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The conservation status of large migratory cyprinids including *Aspiorhynchus laticeps* of Xinjiang China

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Summary

Large fish species are at high risk of extinction because of life cycle characteristics and migratory fishes are often vulnerable to river modifications and overexploitation. The freshwater fish family Cyprinidae has the highest diversity in species, varied morphological and behavioral properties, and a wide range of habitat requirements. This study included an analysis of the conservation attention on large, migratory cyprinid species, a summary of threats jeopardizing the endangered species in this group, and a case study on little known species from northwest China. About 1% of all cyprinid species exceed 1 m in total length, and most of these fishes have migratory behaviors. Most of these species (79%) have not been evaluated for conservation attention, and a minor portion that have been evaluated were considered endangered. The threats to large migratory cyprinids include all the common threats to freshwater biodiversity: overexploitation, habitat alteration, water pollution, flow modification, and species invasion. The first two threats explain most of the decline in abundance and range of large, migratory cyprinids, and the others are sometimes important. The case of the Xinjiang datou fish (*Aspiorhynchus laticeps*) illustrates how an impressive species can be lost without much scientific or public attention. The analysis of conservation attention, threats, and the case study support the conclusion that large, migratory cyprinids are not receiving conservation efforts that should be focused on fish species that are especially vulnerable to human impacts.

Introduction

Knowledge of freshwater biodiversity is poor for many waters and even places considered hotspots of species richness (Dudgeon et al., 2006). Fish that are rare or not easily seen tend to be relatively unsupported by conservation efforts and public concern (Olden et al., 2007). An example of this conservation bias may be species of Cyprinidae: the minnow and carp family. Cyprinidae is a species rich and diversified family, but are known to the public as small fishes (e.g. shiners, *Notropis* spp.) or possibly farm raised carp (e.g. silver *Hypophthalmichthys molitrix*, bighead *Aristichthys nobilis*, grass *Ctenopharyngodon idella*, common carp *Cyprinus carpio*). However this family of fish has great morphological and behavioral variation that includes the smallest and some of the largest freshwater fish. Cyprinids dominate flowing waters over much of the world and the family has 220 genera and from 2105 (Froese and Pauly, 2009) to more than 2400 species (Moyle and Cech, 2000). Whether this family of fish is receiving appropriate conservation attention is uncertain, and Cyprininds attract much less public attention than more familiar fishes like Salmonidae or Acipenseridae.

Many large animals are at a high risk of extinction because of slow growth rates, long life span, and low reproductive rates (Cardillo et al., 2005). These attributes are commonly correlated with large body size (Pimm et al., 1988). Studies of body size and extinction risk in fish (Reynolds et al., 2005; Olden et al., 2007) have reported that the pattern holds for marine systems and is more complicated in freshwaters. Many small fish with inland distributions are impacted by habitat destruction and large fish also sustain harvest and overexploitation (Allan et al., 2005) leading to a bimodal size distribution of threatened fish. Thus large body size in fish is associated with vulnerability to human impacts and declining populations. With generally poor knowledge of aquatic species status, this pattern of conservation need indicates some attention should be aimed at large fishes especially families that are not currently favored in conservation programs.

Fragmentation of landscapes and waterways is an important threat to biodiversity and species security (Wilcove et al., 1998; Ward et al., 1999; Fagan et al., 2002). Many large fishes are migratory and use different habitats through their life cycle making them especially vulnerable to river modifications. Pollution, obstructions (dams, weirs, diversions), and intense predation often by non-native fishes can act to fragment waterways and separate needed habitats jeopardizing many migratory fishes (Maitland, 1995). Effective conservation actions require knowledge of habitat and migration needs of freshwater species (Abell, 2002). Studies of fragmentation effects have shown the serious threat posed to native fishes (e.g. Letcher et al., 2007; Raeymaekers et al., 2009; Bain and Wine, 2010). The information on habitats and movements of large cyprinid fishes may be lacking posing a serious deficiency for species conservation and restoration.

In this paper I test the hypothesis that the level of attention on large and migratory cyprinids is inadequate. A review of the threats against these fish are compared to factors endangering many fishes and aquatic biodiversity in general. I also review the status of one large cyprinid barely known to science and believed to be seriously imperiled. This example illustrates how fish conservation can loose large and unique fish species without significant scientific and conservation attention.

Methods

Data on cyprinid species was compiled using the well established databases. FishBase (Froese and Pauly, 2009) is a worldwide database on species characteristics for fish worldwide. This data set provides maximum lengths and other

characteristics for 2105 cyprinid species. The global register of migratory species (Riede, 2008) provided identification of cyprinid fishes that migrate under the definition that the entire population or any geographically separate part of the population undertake cyclically and predictably movements that are significant (e.g. ≥100 km).

The International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (IUCN, 2009) provided the current conservation status and knowledge for many cyprinid species. The IUCN Red List is the most comprehensive source for status and threats for plant and animal species (Rodrigues et al., 2006). This database has proven useful for determining conservation priorities and allocation of resources for urgent species recovery actions (Hoffmann et al., 2008). Finally, national species protection lists and regional fish status assessments were used to add regional information on the conservation status and threats to cyprinid species.

The information on a defined set of large, migratory cyprinid species was compiled to indicate knowledge and attention on these fishes. The information was synthesized to identify large, migratory cyprinids and their known status and conservation importance. A case study was added to illustrate how lack of knowledge and attention can shape conservation. For the case study, I collected about all known information on one species, and made a reconnaissance investigation of many of its habitats in 1999. While information collected was not scientifically rigorous in all cases, it was the information that ichthyologists and fish conservationist had available to judge species and conservation needs.

Results

The analysis of large and migratory cyprinids shows how common these fish are and the extent of conservation attention they receive. The median maximum length (standard or total length) of cyprinid fishes is 12 cm with a large majority < 50 cm (Fig. 1). The number of cyprinid species with maximum lengths > 1 m are few (30, about 1% of all cyprinid species) making large cyprinid fishes relatively rare. I define large as reaching 1-m maximum length to isolate a reasonable sample of the largest cyprinids. A minor portion (206 species, about 10%) of the cyprinid fishes are classified as migratory in the global register of migratory species (Riede, 2008). Of the 30 large cyprinids, 19 are classified as migratory (Fig. 1). These migratory cyprinids are almost all considered potamodromous because the family is limited to freshwater.

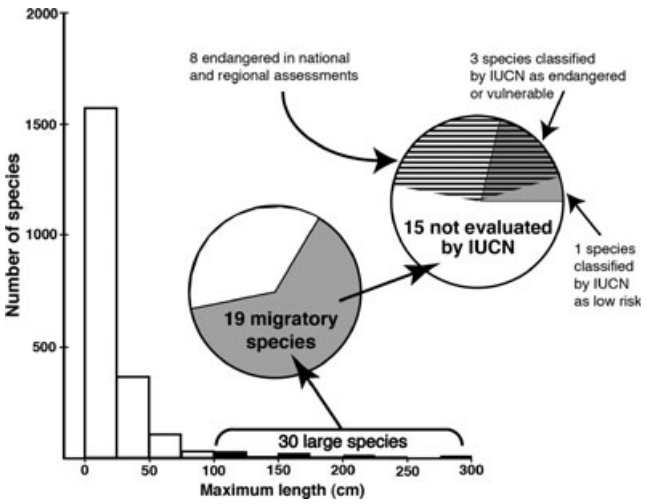

Fig. 1. The maximum length distribution of all cyprinid species (2105) and portion that exceed 1 m in length. The portion of these that are migratory, have been evaluated by the IUCN (2009) for the Red List, and considered endangered in national and regional conservation assessments

Most of the 19 large, migratory cyprinids (79%, 15 species) have not been evaluated by the IUCN for conservation status. The four that had been evaluated, one was considered at low risk, and the others were classified as endangered or vulnerable in the Red List of Threatened Species (IUCN, 2009). I identified eight threatened and endangered species among the 19 using national species protection lists and regional fish status assessments (Fig. 1). Seven of these large migratory cyprinids occur in the Mekong River basin or the Indian subcontinent of Asia. One is from North America. A summary of their maximum size, threats, and conservation status is reviewed in Table 1.

Aspiorhynchus laticeps of Xinjiang China

The Xinjiang datou fish or big-head schizothorcin (*Aspiorhynchus laticeps*) is the only species of the genus *Aspiorhynchus* and was first described in 1876 (Day, 1877). This species is endemic to the Tarim River basin in the Xinjiang Autonomous Region of northwest China. The Xinjiang datou fish once occupied most large streams, rivers, and freshwater lakes with large tributaries (Institute of Hydrobiology, 1993; Yang et al., 1995).in the Tarim River basin.

The maximum size of the Xinjiang datou fish varies by account. FishBase (Froese and Pauly, 2009) reports a maximum size of 61 cm. However, the original description of the species (Day, 1877) used a 132 cm specimen for measurements. Yang et al. (1995) estimated the maximum size at 118 cm from a growth model and this length corresponded with the largest specimen measured in a 1990s survey. The China Red Book of endangered animals (Yue and Chen, 1998) reports the largest specimens on record reached 200 cm. Consequently it is reasonable to conclude this species reaches more than 1 m in total length. Like many large fishes, the species has late maturity and extended longevity (> 40 years) reported from a growth rate investigation (Yang et al., 1995).

The body is elongated and slight compressed with a large broad head, and a wide mouth (width twice open height) having a protruding lower jaw (Bain and Zhang, 2001). A single pair of barbels emerge from the posterior, upper edge of the mouth. Scales are very small and integrated in the skin, with 105–115 along the lateral line. Caudal fin is forked. The color is silvery on the dorsal surfaces with black blotches on some juveniles, and white on ventral surfaces with some faint fin colors: orange in pectoral and pelvic fins, and red on caudal fin.

Adults migrate for spawning from lowland lakes and large rivers to rapidly flowing and rocky mountain streams at the time of peak snowmelt runoff. Eggs are adhesive and are deposited over cobble and boulder substrate. This occurs from late May through June, but some accounts (Institute of Hydrobiology, 1993, Yue and Chen, 1998) report spawning season is April and May. Young datou fish are believed to move downstream during the high flow period to lakes and large rivers (Bain and Zhang, 2001). Morphology and some

Table 1
Large, migratory cyprinid fishes that are considered to be vulnerable to extinction or endangered

Species name	River basins	Max-imum length (cm)	Conservation status	Threats	Sources
Giant barb, *Catlocarpio siamensis*	Mekong	300	IUCN, not evaluated; Cambodia, Rare; FishBase, very high vulnerability	Overfishing and dam blockages on migrations; spawning habitat loss	Rainboth (1996); Mattson et al. (2002); Poulsen et al. (2004); Dudgeon et al. (2006); Stone (2007); Froese and Pauly (2009)
Isok barb, *Probarbus jullieni*	Mekong	150[a]	IUCN, endangered; Cambodia, greatly reduced; Laos, protected; FishBase, very high vulnerability	Overfishing on migrations; impoundment of habitats for spawning, feeding, and rearing	Roberts and Warren (1994); Roberts and Baird (1995); Kottelat (1999); Rainboth (1996); Mattson et al. (2002); Poulsen et al. (2004); Baird (2006); Froese and Pauly (2009); Hogan et al. (2009)
Thicklip barb, *Probarbus labeamajor*	Mekong	150[a]	IUCN, data deficient; Cambodia, greatly reduced; FishBase, very high vulnerability	Overfishing on migrations; impoundment of habitats for spawning, feeding, and rearing	Roberts (1992); Rainboth (1996); Froese and Pauly (2009)
Giant predatory carp, *Aaptosyax grypus*	Mekong	130[a]	IUCN, data deficient; Cambodia, rare; FishBase, very high vulnerability	Overfishing on migrations; impoundment of swift water habitats	Rainboth (1991, 1996); Mattson et al. (2002); Poulsen et al. (2004); Froese and Pauly (2009)
Golden masheer, *Tor putitora*	Indus, Ganges, Brahmaputra	275	IUCN not evaluated; India, endangered; FishBase, very high vulnerability	Overexploitation, destructive fishing with explosives and poison; dams and weirs block migrations; degradation of spawning habitats by heavy siltation	Molur and Walker (1998); Singh and Sharma (1998); Sehgal (1999); Sharma (2003); Stone (2007)
Humpback masheer, *Tor mussullah*	Rivers of Western Ghats Mountains	150	IUCN not evaluated; India, critically endangered; FishBase, very high vulnerability	Overexploitation, destructive fishing with explosives and poison; dams and weirs block migrations; degradation of spawning habitats by heavy siltation	Molur and Walker (1998); Sreekantha et al. (2007)
Curmuca barb, *Hypselobarbus curmuca*	Ganges	120	IUCN not evaluated; India, endangered; FishBase, high vulnerability	Habitat fragmentation; overexploitation; destructive fishing; habitat loss	Molur and Walker (1998)
Colorado pikeminnow, *Ptychocheilus lucius*	Colorado (USA)	180	IUCN, vulnerable; USA Endangered Species	Dams and fragmentation of basin; proliferation of non-native fishes; regulation of flows; altered sediment loads and water temperatures	Miller (1961); Tyus (1990); Holden (1991); Moyle and Cech (2000); U.S. Fish and Wildlife Service (2002); Bestgen et al. (2007)

[a]Standard length.

accounts indicate the datou fish is benthic in habitat use and largely piscivorous (Yue and Chen, 1998).

The Xinjiang datou fish is an endangered species listed in the China Red Book of endangered animals (Yue and Chen, 1998) and it has been given the unusual first-class protection priority (12 of 117 endangered species) under China's national species protection plan (Chun-Guang et al., 2001). Up to the early 1970s, the Xinjiang datou fish had considerable fishery value and was harvested from Lake Bosten and rivers of the Tarim basin (Yan, 2004). The large Bosten Lake (970 km^2 surface area) annually produced 100 metric tons of datou fish until 1965 and then harvest declined to 20 tons a year up to 1974 when the species disappeared with other endemic fishes (Walker and Yang, 1999). The datou fish was suspected of declining throughout its range in the 1970s and 1980s.

Concern about the decline in range and abundance of the Xinjiang datou fish prompted a comprehensive species distribution survey (Yang et al., 1995) in 1992 and 1993 of all waters in the Tarim River basin regarded as potential or known habitats. In the two years of sampling, only 21 specimens were collected by Yang et al. (1995) and captures were limited to three areas: Aximan Lakes associated with the Aksu River, Karilak Lake of the Cherchen River, and Kezier Reservoir and upstream tributaries of the Weigan River. The capture of juveniles younger than the age of Kezier Reservoir (completed 1991) indicates the species is reproducing in this system. All existing populations were supported by lakes that have largely unblocked rivers flowing in to them.

The Xinjiang Uygur Autonomous Region in northwestern China is isolated by distance: at the center of Eurasia and the

most distant region on earth from oceans. The region is large (1 600 000 km^2) and has a population of 18 million people dominated by minority ethnic groups of China (Yan, 2004). A major portion of the Xinjiang Uygur Autonomous Region is the Tarim River basin. This basin (1 020 000 km^2, Xu et al., 2004) includes the longest inland river (no connection to oceans) in the world, the Tarim River (>2000 km), and the world's second largest desert Taklamakan Desert (270 000 km^2). The basin is largely surrounded by the Kunlun Shan and Tian Shan Mountains (exceeding 7000 m elevation) adding a local form of isolation. This basin has great thermal extremes (daily averages: 28 to −18 C) and heterogenous precipitation (annual average 20–50 mm in lowlands and 1000 mm in mountains) with a high rate of evaporation (annual average 2800–3000 mm; Yan, 2004). All these properties put water under great demand for people and the environment.

The Tarim River was characterized before the 1970s as the green corridor due to its forested riparian zone, fringing wetlands and lakes (Xu et al., 2004) bordering the Taklamakan Desert. The river channel was often braided and 2–3 km wide. In the last three decades, the flow of the main river has decreased by 80% (Zhao et al., 2009) and has ceased to flow for hundreds of kilometers of its main channel length in most recent years (Qi et al., 2005; Zhao et al., 2009). An investigation into climate trends (Xu et al., 2004) indicated gradually increasing precipitation across the Tarim River basin. This finding implicates human water use in the upper basin and tributaries as the cause of river flow declines and cessation. Besides water depletion, human demands on water resources has increased desertification, degraded river water quality by salinity increase (1.3 mg L^{-1} 1960s, 7.8 mg L^{-1} 1990s), decreased riparian forests and wetlands by half or more, and reduced groundwater by up to 6 m (Qi et al., 2005). China's government has conducted river restoration by managing reservoirs to maintain flows throughout the Tarim River and this has improved riparian vegetation and migratory bird abundances (Li et al., 2009).

Numerous diversion structures and water storage dams have been built along the Tarim River and its tributaries. These obstructions and the desiccation of some river reaches have fragmented the basin for migratory fish. Blocked access to spawning sites and disrupted migrations appear to be a leading factor in the loss of the datou fish in most river reaches and tributary basins (Yue and Chen, 1998; Xie, 1999). It is also likely that adults may overcome some water diversion structures but later young on downstream migrations can be lost in diversions to agricultural irrigation systems.

The introduction of a wide range of non-native fish species has coincided with dramatic decline and loss of the datou fish in some waters (Walker and Yang, 1999; Yan, 2004). The loss of the species in Bosten Lake coincided with the introduction of 24 or more species to a fauna of four native species. The European perch, *Perca fluviatilis*, became highly abundant in Bosten Lake and supported a major fishery. Its dramatic increase coincided with the disappearance of the datou fish, and the perch then declined in size to have no fishery value (Xie, 1999). Fishing exploitation of datou fish appears to be a contributing factor in populations declines because it has co-occurred with habitat disruptions and non-native fish proliferations. Finally, degraded water quality by increased salinity may be another contribution factor since it is consistently associated with water diversions and reductions in flow.

Conservation actions have been undertaken by the national and regional governments with the recognition and listing of the Xingjiang datou fish as endangered. Kezier Reservoir and upstream tributaries of the Weigan River have been designated a species conservation reserve. Harvest and possession of the Xingjiang datou fish has been banned and fishing activities regulated to minimize incidental catch (Xie, 1999). Public education efforts have been conducted to inform local people of the need for protecting the Xingjiang datou fish (Yue and Chen, 1998). A culture facility has been constructed for the development of a captive population; incidentally caught fish are moved to the facility. Production from the facility is expected to be used to rebuild populations in reserves dedicated to the Xingjiang datou fish. However, the success of this strategy is not yet know. In general not enough information is available to effectively plan restoration measures. The reproductive behavior, spawning habitat, and early life ecology of the species are largely unknown. Culture techniques need to be developed for efficient propagation. Quantitive assessments are needed to determine the viability of current populations and to evaluate the success of restoration efforts. Regional fish biologists and national Chinese conservation experts believe the species may be near extinction making conservation action imperative.

Discussion

About 1% of the highly diverse Cyprinidae family attain large size and most of those are migratory species. Both characteristics elevate vulnerability to human impacts and predispose these species to major declines in range and abundance. The analysis of conservation classifications of large, migratory cyprinids shows that this group is not receiving the attention that can be expected for species sensitive to human threats. Most species in this group have not been evaluated for vulnerability by the IUCN thus they are not identified as vulnerable to extinction. When these species are evaluated, almost all were considered vulnerable to extinction by regional and national organizations. Perhaps the weak conservation focus on these species stem from low public recognition of cyprinids, and their common label as minnows and carp. This group is indeed as impressive as the charismatic families of Salmonidae or Acipenseridae. Large migratory cyprinids merit much more conservation attention because most threats can be managed to protect these unique fishes.

A review of threats to large migratory cyprinids include all five factors that are the most common threats to freshwater biodiversity: overexploitation, habitat loss and degradation, water pollution, flow modification, and species invasion (Allan and Flecker, 1993; Dudgeon et al., 2006). The most common threat to these large migratory species has been overexploitation; especially on migrations. These large fish are vulnerable to fishing exploitation on migrations, and overfishing can drive these species to low abundances and perhaps extinction (Allan et al., 2005). The second most common threat is river basin fragmentation by dams, weirs, and water diversion structures. These waterway modifications interact with the migratory behaviors and disrupt the life cycle of these fishes. About equally common is habitat loss because of impounding flowing waters and alteration of physical conditions required for spawning or rearing. Water pollution from of heavy siltation and altered water temperature from reservoirs has been indicated as important in a few cases. Interactions with non-native fish and regulations of flow rates was a factor for two

species, but not commonly cited as a threat responsible for declining abundance and range. Although all common threats to freshwater biodiversity are involved, the large size and migratory behavior of these species make vulnerability to overfishing and waterway fragmentation especially harmful. These threats can be managed and mitigated if attention is placed on conserving these species.

The case of the Xinjiang datou fish illustrates how we can loose an impressive species that is a top predator in its range without much scientific or public attention. Even though national and regional government programs are attempting to save this species hardly any information gets beyond the Xinjiang Uygur Autonomous Region of China. Information on the life cycle and biological requirements of this fish is very poor and this deficiency is clearly an impediment to conservation planning. The Tarim River basin is much like the Colorado River basin: arid, intense human need for water supply development, and a naturally depauperate fish fauna. These characteristics clearly contribute to river fragmentation, surface water depletion, water quality alteration, and dominance by non-native fishes. All these factors contribute to jeopardizing the continued existence of the Xinjiang datou fish and Colorado pikeminnow. Federal government efforts in both countries are underway to recovery these species and exploitation has been curtailed. However, they are vulnerable because of river fragmentation by water development structures, habitat loss, and domination of their habitat by non-native fishes. Without major changes in water use and non-native species control these species will likely remain endangered. Like most large migratory cyprinids, much more scientific and public attention is needed for conservation success.

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Conflict of interests

The author has declared no potential conflict of interests.

References

Abell, R., 2002: Conservation biology for the biodiversity crisis: freshwater follow-up. Conserv. Biol. **16,** 1435–1437.

Allan, J. D.; Flecker, A. S., 1993: Biodiversity conservation in running waters. Bioscience **43,** 32–43.

Allan, J. D.; Abell, R.; Hogan, Z. S.; Revenga, C.; Taylor, B. W.; Welcomme, R. L.; Winemiller, K., 2005: Overfishing of inland waters. Bioscience **55,** 1041–1051.

Bain, M. B.; Wine, M. L., 2010: Testing predictions of stream landscape theory for fish assemblages in highly fragmented watersheds. Folia Zool. **59,** 230–238.

Bain, M. B.; Zhang, S., 2001: Threatened fishes of the world: *Aspiorhynchus laticeps* Day 1877 (Cyprinidae). Environ. Biol. Fish **61,** 380.

Baird, I. G., 2006: *Probarbus jullieni* and *Probarbus labeamajor*: the management and conservation of two of the largest fish species in the Mekong River in southern Laos. Aquat. Conserv.: Mar. Freshw. Ecosys. **16,** 517–532.

Bestgen, K. R.; Hawkins, J. A.; White, G. C.; Christopherson, K. D.; Hudson, J. M.; Fuller, M. H.; Kitcheyan, D. C.; Brunson, R.; Budame, P.; Haines, G. B.; Jackson, J. A.; Walford, C. D.; Sorensen, T. A., 2007: Population status of Colorado pikeminnow in the Green River Basin, Utah and Colorado. Trans. Amer. Fish. Soc. **136,** 1356–1380.

Cardillo, M.; Mace, G. M.; Jones, K. E.; Bielby, J.; Bininda-Emonds, O. R. P.; Sechrest, W.; Orme, C. D. L.; Purvis, A., 2005: Multiple causes of high extinction risk in large mammal species. Science **309,** 1239–1241.

Chun-Guang, Z.; Yin-Feng, G.; Ya-Hui, Z. 2001: The endangered freshwater fishes and their conservation in China. In: Chinese freshwater fishes: research priorities in fish biology and informatics at the aquatic frontier. S. O. Kullander (Ed.). Proceedings of a Workshop, African, Caribbean and Pacific (ACP) countries and the European Union (EU), ACP-EU Fisheries Research Report 9, Brussels, Belgium, pp. 24–34.

Day, F., 1877: On the fishes of Yarkand. Proc. Zool. Soc. London **53,** 781–807.

Dudgeon, D.; Arthington, A. H.; Gessner, M. O.; Kawabata, Z.; Knowler, D. J.; Lévêque, C.; Naiman, R. J.; Prieur-Richard, A.; Soto, D.; Stiassny, M. L. J.; Sullivan, C. A., 2006: Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. **81,** 163–182.

Fagan, W. F.; Unmack, P. J.; Burgess, C.; Minckley, W. L., 2002: Rarity, fragmentation and extinction risk in desert fishes. Ecology **83,** 3250–3256.

Froese, R.; Pauly, D., 2009. FishBase. World Wide Web electronic publication. http://www.fishbase.org (accessed on 6 August 2009**).**

Hoffmann, M.; Brooks, T. M.; da Fonseca, G. A. B.; Gascon, C.; Hawkins, A. F. A.; James, R. E.; Langhammer, P.; Mittermeier, R. A.; Pilgrim, J. D.; Rodrigues, A. S. L.; Silva, J. M. C., 2008: Conservation planning and the IUCN Red List. Endanger Species Res. **6,** 113–125.

Hogan, Z.; Baird, I. G.; Phanara, T., 2009: Threatened fishes of the world: *Probarbus jullieni* Sauvage, 1880 (Cypriniformes: Cyprinidae). Environ. Biol. Fish **84,** 291–292.

Holden, P. B., 1991: Ghosts of the Green River: impacts of Green River poisoning on management of native fishes. In: Battle against extinction: native fish management in the American Southwest. W. L. Minckley and J. E. Deacon (Eds), University of Arizona Press, Tucson, pp. 43–54.

Institute of Hydrobiology, Academia Sininca, and Shanghai Natural History Museum. 1993. The freshwater fishes of China in coloured illustrations, volume 3. Ministry of Agriculture, Beijing, China. 166 pp, ISBN 7-5323-2960-7.

IUCN, International Union for Conservation of Nature and Natural Resources. 2009. IUCN Red List of threatened species. Version 2009.1. http://www.iucnredlist.org (accessed on 6 August 2009).

Kottelat, M. 1999: *Probarbus jullieni*. IUCN, 2009. IUCN Red List of threatened species. Version 2009.1. http://www.iucnredlist.org (accessed on 6 August 2009).

Letcher, B. H.; Nislow, K. H.; Coombs, J. A.; O'Donnell, M. J.; Dubreuil, T. L., 2007: Population response to habitat fragmentation in a stream-dwelling brook trout population. PLoS ONE **2,** e1139.

Li, Y.; Chen, Y.; Zhang, Y.; Xia, Y., 2009: Rehabilitating China's largest inland river. Conserv. Biol. **23,** 531–536.

Maitland, P. S., 1995: The conservation of freshwater fish: past and present experience. Biol. Conservation **72,** 259–270.

Mattson, N. S.; Buakhamvongsa, K.; Sukumasavin, N.; Tuan, N.; Vibol, O. 2002. Mekong giant fish species: on their management and biology. Mekong River Commission Technical Paper No. 3, Phnom Penh, Cambodia, 29 pp.

Miller, R. R., 1961: Man and the changing fish fauna of the American Southwest. Papers Michigan Acad. Sci. Arts and Letters **46,** 365–404.

Molur, S.; Walker, S. 1998. Conservation assessment and management plan for freshwater fishes of India. Workshop Report by the Conservation Breeding Specialist Group, Zoo Outreach Organization, Tamil Nadu, India. 156 pp.

Moyle, P. B.; Cech, J. J.., Jr, 2000. Fishes: an introduction to ichthyology. Prentice-Hall Inc., Upper Saddle River, New Jersey, USA. 612 pp, ISBN 0130112828.

Olden, J. D.; Hogan, Z. S.; Vander Zanden, M. J., 2007: Small fish, big fish, red fish, blue fish: size-biased extinction risk of the world's freshwater and marine fishes. Glob. Ecol. Biogeogr. **16,** 694–701.

Pimm, S. L.; Jones, H. L.; Diamond, J., 1988: On the risk of extinction. Amer. Nat. **132,** 757–785.

Poulsen, A. F.; Hortle, K. G.; Valbo-Jorgensen, J.; Chan, S.; Chhuon, C. K.; Viravong, S.; Bouakhamvongsa, K.; Suntornratana, U.; Yoorong, N.; Nguyen, T. T.; Tran, B. Q., 2004. Distribution and ecology of some important riverine fish species of the Mekong River Basin. Mekong River Commission Technical Paper No. 10, Phnom Penh, Cambodia. 116 pp, ISSN 1683-1489.

Qi, F.; Wei, L.; Jianhua, S.; Yonghong, S.; Yewu, Z.; Zongqiang, C.; Haiyang, X., 2005: Environmental effects of water resource development and use in the Tarim River basin of northwestern China. Environ. Geol. **48,** 202–210.

Raeymaekers, J. A. M.; Raeymaekers, D.; Koizumi, I.; Geldof, S.; Volckaert, F. A. M., 2009: Guidelines for restoring connectivity around water mills: a population genetic approach to the management of riverine fish. J. Appl. Ecol. **46,** 562–571.

Rainboth, W. J., 1991: *Aaptosyax grypus*, a new genus and species of large piscivorous cyprinids from the middle Mekong River. Japan. J. Ichthyol. **38,** 231–237.

Rainboth, W. J., 1996. Fishes of the Cambodian Mekong. Food and Agriculture Organization of the United Nations, Rome, Italy. 265 pp, ISBN 92-5-103743-4.

Reynolds, J. D.; Webb, T. J.; Hawkins, L. A., 2005. Life history and ecological correlates of extinction risk in European freshwater fishes. Can. J. Fish. Aquat. Sci. **62,** 854–862.

Riede, K., 2008. Global register of migratory species. Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany, http://www.groms.de/ (accessed 6 August 2009).

Roberts, T. R., 1992: Revision of the Southeast Asian cyprinid genus *Probarbus*, with two new species threatened by construction of dams on the Mekong River. Ichthyol. Explor. Freshw. **3,** 37–48.

Roberts, T. R.; Baird, I. G., 1995: Traditional fisheries and fish ecology on the Mekong River at Khone waterfalls in southern Laos. Nat. Hist. Bull. Siam Soc. **43,** 219–262.

Roberts, T. R.; Warren, T. J., 1994: Observations of fishes and fisheries in southern Laos and northeastern Cambodia, October 1993–Febuary 1994. Nat. Hist. Bull. Siam Soc. **42,** 87–115.

Rodrigues, A. S. L.; Pilgrim, J. D.; Lamoreux, J. F.; Hoffmann, M.; Brooks, T. M., 2006: The value of the IUCN Red List for conservation. Trends Ecol. Evol. **21,** 71–76.

Sehgal, K. L., 1999: Coldwater fish and fisheries in the Indian Himalayas: rivers and streams. In: Fish and fisheries at higher altitudes Asia. T. Petr (Ed.). Food and Agriculture Organization of the United Nations, Fish. Tech. Pap. 385, Rome, Italy, pp. 385.

Sharma, R. C., 2003: Protection of an endangered fish *Tor tor* and *Tor putitora* population impacted by transportation network in the area of Tehri Dam Project, Garhwal Himalaya, India. In: Proceedings of the 2003 International Conference on Ecology and Transportation. C. L. Irwin, P. Garrett and K. P. McDermott (Eds), Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina, USA, pp. 83–90.

Singh, D.; Sharma, R. C., 1998: Biodiversity, ecological status and conservation priority of the fish of the River Alaknanda, a parent stream of the River Ganges (India). Aquat. Conserv.: Mar. Freshw. Ecosys. **8,** 761–772.

Sreekantha; Subash Chandran, M. D.; Mesta, D. K.; Rao, G. R.; Gururaja, K. V.; Ramachandra, T. V., 2007: Fish diversity in relation to landscape and vegetation in central Western Ghats, India. Curr. Sci. **92,** 1592–1603.

Stone, R., 2007: The last of the leviathans. Science **316,** 1684–1688.

Tyus, H., 1990: Potamodromy and reproduction of Colorado squawfish in the Green River Basin, Colorado and Utah. Trans. Amer. Fish. Soc. **119,** 1035–1047.

U.S. Fish and Wildlife Service, 2002: Colorado pikeminnow (*Ptychocheilus lucius*) recovery goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region, Denver, Colorado, 111 pp.

Walker, K. F.; Yang, H. Z., 1999: Fish and fisheries of western China. In: Fish and fisheries at higher altitudes Asia. T. Petr (Ed.). Food and Agriculture Organization of the United Nations, Fish. Tech. Pap. 385, Rome, Italy, pp. 237–278.

Ward, J. V.; Tockner, K.; Schiemer, F., 1999: Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regul. Rivers: Res. Manage. **15,** 125–139.

Wilcove, D. S.; Rothstein, D.; Dubow, J.; Phillips, A.; Losos, E., 1998: Quantifying threats to imperiled species in the United States. Bioscience **48,** 607–615.

Xie, Z., 1999. A comprehensive survey and conservation strategy on the resources of Xinjiang datou fish – a rare and endangered species. Fishery Bureau of the Xinjiang Uygur Autonomous Region, Urumqi, Xinjiang, China.

Xu, Z. X.; Chen, Y. N.; Li, J. Y., 2004: Impact of climate change on water resources in the Tarim River basin. Water Resour. Manage. **18,** 439–458.

Yan, G., 2004: Fisheries development in Xinjiang, China. In: Fisheries in irrigation systems of arid Asia. T. Petr (Ed.). Food and Agriculture Organization of the United Nations, Fish. Tech. Pap. 430, Rome, Italy, pp. 95–99.

Yang, Z. L.; Xiao, L. M.; Xie, Z. N.; Zheng, X. M.; Ren, M. L.; Ren, B.; Feng, G. R.; Wang, J. D., 1995. A comprehensive survey and conservation strategy on the resources of Xinjiang datou fish – a rare and endangered species. Fishery Bureau of the Xinjiang Uygur Autonomous Region, Urumqi, Xinjiang, Peoples Republic of China, 28 pp.

Yue, P.; Chen, Y., 1998. China red book of endangered animals, Volume 2: Pisces. Science Press, Beijing, China. 244 pp, ISBN 7-03-006401-1.

Zhao, R.; Chen, Y.; Zhou, H.; Li, Y.; Qian, Y.; Zhang, L., 2009: Assessment of wetland fragmentation in the Tarim River basin, western China. Environ. Geol. **57,** 455–464.

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