (less than 1%), no attempt was made to analyze any correlation between biological traits and status of threat for marine/brackishwater species. See Roberts et al. (1998) for proposed future listings of marine species.

Climate

Table 6 shows the numbers of freshwater-dependent fishes by climatic zones as entered in FishBase. Temperate and subtropical freshwater-dependent fish seem to be about four times more threatened than tropical species. These climatic zones are typically more developed by humans, with few freshwater habitats remaining undisturbed. However, this result is probably strongly biased by the fact that tropical species are less well assessed. In Mexico, which is one of the few well-assessed countries having substantial numbers of tropical species, the percentage of threatened tropical species was higher than the percentage of threatened subtropical species. Overall, it seems that climatic zone, i.e., a preferred range of temperature and habitat types, is in itself not a factor that strongly influences the status of threat.

Migratory behavior

McDowall (1992, 1997) stressed that migratory species are threatened by changes in any of their 'passage habitats', especially densely populated river mouths, which might become bottlenecks where threats are higher. Table 7 shows the statistics of migratory freshwater-dependent fishes, as contained in FishBase. Overall, 5.5% of these species are threatened. Limnodromous (15%), oceanodromous (13%) and anadromous (13%) species clearly face a higher than average threat. Catadromous fishes (1.5%; mostly eels) appear less threatened than others, possibly due to their hardiness and their relatively undisturbed and remote spawning grounds. Many species of the 'unknown' category are probably nonmigratory, which would bring that percentage closer to the average. With the exception of catadromous fishes, it seems that species that depend on wide migrations are more threatened than others.

Table 6. Numbers and percentages of threatened freshwater-dependent fishes by climatic zone.

Climatic zone	Total	Threatened	
		No.	%
Temperate	1 386	187	13.5
Subtropical	826	108	13.1
Tropical	7 643	252	3.3
Total examined •	9 855	547	5.6

Source: FishBase (Froese and Pauly 1998).

Note: The numbers are biased by the better assessment of temperate and subtropical fishes.

Trophic level

FishBase contains estimates of trophic levels, i.e., the rank of a species in the foodweb for 1 197 better known and commercial species (Pauly et al. 1998), but for only 57 threatened fishes. To evaluate the trophic levels of threatened fishes, we estimated the trophic level for additional 16 000 species using the average trophic level of the genus or the family (Table 8). When the frequency of plant feeders (trophic levels 2.0-2.9), omnivores and carnivores (trophic levels 3.0-3.9), and top predators (trophic levels 4.0-5.0) is compared between all fishes and threatened fishes, there are considerably more (45%) herbivorous threatened species than suggested by their contribution (30%) to all fishes. This surprising result appears to be solid because (1) using trophic level averages of genera or families to replace missing specific values tends to mask differences; (2) with 69% of the estimated 25 000 recent fishes covered, the pattern for all fishes is not likely to change significantly; and (3) with 85% of the threatened fishes covered, that pattern is also not likely to change significantly.

Assuming that environmental degradation such as habitat loss, eutrophication and turbidity, as well as introductions, are the most prominent causes of threat

Table 7. Numbers and percentages of threatened freshwater-dependent fishes by type of migratory behavior. Oceanodromous species, such as some sharks, migrate in the oceans and regularly enter freshwater for feeding. Amphidromous species, such as some sticklebacks and flounders, regularly migrate between freshwater and the sea (in both directions), but not for the purpose of breeding.

Migration type	Total	Threated species	
		No.	%
Unknown	8 651	435	5
Nonmigratory	847	73	9
Oceanodromous	16	2	13
Catadromous	65	1	2
Anadromous	136	18	13
Amphidromous	62	3	5
Limnodromous	102	15	15
Total examined	9 879	547	6

Source: FishBase (Froese and Pauly 1998).

to freshwater fishes, these seem to have a stronger impact on plant feeders, possibly by changing or reducing aquatic vegetation and by introducing predators and competitors. This new relationship and its implications need more work beyond the scope of the present study.

Human use of threatened fishes

Fishes are used for a variety of human purposes, several of which support large industries. Table 9 gives an overview of these uses and the percentage of threatened fishes in each category. With the exception of game fishes, the pattern of use of threatened fishes is very similar to that for all fishes. The classification used in FishBase for game fishes is based on angling records (e.g., IGFA 1994), which list the largest specimens ever caught by anglers but do not necessarily indicate that the species is widely targeted as a game fish. We do not believe that sport fishing poses a direct threat of extinction to fishes. Rather we think that game fishes are better known and assessed than others because of higher public awareness.

The 'Fisheries' category includes stocks of nine highly commercial species, such as the Atlantic cod (*Gadus morhua*) and the Nassau grouper (*Epinephelus striatus*). Most of these species are considered under threat because of a recent drastic reduction in some of their stocks. However, whether this constitutes a threat of extinction at the species level is a matter of debate (see e.g., Beverton 1992). No marine fish species is yet known to have been driven to biological extinction by fishing (Musick 1998). However, this may change soon. Roberts et al. (1998) list four marine fish species that are on the edge of extinction due to fishing and collection for the aquarium trade.

Table 8. Numbers and percentages of all and of threatened fishes (IUCN 1996) by trophic level.

Trophic level	All fishes		Threatened	
	No.	%	No.	%
2.0-2.9	5 166	30	243	45
3.0-3.9	11 004	64	274	50
4.0-5.0	1 044	6	26	5
Total	17 214	100	543	100

Source: FishBase (Froese and Pauly 1998).

Note: The high percentage of herbivores (trophic level 2-2.9) among threatened fishes.

Of the threatened freshwater-dependent fishes, 45 species (7%) are used as food, i.e., they are captured in at least one country of their range. They are threatened by habitat loss, dams, pollution, and by subsistence or commercial fisheries. Most of these species are sturgeons, also threatened by the high price of and demand for their eggs as caviar (Birstein 1993).

The use of fishes in fisheries, aquaculture, as bait, game or aquarium fish is usually not considered as contributing to the threat of extinction (e.g., Beverton 1992; Kottelat and Whitten 1997). However, the high demand and price for species such as the humphead wrasse (*Cheilinus undulatus)* in the live foodfish trade or the use of seahorses (Syngnathidae) in the Chinese traditional medicine are posing a very serious threat.

Only 70 (11%) of the threatened freshwater-dependent fishes are reported as protected or restricted in at least one country, indicating a lack of recognition of the problem by national governments and fishery managers.

Fishes *as alien species*

Fishes introduced as alien species have been mentioned as a major threat to native fishes (e.g., Kottelat and Whitten 1997). Fig. 2 shows the correlation between international introductions of fishes and the number of threatened fishes for countries with at least 10 native freshwater fishes and with at least one introduced or threatened species recorded in FishBase. The United States, Mexico, and Indonesia are not true outliers but are countries with high numbers of freshwater fish, which have been more thoroughly assessed than those of other countries. Australian freshwater fishes are also

Table 9. Numbers and percentages of all and of threatened fishes (IUCN 1996) by category of human use. Columns do not add up to totals because species can be used in more than one category.

Human use	All fishes		Threatened	
	No.	%	No.	%
Fisheries	4 213	20	119	19
Aquaculture	302	1.4	17	3
Game	1 077	5	62	10
Bait	191	1	1	0.2
Aquarium	3 009	14	97	15
Traditional medicine	60	0.3	5	0.8
Total used	6 944	33	219	34
Not used	14 213	67	418	66
Total	21 157	100	637	100

Source: FishBase (Froese and Pauly 1998).

well assessed. These countries demonstrate a trend of increased numbers of threatened species with increased numbers of introductions. In most other countries, such as the Philippines, a thorough assessment of the freshwater fish fauna can be expected to significantly increase the number of threatened fishes. In Uganda, Kenya and Tanzania, the high number of threatened species is caused by a single introduction, that of the predatory Nile perch (Lares *niloticus*) into Lake Victoria. In many remote island countries, such as Hawaii, the number of introduced fishes is higher then the number of native freshwater fishes. However, these islands normally do not have primary freshwater fishes and introductions are often restricted to artificial waterbodies, whereas the secondary freshwater fishes (mainly gobies) spawn in the sea and migrate upwards in small creeks for feeding.

Abundance

In FishBase, 5 788 species are assigned a level of abundance for the countries in which they occur. Fishes that are threatened with extinction should, by definition, be occasional (usually not seen) or scarce (very unlikely to be seen). As shown in Table 10, 225 (80%) of the threatened fishes for which abundance data are available do fall into these categories. Also, there is a clear increase in the percentages of threatened fishes towards the 'occasional' and 'scarce' categories. The finding that 20% of the threatened freshwater fishes are listed as 'abundant' or 'common' in FishBase results from the fact that the RedList contains species of which only populations or stocks but not the species in general are under threat.

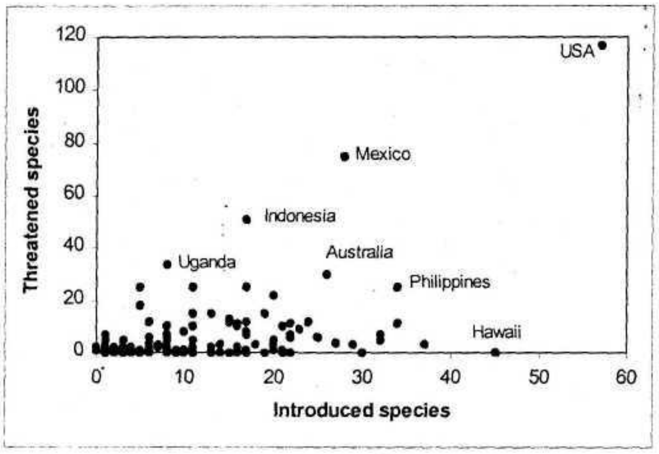

Fig. 2. Numbers of threatened (IUCN 1996) vs. introduced fish species per country. Source: FishBase (Froese and Pauly 1998).

Table 10. Abundance of threatened (IUCN 1996) freshwater-dependent fishes.

Abundance	Total no.	Threatened	
		No.	%
Abundant	550	7	1.3
Common	1 995	37	1.9
Fairly common	419	11	2.6
Occasional	876	44	5.0
Scarce	1 948	181	9.3
Total	5 788	280	4.8

Source: FishBase (Froese and Pauly 1998).

Distribution

FishBase assigns species to the countries from which they have been reported. This information is used to see whether species that are reported from only one country face a higher risk of threat than species that occur in many countries. Of the threatened freshwater-dependent fishes, 82% occur in only one country, compared to 59% for all freshwater fishes in FishBase. Similarly, 91% of threatened plants occur in only one country (IUCN 1997).

FishBase also assigns a latitudinal range to species. This range can be understood as a measure of environmental adaptability of a species. Table 11 shows the median latitudinal range for freshwater-dependent fishes, by category of threat. Note that threatened species have narrower ranges (2-3°) than all examined species (median=6°) or species of least concern (median=9°). Maximum latitudinal ranges of threatened fishes often belong to diadromous fishes such as sturgeons.

Size distribution *of threatened fishes*

It has been suggested that large fishes, because of their attractiveness to fishers and because of life history characters that correlate with size (e.g., slow growth, late maturity) will be more vulnerable than small- and medium-sized fishes (e.g., Roberts et al. 1998). Fig. 3 shows the numbers of threatened freshwater fishes by logarithmic length class, as compared with non-threatened freshwater fishes. There is a clear increase in the relative number of threatened fishes above 100 cm (log 2) maximum length, to a point where most very large freshwater fishes are threatened.

Table 11. Latitudinal range of redlisted (IUCN 1996) freshwater-dependent fishes.

Category	n	Latitudinal range (median)	Range Minimum	Range Maximum
Extinct	50	4	1	20
Extinct in the wild	8	2.5	1	4
Critically endangered	67	2	1	41
Endangered	81	3	1	81
Vulnerable	186	2	1	70
Lower risk (conservation dependent)	11	2	1	4
Lower risk (near threatened)	56	4	1	67
Data deficient	99	2	1	43
Lower risk (least concern)	45	9	1	71
Total	2 658	6	1	94

Source: FishBase (Froese and Pauly 1998).

Note: The narrower median ranges of threatened fishes (2-3°) compared with 'least concern' and 'not evaluated' fishes (6-8°).

Mode of reproduction

All reviews on threats to species agree that habitat loss is the most critical one (e.g., Heywood and Watson 1995). It can be hypothesized that freshwater-dependent fishes that bear or guard their eggs or larvae are less affected by environmental disruption than fishes that depend on specific habitats and environmental conditions for successful reproduction. FishBase contains 2 376 records with a classification of parental care into bearers, guarders and nonguarders, following the classification of Balon (1990) (see Table 12). The percentage of threatened fishes is clearly higher among nonguarders than among bearers and guarders. Nonguarders typically have high fecundities to make up for high mortality rates, and to quickly replenish and expand the population under favorable environmental conditions .(r-strategists). This strategy seems to fail when degrading environmental conditions cause repetitive recruitment failures. On the other hand, the strategy of having few offspring with considerable parental care fails when an introduced predator preys directly on the spawning population and thus quickly reduces the ability of the species to recover, as was apparently the case with many mouthbrooding haplochromines of Lake Victoria after the introduction of the piscivorous Nile perch.

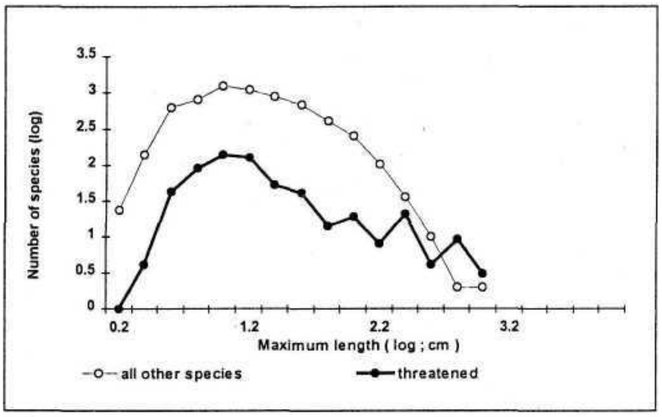

Fig. 3. Size distribution of threatened (IUCN 1996) freshwater-dependent fishes as compared with the size of other freshwater fishes. Source: FishBase (Froese and Pauly 1998).

Human population density

Conflicts over freshwater resources constitute the largest threat to freshwater fishes (e.g., Kottelat and Whitten 1997; McAllister et al. 1997), and coastal habitat is lost in direct proportion to human population density (Camhi et al. 1998). Fig. 4 shows the relationship between human population density and the percentage of threatened freshwater-dependent fishes for countries with more than 10 freshwater fishes in FishBase. City states such as Hong Kong and Singapore with more than 1 000 people per square kilometer were excluded.

Several factors contribute to the variance in this relationship:

- In many countries, the conservation status of freshwater fishes has not been assessed, hence there are many zero values for threatened fishes;

Table 12. Status of threat (IUCN 1996) of freshwater-dependent fishes vs. reproductive guild.

Reproductive guild	Total no.	Threatened No.	Threatened %
Bearers	590	89	15
Guarders	561	85	15
Nonguarders	1 225	373	30
Total	2 376	547	23

Source: FishBase (Froese and Pauly 1998).

- The population density was derived by dividing the total population number by the total area of the country, and thus does not reflect well the population density in the river basins, where more people tend to live;
- Densely populated countries with more than 100 people per square kilometer are often islands or small countries where freshwater fishes that are sensitive to human pressures have probably disappeared long before baseline checklists of freshwater fishes were assembled, resulting in a low percentage of threatened fishes.

Considering only the data below a threshold of 100 people per square km, a clear trend of increasing numbers of threatened fishes with increasing population density is visible, despite the confounding factors discussed above. The decrease in percentage of threatened fishes above 100 people per square kilometer probably results from the disappearance of aquatic habitats altogether.

What to *conserve?*

Zeide (1998) argued that the claim to conserve "every scrap of biological diversity" is fashionable but not honest, given that there is widespread consensus on the need to eradicate disease vectors and a number of human parasites and competitors, such as pests of important crops. There is indeed consensus on the eradication of several introduced fishes, such as the lampreys in the Great Lakes of North America, which considerably damage important commercial species.

There are threatened species that are reported to feed on juveniles or adults of commercial or highly commercial fishes (Table 13). Most of these threatened predators are themselves of high commercial value, thus far outweighing any theoretical gain from their extinction and reduced predation on their commercial prey. Some threatened fishes pose danger to humans and thus their extinction would theoretically reduce human risks of being wounded or poisoned (Table 14). Notably, the incidence of shark attacks on humans reached an average of 30 a year for the period 1940-1970 (Last and Stevens 1994). However, this is considerably less as compared to hazards caused by other animals and we are not aware of any conscious attempt to eradicate a native fish species. Rather, income from

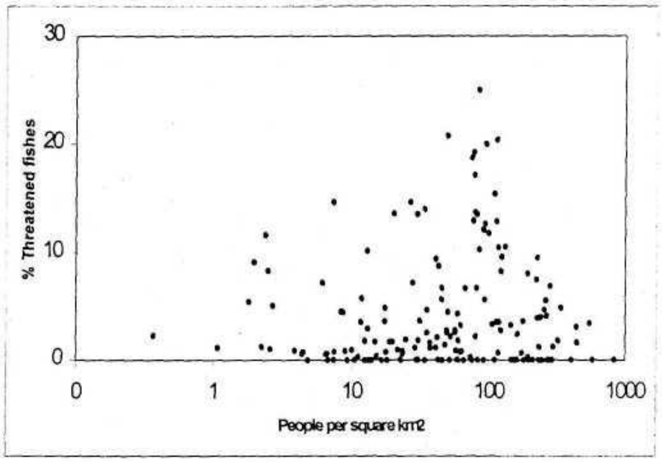

Fig. 4. Relationship between percent threatened freshwater fishes (IUCN 1996) and population density. Source: FishBase (Froese and Pauly 1998).

'shark watching' enterprises is increasingly providing incentives to protect sharks in developing countries such as the Maldives (Andrews 1990).

Summary and Policy Implications

We looked at a wide range of biological characters of fishes to see whether there are any traits that make a species especially vulnerable. The following factors seem to contribute to threats and the likelihood of extinction of fishes:

(1) Dependence on freshwater at any stage of the life cycle;
(2) Restricted latitudinal range or occurrence in only one country;
(3) Occurrence in countries with high population density;
(4) Dependence on spawning or feeding migrations;
(5) Feeding at lower trophic leads (2.0-2.9), for example, herbivorous fishes;
(6) Being large and thus slow-growing, late-maturing, and attractive to fishers;
(7) In freshwater fishes, dependence on the external environment for development of eggs and larvae (nonguarder, r-strategist);
(8) Occurrence in countries with high numbers or aggressive nature of introduced fishes;
(9) Being rare, such as many recently discovered fishes.

Table 13. Threatened fishes (IUCN 1996) that compete with fishers by feeding on juveniles or adults of commercial or highly commercial fishes.

Predator		Prey	
Green sturgeon	*Acipenser medirostris*	Pacific sand lance	*Ammodytes hexapterus*
•White sturgeon	*Acipenser transmontanus*	Eulachon	*Thaleichthys pacificus*
Macedonia shad	*Alosa macedonica*	Roach	*Rutilus rutilus*
Duckbill sleeper	*Butis butis*	Milkfish	*Chanos chanos*
Dusky shark	*Carcharhinus obscurus*	Bluefish	*Pomatomus saltator*
Sandbar shark	*Carcharhinus plumbeus*	Bluefish	*Pomatomus saltator*
Atlantic menhaden	*Brevoortia tyrannus*		
Spot croaker	*Leiostomus xanthurus*		
American eel	*Anguilla rostrata*		
Esonue grouper	*Epinephelus itajara*	Southern stingray	*Dasyatis americana*
Nassau grouper	*Epinephelus striatus*	Bar jack	*Caranx ruber*
French grunt	*Haemulon flavolineatum*		
Yellowtail snapper	*Ocyurus chrysurus*		
Spotted goatfish	*Pseudupeneus maculatus*		
Coney	*Cephalopholis fulva*		
Atlantic cod	*Gadus morhua*	Norway pout	*Trisopterus esmarkii*
Atlantic herring	*Clupea harengus*		
Huchen	*Hucho hucho*	Grayling	*Thymallus thymallus*
Gudgeon	*Gobio gobio gobio*		
Beluga	*Huso huso*	European anchovy	*Engraulis encrasicolus*
European river lamprey	*Lampetra fluviatilis*	Common whitefish	*Coregonus lavaretus lavaretus*
Sea trout ,	*Salmo trutta trutta*		
Roach	*Rutilus rutilus*		
Bigeye tuna	*Thunnus obesus*	Chub mackerel	*Scomber japonicus*

Source: FishBase (Froese and Pauly 1998).

Table 14. Threatened fishes (IUCN 1996) that are dangerous to humans and whose extinction might therefore be considered as desirable.

Type of danger	Fish"	Species
Poisonous to eat	Bluntnose sixgill shark	*Hexanchus griseus*
	European river lamprey	*Lampetra fluviatilis*
	Queen triggerfish	*Balistes vetula*
Reports of ciguatera poisoning	Common seabream	*Pagrus pagrus*
	Cubera snapper	*Lutjanus cyanopterus*
	Hogfish	*Lachnolaimus maximus*
	Humphead wrasse	*Cheilinus undulatus*
Traumatogenic	Blacktip shark	*Carcharhinus limbatus*
	Dusky shark	*Carcharhinus obscurus*
	Sandbar shark	*Carcharhinus plumbeus*
	Sandtiger shark	*Carcharias taurus*
	Great white shark	*Carcharodon carcharias*
	Esonue grouper	*Epinephelus itajara*
	Ganges shark	*Glyphis gangeticus*
	Porbeagle	*Lamna nasus*
	Largetooth sawfish	*Pristis microdon*
	Smalltooth sawfish	*Pristis pectinata*
	Giant grouper	*Epinephelus lanceolatus*
Venomous	Bocaccio	*Sebastes paucispinis*
	Freshwater whipray	*Himantura chaophraya*

Source: Fishbase (Froese and Pauly 1998).

* Phylogenetic rank, size of taxon, human use, or climate zone did not seem to contribute to the risk of extinction.

Most of the identified factors such as range, abundance, exposure to introduced species and exposure to human development have been suggested before as factors contributing to the threat of extinction, and are thus confirmed by our data. Similarly, most policy implications resulting from these threats are well known and a review of strategies and existing instruments is beyond the scope of this study (see citations in Introduction). That herbivory and nonguarding reproductive mode add to the vulnerability of freshwater fish species has, to our knowledge, not been suggested before, and we are looking forward to more detailed studies of these aspects of conservation biology. If confirmed, these threats would call for even more effective measures to preserve wetlands and aquatic ecosystems as important parts of the terrestrial ecosystems that support humans.

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Discussion

Puffin: The World Conservation Union might soon have to think within the species level for a red list of fish. For example, if some of the populations of *Oreochromis niloticus* in Africa were to disappear, the world would lose genetic resources of great importance for aquaculture. The species though would not be in danger. The same can be said for *Sarotherodon melanotheron* in West Africa. A red list that only operates at the species level will not capture threats to important intraspecific taxa and populations.

Froese: I agree. The Red List does include subspecies, but not populations, and it is not targetted at the national level.

Kapuscinski: The same point applies to a number of anadromous species, such as salmon. They follow the dendritic patterns of rivers in their spawning migrations and there is great genetic variation among the different populations.

A. Gupta: In this presentation, you seem to find no role for people in conserving, say, spawning sites or sacred waters, estuaries, etc. Is this just by chance?

Froese: Well, that was not really my topic. I was considering indicators of threats. It is difficult to protect resources, especially in freshwaters because they are under such pressure. The main thing is to limit their disturbance.

A. Gupta: Do you know of any examples of conservation of such resources by community action and institutions - conservation that would not otherwise have been possible?

Froese: In the USA, I know of some species that occur in only one lake and they are conserved because of restricted access.

Kapuscinski: I am only just beginning to get into the literature on this topic. There is a book called *Folk Management in the World's Fisheries* (Dyer and McGoodwin 1994) that has a number of interesting examples. For example, an island population in the Dominican Republic that had settled there only about 200 years ago, were managing a coral reef fishery very successfully until outsiders came in. The fishers were then able to convince the government of the need to continue their form of management and to prevent access by outsiders, including those involved in spearfishing and sport diving. I'm sure there are many other examples.

A. Gupta: The literature on this is very rich. I was just interested as to whether scientists are acknowledging these contributions.

Kapuscinski: In general, biologists (like myself) are not trained to appreciate this literature and are not aware of it. This needs to be put right.

Welcomme: I think that biologists in the tropics are more aware of these contributions and take note of them more than biologists in the temperate zones.

Puffin: Anil Gupta is right. There is a very rich literature on traditional management systems.

Schei: I was a bit surprised that this presentation ranked introduced species so low in the categories of threats.

Froese: Yes - it might seem surprising, though there were no comments from Brian Groombridge on this. The point is that, although there have been a few spectacular examples of species being wiped out by introductions, the number of extinctions due to introduced species is very few, statistically speaking. The number one threat is habitat destruction.

Welcomme: Introductions are often perceived as a far greater problem than they really are. In freshwaters, it is difficult to unravel the impacts of introductions from those of environmental degradation. Many introductions have become problematic only after environmental change in the area. There is no doubt that some introductions, like those of rainbow trout and brown trout, have eliminated some catfish and other stream-living species but, on the whole, most introductions are inocuous. So I agree with Rainer Froese. What did surprise me in this analysis is that migratory species did not appear under greater threat.

Schei: Well, I disagree very much with this point of view because you are mixing up the amount of introductions leading to something wrong with the damage done by a few. I agree that most introductions cause little damage, but in general they are the second most important threat.

Welcomme: This is a question of perception and it is a deeply emotive issue but, when you actually examine the data, the problem is not as severe as it is thought to be. This might send the wrong message, but that's the position.

Schei: I agree that most introductions are not a problem, but most people are 'nice' people and some can do a lot of harm!

Harvey: The people who report the status of stocks have, I think, a duty, especially where there are deficient data or unknowns, to make the public aware of these situations in language that the public can appreciate. A 'twenty per cent of stocks at risk' statement does not seem particularly worrisome to the general public, but in fact the risks might be much higher – the data being deficient.

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