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REVIEW OF FRESHWATER FISH

(Prepared by Dr. Zeb Hogan, COP Appointed Councillor for Fish)

Pursuant to the Strategic Plan 2006-2011 mandating a review of the conservation status for Appendix I and II species at regular intervals, the 15th Meeting of the Scientific Council (Rome, 2008) tasked the COP Appointed Councillor for Fish, Mr. Zeb Hogan, with preparing a report on the conservation status of CMS-listed freshwater fish. The report, which reviews available population assessments and provides guidance for including further freshwater fish on the CMS Appendices, is presented in this Information Document in the original form in which it was delivered to the Secretariat. Preliminary results were discussed at the 16th Meeting of the Scientific Council (Bonn, 2010). An executive summary is provided as document UNEP/CMS/Conf.10.31 and a Resolution as document UNEP/CMS/Resolution 10.12.

Review of Migratory Freshwater Fish

Prepared by Dr. Zeb Hogan, CMS Scientific Councilor for Fish on behalf of the CMS Secretariat

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Acknowledgements

This CMS Review of Migratory Freshwater Fish was prepared by Dr. Zeb Hogan with assistance from the IUCN Freshwater Fish Specialist Group and IUCN SSC Red List Programme. The review is modeled after and draws heavily from the Review of Migratory Chondrichthyan Fishes prepared by the Shark Specialist Group of the IUCN Species Survival Commission on behalf of the CMS Secretariat.

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Executive Summary

Growing evidence shows that freshwater fish are among the most imperilled species in the world (Dudgeon et al. 2006, Abell et al. 2007, Revenga et al. 2005). Recent reviews suggest that 40 percent of North American freshwater fish and 38 percent of European freshwater fish are threatened (Kottelat and Freyhoff 2007). The situation for migratory freshwater fish may be even worse: one recent study of North Atlantic diadromous fish showed that "all species had suffered population extirpations" and many species are classified as endangered (Limburg and Waldman 2009).

This decline of freshwater biodiversity has led for a call for the international community to consider "all reasonable interventions" to halt biodiversity loss (Abell et al. 2007, Dudgeon et al. 2006). The need to study and protect freshwater fish has never been more urgent. While the causes of this biodiversity loss (habitat fragmentation and degradation, flow alteration, overharvest, pollution, and invasive species) are well known, the discussion about – and action toward - protecting global freshwater fish biodiversity, especially migratory freshwater fish biodiversity, has barely begun (Abell et al. 2007).

The Secretariat of the Convention on Migratory Species, recognizing the need for action, called upon Parties to strengthen measures to protect migratory freshwater fish. As a first step in the process, the Secretariat requested a review of the conservation status of migratory freshwater fish to determine which species would benefit from listing on the Appendices of the Convention.

Dr. Zeb Hogan, the CMS Scientific Councillor for Fish, was asked to prepare a review of the conservation status of migratory freshwater fish to determine which species qualify for listing on the CMS Appendices according to their status and conservation needs. This report, modelled after the December 2007 Review of Migratory Chondrichthyan Fishes, summarizes the results of the review.

The first steps of this assessment were to 1) determine the number of threatened freshwater fish species and 2) determine the number of migratory freshwater fish species. Those lists were then integrated to develop a list of threatened migratory freshwater fish. Of approximately 15,000 species of freshwater fish, 3,146 have been assessed by IUCN and 1,116 are considered threatened (with an additional 102 extinct and 677 Near Threatened or Data Deficient). Of those 1,116 threatened species, 223 occur in more than one country, making them potential candidates for CMS listing depending on migratory status. Based on data from Fishbase (which lists 1,182 species of migratory freshwater fish) and IUCN, ~30 species meet all criteria: migratory, transboundary freshwater fish with unfavourable conservation status. An additional ~10 species were added to this list based on information from other sources including additional 5,000+ IUCN Red List assessments completed in 2010 and 2011, CMS scientific councillors, the Global Registry of Migratory Species (GROMS) and published primary research.

The assessment includes four sets of data (threatened freshwater fish, threatened freshwater fish that occur in more than one country, migratory freshwater fish, and threatened migratory freshwater fish). The databases have been compiled using Microsoft Excel and the final integrated spreadsheet includes ~30 species of CMS migratory freshwater fish. The data fields in the spreadsheet include order, family, genus, species, migratory pattern, IUCN conservation status, and details on the IUCN Red List threat category. More detailed information has been prepared for an additional ~10 species which might benefit from CMS listing – some at species, some at genus, and others at family level.

This preliminary review identifies several species assemblages (groups of related migratory species) that would likely benefit from listing on CMS. These are groups of fish that contain many threatened species, occur in areas with many transboundary issues, or both. These groups include sturgeon and salmon, sawfish (Pristiformes), freshwater stingrays (Himantura

spp.) anguillid eels (Anguillidae), shad (Alosinae), large, migratory pimelodids and characids of South America, pangasiid catfish of Southeast Asia (most notably the Mekong River), mahseer (Tor spp. and related species), Alestiidae of the Lake Chad basin, and cichlids of the East African Great Lakes. While this is not a comprehensive list of potential CMS candidates, it represents a starting point for discussions.

This review also highlights the importance of several generic actions to improve the management and conservation status of migratory fish, including: 1) development of baseline information on current and historical abundance of migratory fish; 2) improvement of knowledge of migratory fish ecology; 3) mitigation of problems created by damming; 4) reduction of habitat degradation, including pollution; 5) initiation of trans-boundary monitoring and management programs in partnership with other management frameworks and including regional migratory fish workshops and data sharing.

It should be noted that knowledge of freshwater biodiversity, especially in Africa, Asia, and South America, is incomplete. Over one hundred new species of freshwater fish are described each year (Lundberg et al. 2000) and of all freshwater fish species less than half have been assessed by IUCN. Detailed data on freshwater fish migrations are even scarcer. As a consequence, this review should be considered a work in progress. As more information on the conservation status and migratory behaviour of freshwater fish becomes available, the database must be updated especially considering the recent initiative by IUCN to complete Red List assessments for all species on freshwater fish.

1 Introduction

1.1 Background

Appendices I and II of the Convention on Migratory Species (CMS) currently include twenty-one species of freshwater fish, including one teleost (the Mekong giant catfish, *Pangasianodon gigas*) and twenty species of Acipenseriformes (sturgeon and paddlefish). The European sea sturgeon (*Acipenser sturio*) and the Mekong giant catfish are listed in Appendix I. An additional nineteen species of sturgeon and paddlefish are listed on Appendix II.

CMS, recognizing the large number of migratory freshwater fish, their importance, and the many threats to their populations and ecosystems, has called upon parties to strengthen measures to protect migratory freshwater fish. As part of the move to strengthen measures to protect migratory fish, the CMS Secretariat has initiated a review the conservation status of migratory freshwater fish, primarily to determine the current state of information on migratory freshwater fish and identify species that might benefit from listing on the Appendices of the Convention on Migratory Species. This report, modeled after the December 2007 Review of Migratory Chondrichthyan Fishes, summarizes the results of this review.

1.2 Rationale

Freshwater fish are among the most imperiled species on Earth (Dudgeon *et al*. 2006, Abell *et al*. 2007, Nilsson *et al.* 2005). Recent reviews suggest that 40 per cent of North American freshwater fish and 70 per cent of all large-bodied freshwater fish are threatened (Stone 2007). The situation for transboundary (i.e. crossing international borders) stocks of migratory freshwater fish may be even worse. One recent study of European diadromous fishes, for example, showed that "all species had suffered population extirpations" (Limburg and Waldman 2009).

Given the urgent need for action to protect migratory fish, identification of transboundary stocks is imperative. The scale of the issue, however, is immense. According to Varis et al. (2008), there are over 250 transboundary rivers and lakes in the world and over 47% of the area of the world falls within a transboundary basin (Table 1).

Table 1. Transboundary river basins (from Varis *et al*. 2008)

Continents	**Number of basins**
Africa	60
Asia	53
Europe	71
North and Central America	39
South America	38
Total	261

Many of the world's largest rivers including the Danube, the Nile, and the Amazon pass through several countries covering a significant portion of Europe, Africa and South America, respectively (Table 2).

Table 2. The largest transboundary river basins of the world (from Wolf et al. 1999)

Basin name	**Area of basin (km^2)**	**Countries (greatest surface area listed first)**
Africa		
Congo/Zaire	3,699,100	Democratic Republic of the Congo, Central African Republic, Angola, Republic of the Congo, Zambia, United Republic of Tanzania, Cameroon, Burundi, Rwanda, Gabon, Malawi
Lake Chad	2,394,200	Chad, Niger, Central African Republic, Nigeria, Algeria, Sudan, Cameroon, Chad, Libya
Niger	2,117,700	Nigeria, Mali, Niger, Algeria, Guinea, Cameroon, Burkina Faso, Benin, Cote d'Ivoire, Chad, Sierra Leone
Nile	3,031,700	Sudan, Ethiopia, Egypt, Uganda, United Republic of Tanzania, Kenya, Democratic Republic of Congo, Rwanda, Burundi, Eritrea, Central African Republic
Okavango	706,900	Botswana, Angola, Namibia, Zimbabwe
Orange	945,500	South Africa, Namibia, Botswana, Lesotho
Zambezi	1,385,300	Zambia, Angola, Zimbabwe, Mozambique, Malawi, United Republic of Tanzania, Botswana, Namibia, Democratic Republic of Congo
Asia		
Amur	2,085,900	Russia, China, Mongolia, North Korea
Aral Sea	1,231,400	Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, Afghanistan, Turkmenistan, China, Pakistan
Ganges-Brahmaputra	1,634,900	India, China, Nepal, Bangladesh, Bhutan, Myanmar
Indus	1,138,800	Pakistan, India, China, Afghanistan, Nepal
Mekong	787,800	Lao PDR, Thailand, China, Cambodia, Vietnam, Myanmar
Ob	2,950,800	Russia, Kazakhstan, China, Mongolia
Tigris-Euphrates	789,000	Iraq, Turkey, Iran, Syrian Arab Republic, Jordon, Saudi Arabia
Europe		
Danube	790,100	Romania, Hungary, Austria, Serbia, Montenegro, Germany, Slovakia, Bulgaria, Bosnia and Herzegovina, Croatia, Ukraine, Czech Republic, Slovenia, Republic of Moldova, Switzerland, Italy, Poland, Albania
Volga	1,554,900	Russia, Kazakhstan, Belarus
North America		
Colorado	655,000	United States, Mexico
Mississippi	3,226,300	United States, Canada
Nelson-Saskatchewan	1,109,400	Canada, United States
St. Lawrence	1,055,200	Canada, United States
South America		
Amazon	5,883,400	Brazil, Peru, Bolivia, Colombia, Ecuador, Venezuela, Guyana, Suriname, French Guiana
La Plata	2,954,500	Brazil, Argentina, Paraguay, Bolivia, Uruguay
Orinoco	927,400	Venezuela, Columbia, Brazil

The transboundary nature of many migratory stocks presents unique challenges, requiring management of both habitat and species at the local, national, and – most relevant to this study - international level (Rabinowitz 1995). While the basic management principles for transboundary stocks are similar to those for other fish stocks, the situation for migratory species is more complicated, often involving long distances, many different stakeholders, a variety of cultures and motivations, and several life stages of the species or stock in question (Coates *et al.* 2000).

The complexity of management of transboundary freshwater fish stocks, combined with our lack of knowledge about the ecology and conservation status of freshwater fish, underscores the importance of identifying freshwater fish stocks and species in need of international cooperative action. This review is designed as a first step toward identifying stocks and species that would benefit from transnational cooperation and outlining possible mechanisms to facilitate such action.

1.3 Objectives

The objectives of this review are to:

1) Provide an overview of freshwater fish biodiversity and the current state of knowledge about migratory freshwater fish

2) Identify migratory freshwater fish species that might benefit from CMS listing

3) Provide a starting point for discussions about how CMS can best facilitate better management and protection of migratory freshwater fish.

2 Definitions

2.1 Definition of a CMS (transboundary) Migratory Species

According to Article 1 of CMS a migratory species is defined as an "entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of those members cyclically and predictably cross one or more national jurisdictional boundaries." For the purposes of migratory freshwater species, the definition could also include not just national boundaries between states, but also transboundary rivers and lakes where a water body or watershed is shared by more than one country.

Under this definition (taken from :

i) The word "cyclically" in the phrase "cyclically and predictably" relates to a cycle of any nature such as astronomical (circadian, annual, etc.), life, or climatic, and of any frequency.

ii) The word "predictably" in the phrase "cyclically and predictably" implies the phenomenon can be anticipated to recur in a given set of circumstances, though not necessarily regularly in time.

iii) National jurisdictional boundaries include national land and water borders, including instances where the borders between states may occur at mid-river or mid-lake.

Determining whether or not a species is a "CMS migratory fish" is confounded somewhat both by lack of specific spatial data on fish movements and because species may consist of several populations, some of which make transboundary migrations and some which do not (Coates et al. 2000).

The complexity of the issue (and lack of data about many species) should not be an insurmountable obstacle, however, to the management of transboundary fish stocks. By their very nature, transboundary water bodies are shared by more than one country and it is only through cooperation that all parties can

optimize the mutual benefits that come from sustainable use of aquatic resources. Thus, while we may not have perfect information about the migrations, ecology, and conservation status of many freshwater fish, we can be sure that increased international cooperative management of transboundary rivers is an important priority and one that will have broad benefits for both people and migratory fish.

2.2 Definition of "unfavorable conservation status"

According to Article 1 of CMS, a migratory species can be considered of unfavourable conservation status if it meets one or more of the following criteria:

1) the range of the migratory species is currently reduced, or is likely to be reduced, on a long term basis;

2) there is not, or will not be in the foreseeable future, sufficient habitat to maintain the population of the migratory species on a long term basis;

3) the distribution and abundance of the migratory species does not approach historic coverage and levels to the extent that potential suitable ecosystems exist and the extent that is consistent with wise wildlife management.

Many species of freshwater fish meet more than one of these criteria because the main threats to migratory freshwater fish include habitat fragmentation, reduced access to spawning sites, habitat degradation, and overexploitation (Dudgeon et al. 2006, Allan et al. 2005, Casselman and Cairns 2009, Froese and Torres 1999).

2.3 Freshwater fish definition, diversity, taxonomy, and nomenclature

For the purposes of this review we define a freshwater fish as any species of fish that spends some or all of its life in freshwater. This definition is similar to that of Fishbase which divides freshwater fish into three categories:

(1) exclusively freshwater,
(2) occurring in fresh and brackish waters,
(3) or occurring in fresh, brackish and marine waters.

This definition includes obligate freshwater species (fish that spend their entire life in freshwater) as well as diadromous (fish that move between fresh and saltwater). To clarify, a "**potamodromous**" fish migrates wholly within freshwater, whereas a "**diadromous**" fish can either be "**anadromous**" (spending most of its life in marine waters and migrating to fresh water to breed), "**catadromous**" (spending most of its life in fresh water and migrating to the sea to breed), or "**amphidromous**" (regularly migrating from fresh water to the seas, or vice versa, but not for breeding). All four types of fish are included in this report.

Freshwater fish include approximately 170 families (over 200 if brackish water species are included) 2,500 genera, and almost 13,000 species (Leveque et al. 2008). The total number of species approaches 15,000 when diadromous species, such as most salmon, sturgeon, sawfish and anguillid eels, are included in the tally (Table 3). In addition to named species, approximately 250 new species of fish are described every year (Berra 2001). Even in well known areas such as Europe, the freshwater fish fauna has not been completely catalogued (Kottelat and Freyhoff 2007).

Table 3. Global distribution of freshwater fish (from Leveque et al. 2008)

Region	**Obligate freshwater (# species)**	**Brackish/marine tolerant (# species)**	**Total (# species)**
Africa	2,945	295	3,240
Asia	3,553	858	4,411
Europe	330	151	481

Russia	206	175	381
Oceania	260	317	577
North America	1,411	330	1,741
South America	4,035	196	4,231
Total	12,740	2,322	15,062

Freshwater fish are an extremely diverse group including some representatives from all major groups of fish: hagfish, lampreys, sharks, rays, and finned bony fishes. Finned bony fishes form the bulk of freshwater fish species with the representatives of the orders Characiformes, Cypriniformes, Siluriformes, Gymnotiformes, Perciformes, and Cyprinodontiformes the most common (Table 4).

Table 4. Number of families and species from the most common fish groups (modified from Leveque et al. and Nelson 2006).

Order	**Number of families**	**Number of species**
Characiformes	17	1,674
Cypriniformes	7	3,268
Cyprinodontiformes	9	1,008
Perciformes	51	2,335
Siluriformes	34	2,750

3 Freshwater fish distribution, ecology, and threats

3.1 Freshwater fish distribution

Freshwater fish occur almost everywhere there is fresh water – in rivers, streams, lakes, springs, swamps, and bogs and every continent except Antarctica. Each continent, and often each river basin, has a distinct fish fauna that is primarily due to the physical barriers that limit freshwater fish dispersal. As a general rule, diversity is lower in temperate regions and higher in tropical areas. For freshwater fish, the tropical zones of South America, Africa and Asia are the most diverse regions on Earth (Berra 2001).

Over 1,000 species of freshwater fish occur in North America, a large number of species relative to other temperate regions (Leveque et al. 2008). Historically, diadromous species (especially salmonids, shad, and sturgeon) dominated freshwater fauna in streams along the Pacific and Atlantic coast. However, the abundance of fish of these groups has declined over the last several decades primarily due to overexploitation and habitat degradation. The freshwater fish fauna of North America is well studied and most species that occur in North American rivers and lakes have been described.

South America is home to more species of freshwater fish than any other continent. The fish fauna is dominated by small bodied fish but South America is also home to some of the world's largest species, including air breathing arapaima (*Arapaima gigas*) and the goliath catfish (*Brachyplatystoma filamentosum*). Roughly half of South America's 4,000+ fish species occur in the Amazon River, including several species which are thought to make some of the longest migrations (from the mouth of the Amazon to the headwaters) of any species of freshwater fish. South American freshwater fish fauna has not been completely surveyed and some biologists estimate that an additional 1,000-2,000 species of fish remain to be described (Lundberg et al. 2000)

Europe has low fish diversity compared with other continents but a high degree of endemism in some sites, especially in countries bordering the Mediterranean. Estimates of the total number of native European species has been steadily rising over the last decade: Maitland (2000) estimated 250 species, while Kottelat (1997) counted 358 species, and Kottelat and Freyhoff (2007) identified 546 species. The

Danube is the most species rich river, containing approximately 100-115 species of native fish (Leveque et al. 2008, Kottelat and Freyhoff 2007, Tockner et al. 2009).

Africa has a large number of freshwater fish species (approximately 3000 species at last count) due in large part to high fish diversity in the Congo and in the African Great Lakes (Leveque et al. 2008). Very few diadromous species occur in Africa, except in Madagascar, where the freshwater fish fauna is dominated by species of marine origin. The freshwater fish fauna of Africa has not been completely surveyed and therefore it is likely that many species have yet to be described (Leveque et al. 2008).

Asia, especially tropical Asia, has high freshwater fish diversity. The Mekong River alone is thought to contain about 1,000 species of freshwater fish, including some highly migratory species such as pangasiid catfish (Hogan et al. 2004). Asia is also home to several of the largest, and most endangered migratory freshwater fish, including the golden mahseer (*Tor putitora*), Chinese paddlefish (*Psephurus gladius*), Mekong giant catfish (*Pangasianodon gigas*), and giant freshwater stingray (*Himantura polylepis*). Information on the abundance, ecology, and conservation status of many species in Asia is lacking (Hogan 2011).

Freshwater fish diversity is low in Oceania. The fauna is dominated by species of marine origin, including a large number of diadromous species.

3.2 Migratory fish ecology and life history

Migratory freshwater fish are widely distributed and comprise most, if not all, major taxonomic groups. Diadromous fish, i.e. fish that move between freshwater and marine waters to complete their life cycle, are the most conspicuous group of migratory fish yet in many tropical areas an estimated 95 per cent of migratory fish are obligate freshwater species. While migratory behavior is relatively common in freshwater fish (55 per cent of Canadian freshwater fish and between 40-70 per cent of common Mekong food fish are thought to be migratory) specific information on the scale of migrations if often lacking (Baran and Myschowoda 2009) . Several species of freshwater fish, including sturgeon, salmon, anguillid eels, pimelodid and pangasiid catfish clearly make long distance migrations of hundreds if not thousands of miles (Barthem and Goulding 1997, Lucas and Baras 2001, Carolsfeld et al. 2003, Hogan et al. 2007). Lucas and Baras (2001) compiled a list of examples of long-distance migrations of freshwater tropical fish (table 5). The list highlights the long distance migrations of species from Africa, Asia, and South America but also illustrates a lack of comprehensive study because a significant percentage of 15,000 freshwater fish species are believed to be migratory (and yet we only know of a handful of examples from the tropics).

Table 5. Examples of long-distance migrations of freshwater tropical fish (Modified from Lucas and Baras 2001). Note that some of the studies were done over 50 years ago, an indication of the paucity of information about (and lack and difficulty of study of) freshwater fish migrations in tropical systems.

Fish species	**Ecosystem**	**Approximate migration distance (km)**	**References**
Alestes baremoze	Lake Chad tributaries	650	Blache and Milton 1962
Alestes dentex	Lake Chad tributaries	650	Blache and Milton 1962
Barbus atianalis	Lake Victory tributary	80	Whitehead 1959
Brachyplatystoma flavicans	Amazon River	3,500	Barthem and Goulding 1997
Brachyplatystoma vaillanti	Amazon River	3,500	Barthem and Goulding 1997
Brycinus leuciscus	Niger River	400	Daget 1952
Hydrocynus brevis	Lake Chad tributary	100+	Benech et al. 1983
Labeo senegalensis	Lake Chad tributary	250-300	Benech and Quensiere 1983

Pangasius krempfi	Mekong River	700+	Hogan et al. 2007
Prochilodus lineatus	Upper Parana River	600-700	Godoy 1972
Prochilodus platensis	Middle Parana River	700	Bonetto et al. 1981
Pseudoplatystoma corruscans	Paraguay River	400	Bayley 1973
Pseudoplatystoma fasciatum	Magdalena River	500-700	Lucas and Baras 2001
Salminus brasiliensis	Parana River	850	Bonetto et al. 1981

It is important to recognize that not all continents are equal in the context of analysis of threatened, transboundary fish. The freshwater fish of North America, for example, have been relatively well studied. Information exists of the migratory patterns of many fish species and several make long distance migrations. Yet in North America, few rivers are transboundary and even when rivers are transboundary, they flow through only two countries (either Canada and the United States or the United States and Mexico) with one country often at the periphery of a given migratory species range (e.g. Mississippi paddlefish, *Polyodon spathula*, in Canada).

In Europe, on the other hand, most rivers are transboundary and the fish fauna is relatively well studied, so it is possible to identify several freshwater fish species that make – or once made - transboundary migrations. The situation is complicated however by the widespread and dramatic history of human alterations to European Rivers. Today, few European rivers are free flowing and the long history of environmental change and degradation means that it is difficult to establish an ecological baseline (historical distribution, abundance, and ecology) in many locations (Tockner et al. 2009, Holcik 1995, Holcik *et al*. 1988). In many cases, populations of long-distance migratory species such as salmon, shad, eels, and sturgeon have gone extinct. Therefore, the question becomes: is CMS the proper instrument to restore these stocks even if, in many cases, they no longer exist.

South America, in contrast to Europe, is dominated by a small number of large, highly diverse, transboundary rivers. The Amazon, the largest river in the world by volume, is home to over 2,000 fish species many of which are endemic (Pringle et al. 2000). Unfortunately for this analysis, the lack of baseline (pre-development) data, combined with inadequate knowledge about the migratory behavior and conservation status of freshwater fish, make a comprehensive analysis almost impossible. In other words, while many, if not all, Amazon species would benefit from international collaboration to sustainably manage the Amazon and associated natural resources, it is not possible to create a definitive list of transboundary migratory species at this time. The list of potential CMS candidate species will grow as our knowledge of fish ecology grows (with a significant amount of research still needed in this area).

In Africa, much of the fish diversity occurs in the East African Great Lakes (Lake Victoria, Lake Tanganyika, and Lake Malawi). While the rich biodiversity and threats in this region have been relatively well documented (table 6), it is debatable whether or not species in these lakes qualify for CMS listing. Aside from the East African Great Lakes, Africa is dominated by four rivers: the Nile, the Niger, the Congo, and the Zambezi. The Nile and Zambezi are perhaps the best studied, but both systems have been highly modified. Most of the research that exists was conducted after the ecological impacts of development occurred (Pacini and Harper 2000). The Niger River and Lake Chad occur in a region susceptible to climate change – both systems have undergone extended drought in recent times with fish populations declining dramatically. The Congo, the continent's largest river, is diverse but relatively unstudied.

Asia is home to a large number of important rivers: the Yangtze and the Yellow River in China, the Lena and Yenisei in Russia, the Brahmaputra, Ganges, and Indus in South Asia, and the Mekong and Salween in Southeast Asia. Of the transboundary rivers, the Mekong has been perhaps the best studied. Migratory species make up an estimated 40-70 per cent of Mekong fisheries (Baran and Myschowoda 2009). While both Africa and Asia contain very high freshwater fish biodiversity, many rivers have not been well studied and the ecology and conservation status freshwater fish is poorly documented (Pacini and Harper 2000, Dudgeon 2000, Dudgeon 2003). Australia's freshwater fauna (with the exception of diadromous species like eels and sawfish) is isolated from other countries by the Indian, Pacific, and

Southern Oceans and so does not qualify for listing on CMS.

Table 6. The freshwater fish biodiversity and associated threats in the East African Great Lakes region (modified from Allan *et al*. 2006).

Lake	**Countries**	**Biodiversity**	**Main threats**
Lake Malawi	Malawi and Mozambique	400-800 cichlid species; 17 deep water catfish	Overfishing; deforestation; siltation; eutrophication
Lake Tanganyika	Burundi, Democratic Republic of Congo, United Republic of Tanzania, and Zambia	~500 fish species, including endemic cichlids, eels, catfishes, and perches	Sedimentation; pollution; overfishing; climate change
Lake Victoria	Kenya, United Republic of Tanzania and Uganda	~600 endemic fish species	Overfishing; invasive species; land use change and siltation; pollution

Several geographic regions stand out because of the likelihood that transboundary fish stocks and transboundary impacts exist. These regions include the Lake Chad Basin and East African Great Lakes, the rivers of the Himalayas, the Mekong River, the Amur, the Aral and Caspian Seas, the Danube, the Amazon River, the La Plata River, the countries bordering the North Atlantic in North America and Europe, and the Colorado River Basin and other river basins of the desert southwest of North America (Carolsfeld *et al*. 2003, Dudgeon *et al*. 2006, Dekker 2009, Hogan *et al*. 2008, Hogan *et al*. 2009, Jayaram 2005, Jelks *et al*. 2008, Roberts and Vidthayanon 1991). International cooperative action could improve the conservation status of historic or existing transboundary fish stocks in each of these regions.

3.3 Threats to migratory freshwater fish

The threats to freshwater fish have been well documented: cumulative impacts from habitat degradation, over-exploitation, pollution, invasive species, flow modification, and climate change (Allan *et al*. 2005, Froese and Torres 1999, Lelek and Kohler 1990, Poff *et al*. 2007, Xenopoulos *et al*. 2005, Leidy and Moyle 1998). Habitat degradation includes such threats as deforestation, clearing of flooded forest, channelization, dredging, extraction of water for human use, and eutrophication. Habitat degradation has caused serious declines of a number of migratory species including sturgeon, shad, eel and trout species in Europe, sturgeon and other migratory fish in Asia, catfish and characids in South America, and sturgeon, salmon, paddlefish, and many other species in North America (Chang and Cao 1999, Holcik 1995, Humphrey and Bain 1990, Jelks *et al*. 2008, Munro *et al*. 2007). Pollution is often a serious problem in areas with heavy industry or high human population density (Lelek and Kohler 1990). In the Yellow River Basin of China, for instance, officials believe one third of all fish species have gone extinct. Invasive species are increasingly recognized as a major threat to freshwater biodiversity (Leveque et al. 2008). For example the Nile perch *Lates niloticus* was introduced into Lake Victoria in the 1950's or 1960's and is believed to have caused the extinction of hundreds of endemic species (Goudswaard *et al*. 2008). Flow modification has been shown to cause species extirpation as well as loss of ecosystem services and homogenization of regional fish faunas (Poff *et al*. 1997, Poff *et al*. 2007). Changes in flow can be especially problematic for migratory species because seasonal flows often cue migratory behavior (Baran and Myschowoda 2009). Climate change can exacerbate these problems because models predict losses in river discharge due to climate change (Thieme *et al*. 2010), and river discharge and species diversity are correlated (Xenopoulos *et al*. 2005).

River regulation, especially river regulation using dams, deserves special mention due to a long history of impacts on migratory fish (Kareiva et al. 2000, Kottelat and Freyhoff 2007, Nilsson et al. 2005, Lepage

and Rochard 1995). The negative impacts of dams on many populations of sturgeon and salmon has been well documented (Jaric et al. 2009, Kottelat and Freyhoff 2007, Munro et al. 2007). While perhaps less well documented, the impact of dams on other species of fish, notably migratory potamodromous species, has also been significant (Barthem and de Brito Ribeiro 1991, Barthem and Goulding 2007, Carolsfeld et al. 2003, Xie 2003). Quiros (2003) describes the situation in the La Plata River basin: "for the dammed and highly regulated river reaches, potamodromous fish abundance declined concomitantly with river regulation and development. Hydroelectric dams have created inappropriate habitats for migratory fish because they act as barriers to crucial fish migrations. In river reaches that were transformed into a cascade of reservoirs, potamodromous fish are absent or their abundance has drastically diminished." The description holds true from many other impacted basins worldwide.

For migratory fish that occur in international river basins, a major management need is collaborative measures to maintain river health (manage for environmental flows, limit pollution, control spread of invasive species) and regulate fisheries. Unfortunately such regulation and management does not often occur at an international scale. When it does occur it often focuses on water rights rather than ecosystem health or biodiversity issues. CMS intervention will yield the greatest benefits if it stimulates measures to safeguard biodiversity and river health on a transnational scale. For example, Duda and La Roche (1997) suggest control of land-based pollution, prevention of deforestation, prevention of degradation of wetlands, collaborative measures to reduce fish overexploitation, and identification of sources of invasive species as effective steps to control major threats to transboundary water body ecosystem health and biodiversity. Likewise, Dudgeon *et al*. 2006 stress the importance of environmental flow requirements and "robust risk assessment procedures, monitoring, and adaptive management".

4 Methods

4.1 Data sources

The analysis and data presented in this paper draw from two main sources: the IUCN Red List and Fishbase. Although neither the IUCN Red List or Fishbase explicitly identifies threatened, migratory fish that make movements across international borders, it was possible to generate a list of threatened, migratory fish and this list has been used to try to single out freshwater fish that might benefit from CMS listing. The preliminary list was generated by identifying fish species of unfavorable conservation status (Critically Endangered, Endangered, or Vulnerable), determining which of those fish occur in more than one country(distribution data available from IUCN and Fishbase), and which are migratory (data on migratory behavior available from IUCN and Fisbase but information is not complete). In addition to the IUCN Red List and Fishbase, a wide variety of other sources was also used to identify candidate species, including (but not limited to) Berra (2001), Kottelat and Freyhoff (2007), Carolsfeld et al. (2003), Rainboth (1996), and Coates et al. (2000). "Migration of Freshwater Fishes" by Lucas and Baras (2001) was particularly useful for its detailed taxonomic analysis of migration in freshwater fishes. The Wetlands International IUCN Freshwater Fish Specialist Group members were also consulted and provided feedback on the provisional list developed as part of this review.

Published IUCN Red List assessments were used as the primary basis for determining whether a given migratory species qualified as "of unfavorable conservation status" according to CMS guidelines. Several other references were used to determine the conservation status of species not listed on the IUCN Red List (Kottelat and Freyhoff 2007, Berra 2001, Carolsfeld et al. 2003).

It should be noted that lack of information on both the ecology and conservation status of freshwater fish seriously limited the analysis presented in this review. Out of approximately 13,000 freshwater fish, Fishbase lists only ~1200 as migratory and only 83 as both threatened and migratory. Likewise, out of 13,000 freshwater fish, only ~3200 had been evaluated by IUCN by early 2010 and of those considered threatened (CR, EN, or VU) only 221 species occur in more than one country. Therefore, it is extremely difficult to generate a comprehensive list of migratory freshwater fish that meet CMS criteria for listing under the convention. This analysis underscores the need for more information on the conservation status and life history characteristics of the majority of freshwater fish. Studies to gather this information should be a priority for CMS parties considering international collaborative action.

4.2 Database structure

The data are presented in simple Excel files so that they can be easily improved or integrated with other data as more information becomes available on the distribution, ecology, and conservation status of migratory, freshwater fish. The spreadsheet includes taxonomic order, family, species, region of occurrence, countries of occurrence (range states), migratory status according to the CMS definition, IUCN Red List category, and criteria for IUCN listing. For the most part the author used the methodology of the Review of Migratory Chondrichthyan Fishes (Shark Specialist Group 2007), although this was not possible in every instance. The lack of information on the migratory and conservation status of several thousand species of fish means that this review is not comprehensive. In particular, information on the migratory behavior of freshwater fish has not been well documented, especially for tropical species inhabiting large rivers.

4.3 Salmon and sturgeon

It is important to note that the author was asked not to include salmon or sturgeon in the analysis. Nonetheless, the sturgeon family Acipenseridae is one of the most threatened and most highly migratory groups of fishes on Earth (Munro et al. 2007). And while sturgeon are not the focus of this report, it is worth recognizing that most species of sturgeon fit the criteria for listing in the Appendices of the Convention of Migratory Species: they are migratory, they are threatened, they would benefit from international cooperation, and several species occur in countries that are CMS signatories. For this reason, twenty of approximately twenty six species have already been listed in CMS Appendix I or Appendix II.

5 Results

5.1 Migratory, transboundary fish of unfavorable conservation status

Of approximately 15,000 species of freshwater fish, this analysis originally included 3,146 assessed by IUCN and 1,116 considered threatened (with an additional 102 extinct and 677 Near Threatened or Data Deficient). Of those 1,116 threatened species, 223 occur in more than one country, making them potential candidates for CMS listing depending on migratory status. Data from Fishbase identified approximately 1200 species of migratory freshwater fish, roughly 50% diadromous species and 50% potamodromous. Once the migratory species database was integrated with the Red List database, approximately 50 species met all criteria: migratory, transboundary freshwater fish unfavorable conservation status. Sturgeon and salmon were removed from the list, as was the Mekong giant catfish, *Pangasianodon gigas* (since it is already listed on Appendix I of CMS). An additional two species were subsequently added after the IUCN Red List was updated with over 3,000 newly reviewed assessments from Africa. After revisions, thirty-four (34) species meet all criteria. For each of these species, the author provides taxonomic information (order, family, genus, species), common name, migratory status, distribution, and IUCN Red List Status (Table 7).

An additional ca 10 species were identified as CMS migratory fish based on information from other sources including additional IUCN Red List assessments completed in 2010 and 2011, CMS scientific councillors, the Global Register of Migratory Species (GROMS), and published primary research. These species have been selected on the basis of their conservation status, management needs, and the potential for CMS to stimulate management that appears unlikely to occur otherwise. Rather than propose a large number of species for listing on CMS, a relatively small number of species and species groups have been identified that clearly meet the criteria for listing. These species and species groups can serve as a starting point to identify additional species that may qualify and would benefit from being included on CMS.

Table 7:

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Pristiformes	Pristidae	Anoxypristis cuspidata	Knifetooth sawfish	A	CR	A2bcd+3cd+ 4bcd	Australia, Bangladesh, China (jnc.Taiwan), India, Indonesia, Japan, Korea, Republic of; Malaysia, Myanmar, Oman, Pakistan, Papua New Guinea, Philippines, Singapore, Somalia, Sri Lanka, Thailand, Vietnam	A marine, euryhaline (moving between fresh and salt water) or marginal (brackish water) species found from inshore waters to a depth of 40 m. Though details of its ecology are not precisely known, it probably spends most of its time on or near the bottom in the shallow coastal waters and estuaries it inhabits. Populations are becoming increasingly rare and fragmented and all those known are severely threatened by target and bycatch fisheries and deterioration of habitats.
Pristiformes	Pristidae	Pristis microdon	Largetooth sawfish	A	CR	A2abcd+3cd +4bcd	Australia, Bangladesh, Cambodia, India, Indonesia, Malaysia, Mozambique, Myanmar, Papua New Guinea, Philippines, South Africa, Sri Lanka, Thailand	This species, like the largetooth sawfish of the Americas, occurs far up rivers and in freshwater lakes throughout its range. However, it no longer occurs in a number of freshwater habitats where it was formerly recorded. Freshwater records of Pristis microdon include rivers of South Africa, in the Shire, Zambezi, Sabie, and Lundi Rivers of Mozambique and Zimbabwe; Ganges and Bramaputra Rivers of India; possibly from the Chaophraya at Nantaburi above Paknam in Thailand; Perak, and possibly the Trembeling and Linggi Rivers in mainland Malaysia; the Kinabatangan and other large rivers in Sabah, Borneo; Grand Lac in Cambodia (Kampuchea); at Lake Naujan, Mindoro Island in the Philippines; Indragiri River near Rengat, Sumatra and Bandjermassing, Borneo in Indonesia; the Fly river system, Sepik and Laloki Rivers, and Lake Murray in Papua-New Guinea; Gilbert, Mitchell, Daly, Victoria, Ord, Fitzroy, Lynd, Walsh, Palmer, and Alligator Rivers, and Teogangini Creek in Australia
Pristiformes	Pristidae	Pristis pectinata	Smalltooth sawfish	A	CR	A2bcd+3cd+ 4bcd	Angola, Australia, Bangladesh, Belize, Benin, Brazil, Cameroon, Cape Verde, Colombia, Cuba, Dem. Rep. of the Congo, Congo, Cote d'Ivoire, Ecuador, (France Guyana, Réunion), Equatorial Guinea, French Guiana, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, India, Indonesia, Israel, Jamaica, Kenya, Lebanon, Liberia, Madagascar, Mauritania, Mauritius, Mexico, Morocco, Netherlands (Aruba, Curaçao), Mozambique, Myanmar, Namibia, Nicaragua, Nigeria, Oman, Pakistan, Peru, Philippines, Sao Tomé and Principe, Senegal, Sierra	Populations are becoming increasingly rare and fragmented and all those known are severely threatened by target and bycatch fisheries and deterioration of habitats. Many populations have been extirpated or nearly extirpated from large areas of their former range, with no or only very few observations reported in most range states since the 1960s, although they were reportedly common in many inshore waters at the end of the 19th century and early 20th century. Possibly originally the most widespread Pristis species, but populations highly disjunct. Possibly less well adapted to freshwater than members of the Pristis pristis complex. Western Atlantic: North Carolina USA, to the Gulf of Mexico and Brazil (reported as far north as New York USA and as far south as Uruguay and northern Argentina). Eastern

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
							Leone, Somalia, (Spain – Canary Islands), Sri Lanka, South Africa, Suriname, Syrian Arab Rep, Thailand, Trinidad & Tobago, United Rep. of Tanzania, Togo, United Kingdom (Bermuda, Gibraltar), USA, Venezuela, Western Sahara	Atlantic: Mediterranean Sea and southern Portugal (now extirpated), Morocco to southern Angola (possibly northern Namibia), including Cameroon.
Pristiformes	Pristidae	Pristis perotteti	Large-tooth sawfish	A	CR	A2abcd	USA (Texas (historically), Louisiana, and occasionally south Florida), Mexico, Belize, Guatemala, Honduras, Nicaragua, Costa Rica, Colombia, Venezuela, Caribbean Sea, Guyana, Suriname, French Guiana and Brazil. Eastern Atlantic: Historically reported from: Gibraltar, Spain, Morocco, Western Sahara, Mauritania, Senegal, Mali, Gambia, Guinea-Bissau, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Congo, Democratic Republic of Congo, Angola, and also possibly in the Mediterranean Sea. Present reported range: Senegal, Gambia, Sierra Leone, Liberia, Ivory Coast, Congo, Democratic Republic of Congo and Angola.	Large, previously widely distributed marine, estuarine and freshwater sawfish. It has been taken in (former) directed fisheries and is extremely vulnerable to bycatch in virtually all fisheries throughout its tropical Atlantic range. The relationship of this species, to a similar form that occurs in the tropical Eastern Pacific is uncertain, but is currently being investigated, and the present assessment relates only to the Atlantic form. The species has been extirpated from most of its former range and its population status is known to be critical especially in Lake Nicaragua, other Central/South American sites and in West Africa.
Pristiformes	Pristidae	Pristis pristis	Common sawfish	A	CR	A2abc+3cd	Angola, Australia, Benin, Cameroon, Cape Verde, Colombia, Congo, Dem Rep of, Congo, Costa Rica, Cote d'Ivoire, Ecuador, El Salvador, Equatorial Guinea, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea Bissau, Honduras, India?, Liberia, Mauritania, Mexico, Morocco, Nicaragua, Nigeria, Panama, Papua New Guinea, Sao Tomé and Principe, Senegal, Togo, Western Sahara. Extinct from?: (United Kingdom –Gibraltar) , Malta, Portugal (Madeira), Spain (Canary Islands).	A sketchily-known large sawfish of the Mediterranean (where it no longer occurs) and eastern Atlantic. It has been recorded from Portugal south to Angola and possibly to Namibia. Freshwater records of Common Sawfish are from Mali or Senegal in the Faleme River and possibly Gambia in the Gambia River.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Rajiformes	Dasyatidae	Dasyatis laosensis	Mekong stingray	P	EN	A1cde+2cde, B1+2ce	Lao PDR, Thailand	This species is uncommon throughout its range. Population decline has been observed (from occurrence in markets) for the past twenty years, and almost absent from markets in Thailand in the last ten years, though fishers in southern Lao PDR do not consider it to be especially rare (I. Baird pers. comm. 2011). Fish sellers report that a specimen has not been landed for several years in Thailand, and a population decline of 50% is inferred to have occurred over the last twenty years. This decline in numbers is estimated to continue in the future, and will be exacerbated by mainstream dam development on the Mekong mainstream and tributaries.
Rajiformes	Dasyatidae	Himantura chaophraya	Freshwater whipray	P	VU	A1bcde+2ce	Cambodia; India (Bihar - Presence Uncertain, Jharkand - Presence Uncertain, Uttar Pradesh - Presence Uncertain, West Bengal - Presence Uncertain); Indonesia (Jawa - Presence Uncertain, Kalimantan); Lao People's Democratic Republic; Malaysia (Sabah, Sarawak); Thailand; Viet Nam	The species is known from several disjunct freshwater localities in south and southeast Asia, from India to eastern Indonesia (Last et al. 2010), although the presence and taxonomic status of some of the reported populations requires confirmation. In Thailand it is known from the Chao Phraya, Nan, Mekong, Bangpakong (Bang Pakong), Tachin and Tapi (Tapee) rivers. It is recorded from the mainstream of the Mekong in Lao PDR, Viet Nam and Cambodia. It is possibly present as far upstream on the Mekong as Chiang Khong in northern Thailand, where unidentified stingrays have been seen (Z. Hogan, pers. comm.).Although the species is still harvested in significant numbers in many areas where it occurs, catch data and local knowledge indicates a significant decline over the past 20-30 years. Past and future harvest, habitat degradation, and future habitat modification due to dam building are likely to continue to negatively impact this large-bodied, long-lived species. Future threats to the species include the development of mainstream dams on the Mekong River. The species habitat and reproductive success would be greatly impacted if these dams were to be developed. Further research and survey is required to confirm the presence, population trend, and taxonomic status of populations of the species from all parts of its range, especially India, Bangladesh, Myanmar, Viet Nam, parts of Indonesia and Malaysia, and Papua New Guinea.
Rajiformes	Dasyatidae	Himantura fluviatilis	Ganges stingray	P	EN	A1cde+2cde, B1+2c	Bangladesh, India, Nepal	This species is mostly restricted to freshwater habitats in the Ganges river system, extending 1,000 miles (1,609 km) above the tidal reach and from several localities, however there are also marine records of the species in the Bay of Bengal and off Madras.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Clupeiformes	Clupeidae	Alosa immaculata	Pontic shad	P	VU	B2ab	Bulgaria, Georgia, Hungary, Moldova, Romania, Russian Federation, Serbia, Turkey, Ukraine	Impoundment of main rivers (all happened more than 10 years ago) has significantly reduced available spawning sites and migration routes. The current threat to the species is overfishing, at sea and in the rivers during the migration runs, which is causing a population decline of unknown levels. The area of the remaining spawning grounds is estimated to be less than 2,000 km² and based on the fishing in the lower courses of rivers during the migration runs, the species is found in six locations (Dneister, Dneiper, Danube, Kuban, Pivdenny Bug and Don).
Clupeiformes	Clupeidae	Alosa volgensis		ANA	EN	B2ab	Azerbaijan; Iran, Islamic Republic of; Kazakhstan; Russian Federation; Turkmenistan	The species is known from the Caspian Sea from where adults used to ascend rivers from the Terek to Ural to spawn. Since the 1960s canalization and channelization of the river mouths have destroyed spawning sites and migratory routes, in addition to those lost during the dam constructions in the 1950s and 1960s. Now the species is only known to ascend the Volga to spawn, where it is extremely rare (no statistics are available from commercial catches and it is rarely recorded from scientific surveys) and the spawnings are mostly unsuccessful (very few juveniles are recorded). The species' current status in the Ural is unknown. The area of the remaining spawning sites is estimated to be less than 500 km², and it is only just below the Volgograd dam (one location, possibly more if it spawns in the Ural). There is a continuing decline in the quality of these sites due to sedimentation from the dam and channelization and canalization of river mouths.
Anguilliformes	Anguillidae	*Anguilla anguilla*	European eel	C	CR	A2bd+4bd	Albania, Algeria, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Estonia, Faroe Islands, Finland, France, Georgia, Germany, Greece, Holy See (Vatican City State), Iceland, Ireland, , Israel, Italy, Latvia, Lebanon, Libya, Lithuania, Luxembourg, Monaco, Montenegro, Morocco, Netherlands, Norway, Palestinian Territory, Poland, Portugal, Romania, Republic of Moldova, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Syrian Arab Republic, the former Yugoslav Republic of Macedonia, Tunisia, Turkey, Ukraine, United Kingdom	Anguilla anguilla is found in all European rivers draining to the Mediterranean, North and Baltic seas, in the Atlantic south to Canary Islands and parts of Mediterranean north Africa and Asia. It very rarely enters the White and Barents seas, but is recorded eastward to the Pechora River in northwest Russia. The species occurs in low abundance in the Black Sea where it migrates east to the Kuban drainage (occasional individuals reach the Volga drainage through canals), in northern Scandinavia and eastern Europe, but 'trap-and-transport' stocking is interfering with natural population numbers (W. Dekker pers. comm. 2007). Large parts of the population remain at sea particularly in the north western Atlantic and Mediterranean. It is also widely stocked in most inland waters of Europe. The species is thought to breed in the Sargasso Sea in the West Central Atlantic, migrating across the Atlantic from Europe.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
							(inc. Gibraltar, Guernsey, Isle of Man and Jersey)	
Cypriniformes	Cyprinidae	*Aspiolucius esocinus*	Pike asp	P	VU	A1acde	Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan	
Salmoniformes	Salmonidae	*Trutta aralensis*	Aral trout	P	CR	A1ace	Kazakhstan, Tajikistan, Uzbekistan	Once occurred in the Aral Sea where it was extirpated, but still extant in the Amu Darya River.
Salmoniformes	Salmonidae	*Coregonus lavaretus*	Common whitefish	ANA	VU	D2	France, Switzerland	Abundant in Lake Bourget. In Lake Aiguebelette its population status is unknown. The species is extirpated in Lake Geneva (early 1900s), but as offspring of Lake Bourget population are hatched and reared in Thonon (on the shores of Lake Geneva), escapes should be expected.
Cypriniformes	Cyprinidae	*Cyprinus carpio carpio*	Common carp	P	VU	A2ce	Afghanistan, Armenia, Austria, Azerbaijan, Bulgaria, China, Croatia, Georgia, Germany, Hungary, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Romania, Republic of Moldova, Russian Federation, Serbia, Slovakia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan	The native populations (Black, Caspian and Aral Sea basins) are slowly but continuously declining due to river regulation. Adults often make considerable spawning migrations to suitable backwaters and flooded meadows.
Cypriniformes	Cyprinidae	*Gila elegans*	Bonytail	P	EN	B1+2ac	Mexico, United States	This fish species experienced the most abrupt decline of any of the long-lived fishes native to the main-stems of the Colorado River system and, because no young individuals have been found in recent years, has been called functionally extinct. Bonytail chubs were one of the first fish species to reflect the changes that occurred in the Colorado River basin after the construction of Hoover Dam; the fish was extirpated from the lower basin, including Mexico, between 1926 and 1950. (http://www.fws.gov/nevada/protected_species/fish/species/btail_chub.html)
Salmoniformes	Salmonidae	*Hucho hucho*	Huchen	P	EN	B2ab	Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Germany, Hungary, Montenegro, Poland, Romania, Serbia, Slovakia, Ukraine	Native only in the Danube drainage, where it has a very fragmented distribution. The species has undergone a massive decline starting over 100 years ago. Historically overfshing, pollution and dam construction caused the decline of the species. Currently the main the threats are hydropower stations which heavily regulate flow regime (which impacts upon their prey and habitat), and pollution in some countries.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Salmoniformes	Salmonidae	*Hucho perryi*	Japanese huchen	ANA	CR	A4abcd	Japan, Russia	The species is known to exhibit both freshwater and anadromous life histories. The species is long lived, slow growing and exhibits delayed age at maturity relative to other salmonids. The species spawns during the spring to early summer, depending on location within their natural range. Peak spawning occurs during May-June along the Sea of Japan coast, late June in Sakhalin, and mid-March to late April in eastern to northern Hokkaido. Anadromous life history forms are thought to reside in estuarine waters during the summer growing season, and overwinter in lower reaches of rivers beginning in mid-September to late October.
Cypriniformes	Cyprinidae	*Luciobarbus brachycephalus*	Aral barbel	P	VU	A2cd	Afghanistan, Armenia, Azerbaijan, China, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Russian Federation, Tajikistan, Turkmenistan, Uzbekistan	Aral basin (extirpated in the sea - due to salinity, only survives in the reservoirs of its tributaries), Chu drainage and southern and western Caspian Sea. For spawning, migrates up larger tributaries of western and southern coasts: Terek, Samur, Kura, lower Aras. Rarely in lower Volga (up to Volgograd) and Ural. Populations have declined sharply due to damming in the 1950's and 1960's in the Caspian Sea. In the Aral sea the species declined due to the shrinking (increased salinity) of the Aral sea (started in 1970s to present) and damming of its tributaries (1950's to 1970's).
Osteoglossiformes	Mormyridae	*Marcusenius victoriae*	Victoria stone-basher	P	EN	A2bcde	Kenya, Rwanda, Uganda, United Republic of Tanzania,	
Siluriformes	Bagridae	*Mystus bocourti*		P	VU		Cambodia, Lao PDR, Thailand, Vietnam	*M. bocourti* is a demersal and potamodromous species which occurs in medium to large-sized rivers. There are a number of large dams and other water diversion projects which are an additional threat to M. bocourti in both the Chao Phraya and Mekong basins; effects of developments such as these to the freshwater ecosystem include alterations to the hydrological cycle, and changes to the levels of sedimentation and dissolved o^2. Dams also act as a physical barrier, which is especially pertinent to M. bocourti, a potamodromous species. More dams are currently under construction and planned for the future.
Cypriniformes	Cyprinidae	*Opsaridium microcephalum*		P	VU	A2bcd	Malawi, Mozambique, United Republic of Tanzania	Adults are found in shallow water in the lake over sand habitats. Juveniles occur in streams and near river outlets in the lake. It feeds on small zooplanktivorous fish, which move in shoals along the shoreline. It migrates upstream into large rivers to spawn in the cool waters of mountain streams. It spawns in a gravel substratum, often in very shallow water.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Cypriniformes	Cyprinidae	*Opsaridium microlepis*	Lake salmon	P	EN	A2bcd	Malawi, Mozambique, United Republic of Tanzania	It migrates up rivers from the lake to spawn during the rainy season. Spawning mainly takes place at night and requires well-oxygenated flowing waters and silt free gravel. Spawning takes place in very shallow water and occurs over an extended period during and after the rains. Extremely high mortalities of adults during spawning runs due to total blocking of rivers with gill nets and weirs as well as drifting gillnets. This prevents upstream migration in low rainfall years.
Perciformes	Osphro-nemidae	*Osphronemus exodon*	Elephant ear gourami	P	VU	A2ce	Cambodia, Lao PDR, Thailand	*O. exodon* undertakes lateral migrations from the Mekong mainstream into floodplain areas during the flood season and returns to the Mekong River or other permanent water bodies during the dry season; these movements are triggered when water levels change. A major threat to species in the Mekong river is habitat degradation from the construction of dams and other water management projects. The effects of such projects include disruption to the natural flood/drought cycle of the river. Changes in river hydrology may have more of an effect on *O. exodon* than some other species as it is potamodromous, with migration into flood plain areas triggered by changes in the water level.
Perciformes	Gobiidae	*Pandaka pygmaea*	Dwarf pygmy goby	A	CR	A1ace	Indonesia, Philippines, Singapore	Species listed as amphidromous in Fishbase but unlikely that the species moves regularly across international borders.
Siluriformes	Pangasiidae	*Pangasianodon gigas*	Mekong giant catfish	P	CR	A4bcde	Cambodia, Laos, Thailand, Vietnam (possibly Myanmar and China)	The Mekong giant catfish is already listed on CMS Appendix I and II.
Siluriformes	Pangasiidae	*Pangasius sanitwongsei*	Giant pangasius	P	CR	A2acd	Cambodia, China, Lao PDR, Myanmar, Thailand, Vietnam	The giant pangasius catfish once occurred in both the Chao Phraya and Mekong rivers, but wild self-sustaining populations now appear limited to the Mekong. The giant pangasius catfish is a main river species. Adults seem to favor the deep pool areas of Chiang Saen, Chiang Khong, Loei, Xayaburi, Stung Treng, and Kratie while the young are widespread in the main channel especially along the Thai-Lao border and in Cambodia downstream of Kratie. Spawning occurs in April and May. Poulsen et al. (2004) reports that the population may be divided into two breeding groups, one distributed from Chau Doc, Vietnam to the Khone Falls in Laos and the other distributed along the Thai-Lao Mekong from Nakorn Phanom to Chiang Saen.
Acipen-seriformes	Polyo-dontidae	*Polyodon spathula*	Mississippi paddlefish	P	VU	A3de	Canada, United States	There have been no Canadian records since the early 1900s. Canada never was a significant part of the distribution.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Cypriniformes	Cyprinidae	*Probarbus jullieni*	Isok barb	P	EN	A1ac	Cambodia, Lao PDR, Malaysia, Thailand, Vietnam	Trophic migrations occurs throughout its occurrence range which takes place mainly at the onset of the flood season and are mainly undertaken by juveniles and subadults. Upstream spawning migrations take place between October and February from Kompong Cham in Cambodia to Chiang Khong in Thailand. At Chiang Khong , fishermen reported that Probarbus moves up the tributary Nam Ta in Laos to breed in March-April. May be caught individually or in small numbers of any size incidentally with gillnetting and other fishing activities, at virtually any time or place in the Mekong mainstream, but mostly caught during November-January spawning migration, when it is by far the most important species in fisheries catch. In the Mekong this important fisheries species is under serious long-term decline and this decline evidently is basin wide and the most obvious (but not necessarily only) reason is overfishing with gillnets during the reproductive migrations and spawning periods. (http://www.fishbase.org/summary/Probarbus-jullieni.html)
Cypriniformes	Cyprinidae	*Ptychocheilus lucius*	Colorado pikeminnow	P	VU	D2	Mexico, United States	Colorado River endemic. Restricted to large rivers of the Colorado River basin, formerly in the mainstream Colorado River and major tributaries (Gunnison, White, Yampa, Dolores, San Juan, Uncompahgre, Animas, and Green rivers) from Mexico and Arizona to Wyoming. Present distribution is drastically reduced from the original. By the mid-1980s it occurred only in the upper Colorado River basin of Colorado, Utah, New Mexico, and Wyoming; mainly in the Green River in Utah and in the Yampa and Colorado rivers in Colorado and portions of Utah; has not been seen below Glen Canyon Dam since 1968.
Perciformes	Gobiidae	*Silhouettea sibayi*	Barebreast goby	A	EN	B1ab+2ab	Mozambique, South Africa	Described from Lake Sibayi and Kosi Bay, northern KwaZulu-Natal. Recently recorded from the Maputo Special Reserve. Unclear whether or not species is migratory or stocks are transboundary.
Clupeiformes	Clupeidae	*Tenualosa thibaudeaui*	Laotian shad	P	EN	A1a	Cambodia; Lao PDR; Thailand; Vietnam	This species is endemic to the Mekong basin. It is strongly migratory, moving from the Tonle Sap Lake in Cambodia, and passes upstream through the Khone Falls in southern Lao PDR. Causes of this decline are overfishing and dam construction. The species is likely to be greatly impacted my mainstream dams on the Mekong if they were to be constructed.

Order	Family	Species	FishBase name	Migratory Status	IUCN Category	IUCN Assessment	Distribution	Notes (from IUCN 2010)
Characiformes	Alestidae	*Micralestes comoensis*		P	VU	B1ab+2ab;D 2	Burkina Faso, Côte d'Ivoire.	This migratory species is known from the upper Comoe in Côte d'Ivoire and Burkina Faso. Drought, pollution and deforestation threaten this species.
Cypriniformes	Cyprinidae	*Barbus liberiensis*		P	EN	B2ab	Liberia, Sierra Leone	This migratory species in only known from a few lakes and streams in Liberia and Sierra Leone. Due to the lack of detailed information about the distribution or ecology of the species, it is probably not a good candidate for listing at this time.

6 Additional species that may benefit from CMS listing

6.1 *Brycon orbignyanus* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

B. orbignyanus is a medium-sized, migratory characid. Historically, *B. orbignyanus* occurred throughout the La Plata River basin and, given the migratory nature of the fish and the transboundary nature of the La Plata system, some stocks were almost certainly shared by Uruguay, Argentina, Brazil, and Paraguay (Lopera-Borreo 2009). While *B. orbignyanus* has not been evaluated by IUCN, Carolsfeld et al. (2003) lists it as extirpated from the Upper Uruguay and threatened in the Lower Uruguay, the Upper Parana, and the Parana/Paraguay (Carolsfeld et al. 2003). The species was once common in the Parana but it is now very rare (Agostinho et al. 2003). Quiros (2003) reports sharp declines in abundance and disappearance from many from areas in the Parana where they were abundant during the pre-development period. Population decline has been attributed to removal of riparian vegetation and damming. Agostinho et al. (2003) states migratory neo-tropical species such as *B. orbignyanus* generally range widely and may undergo migrations of 1000 km or more. Dams have had a significant impact on B. orbignyanus, separating spawning grounds from nursery areas and feeding sites (Agostinho et al. 2003).

6.2 *Salminus brasiliensis* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

Salminus brasiliensis (family Characidae) is native to southern South America in the Paraná, Paraguay and Uruguay rivers (de la Plata River Basin). It is the largest characin of the Parana basin and a top predator. *S. brasiliensis* occurs throughout the Parana-Paraguay basin, many populations, especially in the lower basin, appear to have decreased significantly (Kawakami de Resende 2003). It is also rare in many tributaries of the Upper Parana including the Tiete, Paranapanema, Paranaiba, and Grande Rivers (Agostinho et al 2003). Quiros (2003) reports sharp decline of populations in many sections of the Parana, Paraguay, and Uruguay Rivers. *S. brasiliensis* make annual spawning migrations of up to 1,000 kilometers to reach spawning sites (Petrere 1985). One tagged fish migrated 1,440 km from the La Plata estuary to Posadas, Argentina (Sverlij and Espinach-Ros 1986). The species is listed as threatened by the Brazilian state of the Rio Grande do Sul due to habitat destruction, blockage of migratory routes by dams, and overfishing (Marques 2002).

6.3 *Piaractus mesopotamicus* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

P. mesopotamicus is a highly migratory species endemic to the La Plata drainage in Argentina, Bolivia, Brazil, Paraguay, Uruguay (Agostinho et al. 2003). Historically it was found throughout the entire system (Kawakami de Resende 2003). It has now disappeared from the La Plata River as well as the lower Parana. An important food fish, it is now considered overexploited in the Upper Paraguay and Upper Parana and is threatened below the confluence of the Parana and the Paraguay Rivers (Carolsfeld et al. 2003). *P. mesopotamicus* is one of many highly migratory freshwater fish of the La Plata that would benefit from an Appendix II CMS listing to stimulate international cooperative management.

6.4 *Pseudoplatystoma corruscans* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

Pseudoplatystoma corruscans has been extirpated from the Upper Uruguay, is overexploited in the Upper Paraguay, and is considered threatened in the Parana/Paraguay (Carolsfeld et al. 2003). In the Upper Parana, an area that has been significantly modified by dams, successful reproduction appears dependent on availability of spawning sites and nursery areas (Agostinho et al. 2003). Quiros (2003) reports “a noticeable decrease in the frequency of the top predators *Pseudoplatystoma fasciatum* and *Pseudoplatystoma corruscans* in landings from the lower middle Parana and Uruguay southwards to the Rio de La Plata. Kawakami de Resende (2003) notes that *P. corruscans* is becoming scarce in the La Plata River. *P. corruscans* is a migratory species (Bayley 1973, Lowe-McConnell 1986) that occurs in river basins that cross national boundaries, and as such, would benefit from international cooperative management (Kawakami de Resende 2003).

6.5 *Pseudoplatystoma fasciatum* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

P fasciatum has been extirpated from the Upper Uruguay, is overexploited in the Upper Paraguay, and is considered threatened in the Parana/Paraguay (Carolsfeld et al. 2003). Quiros (2003) reports "a noticeable decrease in the frequency of the top predators *P. fasciatum* and *P. corruscans* in landings from the lower middle Parana and Uruguay southwards to the Rio de La Plata. Agostinho et al. (2003) states migratory neo-tropical species generally range widely with spawning sites and growth areas up to 1000km or more apart….the most conspicuous impact dams have on migratory fish….is the separation of spawning grounds from nurseries and feeding sites".

6.6 *Zungaro jahu* (Distribution: Argentina, Bolivia, Brazil, Paraguay, Uruguay)

Z. jahu is one the largest freshwater fish in South America and the heaviest in the Parana River, growing to approximately 150 cm total length and 150 kg. Historically, catches in the Uruguay/Parana/Paraguay basin were dominated by large migratory fish like *Z. jahu* (Quiros 2003). Recently, it is reported as extinct from the Upper Uruguay, threatened in the Upper Paraguay, Upper Parana, and Parana/Paraguay (Carolsfeld et al. 2003). In the Upper Parana, populations have been drastically reduced, probably due to overfishing (Agostinho et al. 2003). Catches from Itaipu Reservoir have been decreasing since 1989 with fish mainly found in the fluvial zone and virtually absent from the lacustrine section (Agostinho et al. 2003). It has almost disappeared from the lower Parana and Uruguay Rivers and has not been seen in the La Plata River since the 1980's (Kawakami de Resende 2003). Quiros reports that "river regulation and basin development have led to some striking changes in fisheries in both the upper and the lower basin. The obligatory migratory fish abundance has sharply decreased in the upper basin and the size of potamodromous fish decreased appreciably in the remnant floodplains in the upper basin…fisheries retain several of their original characteristics in unregulated and less developed river reaches, although many changes are still evident. For these reaches, large potamodromous fish are still present in the catch and are highly preferred by fishers, but the abundance of large piscivores is lower". Fish size is also smaller in many reaches (Petrere et al. 2000; Quiros and Vidal 2000, Quiros 2003). While details of the specific migration patterns of *Z. jahu* are lacking, river flow seems to stimulate migration and spawning. More study is needed to identify critical spawning and nursery habitats (Agostinho et al. 2003).

6.7 *Brachyplatystoma rousseauxii* and *Brachyplatystoma vaillantii* (Bolivia, Brazil, Columbia, Ecuador, French Guiana, Peru, Venezuela)

Catfish of the genus Brachyplatystoma are widespread in South America, occurring most notably in the Amazon River Basin. They are highly migratory, large bodied catfish, and certain species, such as *B. rousseauxii* and *B. vaillantii* are believed to undertake the longest migrations of any freshwater fish (Barthem and Goulding 1997, Lucas and Baras 2001, Carolsfeld et al. 2003, Barthem and Goulding 2007, Vasquez et al. 2009). The Amazonian range of several species, particularly *B. rousseauxii* and *B. vaillantii* extends approximately 2,500,000 square kilometres and is believed to include portions of Brazil, Columbia, Peru, Bolivia, and possibly Ecuador (Barthem and Goulding 1997). Mature *B. rousseauxii* and *B. vaillantii* spawn in the Amazon along the Brazilian-Columbian-Peruvian border (Barthem and Goulding 1997, Barthem and Goulding 2007). Young fish are carried downstream to the Amazon estuary, which is believed to be a nursery ground (Barthem and Goulding 2007). Several other species of large catfish are believed to exhibit similar migratory behavior but more data is needed to confirm their movement patterns. *B. rousseauxii* and *B. vaillantii* are targeted – and some argue overexploited as part of a major international fishery (Barthem and Petrere 1995, Alonso 2002, Petrere et al., 2004, Batista et al., 2005; Garcia et al., 2009). Young fish face heavy fishing pressure in the Amazon estuary in Brazil - a nursery area for fish harvested in Bolivia, Columbia, Peru, and Ecuador – whereas adults in the Andean foothill region of the Amazon River Basin face threats not only from fishing, but also from dams, mining, and agriculture. Given the highly migratory nature of these species, and the threats they face, Barthem and Goulding (1997, 2007) and Carolsfeld et al. (2003) have called for international cooperation to aid with management. Vasquez et al. 2009 writes: "the exceptional life cycle of these species and of *B. rousseauxii* in particular, encompassing the entire length of the Amazon River, requires concerted conservation and management measures over the entire distribution area" which includes at least five

different countries (Bolivia, Brazil, Colombia, Ecuador and Peru) with contrasting fishing practices and regulations (Barthem and Goulding 1997, Petrere et al. 2004).

6.8 *Pangasius hypophthalmus* (Distribution: Cambodia, Lao PDR, Thailand, Vietnam)

The migratory catfish *P. hypophthalmus* is listed as Endangered by IUCN. The species has been nearly extirpated in the Chao Phraya River. In the Mekong River, populations of river catfish have declined significantly in the Thai and Laos Mekong. Cambodian fishers (age 40+, n=43) estimate that overall catch of *P. hypophthalmus* has declined by 68 per cent since 1980. Individually, many fishers report that catch per fisher has declined by as much as 99 per cent since 1980 from several tons per season to 10-100 kilograms per season (Hogan unpublished data). While adult fish are still present in the fishery, fishers have not caught the largest class of fish (35-80 kilograms) since 1972. Fishers in the Tonle Sap River report that catches of river catfish (*P. hypophthalmus*) have dropped by 90 per cent in the largest fishing lots of the Tonle Sap Lake – from about 100 MT 20 years ago to just 5 or even 1 MT today (Hogan unpublished data). *P. hypophthalmus* is thought to be highly migratory – adults move up the main Mekong River at the beginning of the rainy season to spawn and young fish drift downstream from spawning grounds to nursery sites (So *et al.* 2006). Stocks in the lower Mekong are shared by Cambodia and Vietnam and populations in the middle Mekong are shared by Lao PDR and Thailand (Poulsen and Joergensen 2000, Van Zalinge et al. 2002).

6.9 *Tor putitora* (Distribution: Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal, Pakistan, Sri Lanka, Thailand)

T. putitora is a large, migratory cyprinid. It reportedly reaches a maximum length of 270 cm and can weigh up to 80 kg (MacDonald 1948, Jayaram 2005). *T. putitora* occurs primarily in larger rivers, migrating to headwater creeks to spawn. Once spawning is over, they move downstream to feeding areas of larger rivers where they grow older and larger every year and continue to spawn (Malik and Negi 2007). IUCN reports "the species is under severe threat from overfishing, loss of habitat, decline in quality of habitat resulting in loss of breeding grounds, and from other anthropogenic effects that have directly resulted in declines in harvest in several locations. In addition, with several dams planned for construction in the future in the Himalayan region, they could have a more drastic effect on *T. putitora* populations blocking their migrations and affecting their breeding." *T. putitora* exists in transboundary stocks in most large rivers flowing out of the Himalayas including territory of Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal and Pakistan. *T. putitora* is an ideal candidate for an Appendix II listing to improve management throughout its range.

6.10 *Bagarius yarrelli* (Distribution: Bangladesh, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, Pakistan, Thailand, Vietnam)

B. yarrelli is a large, predatory catfish that is widespread in Asia. In India, it occurs in the Indus, Ganges, and Brahmaputra river basins (Froese and Pauly 2010). Based on available data, it appears that populations of the *B. yarrelli* in the Indus and Ganges drainages have declined significantly since 1980 (V. Badola, Otter Reserves, personal communication). Likewise, Sheikh et al. (1997) reported that abundance of large-sized *B. yarrelli* has declined dramatically in certain sections of Brahmaputra. In the early 1980's, Sheikh et al. (1997) found *B. yarrelli* weighing up to 300 kg, but by the early 1990's, the size of fish had decreased significantly due to increasing exploitation rates (Sheikh et al. 1997). Capture rates in the early 1990's were estimated at ten times the capture rates of the early 1980's, resulting in an increase in catch of juvenile fish (Sheikh et al. 1997). *B. yarrelli* is found mainly in rapids of the main Mekong River and its largest tributaries. It can attain sizes over 2 m and 100 kg in the Mekong River, but large adults are rare. *B. yarrelli* is threatened by over-harvest, habitat degradation, and water extraction (Sheikh et al. 1997). IUCN lists *B. yarrelli* as Near Threatened. In South Asia, *B. yarrelli* stocks are found in rivers shared by India, Nepal, Bhutan, Bangladesh and Pakistan. In Southeast Asia, the species is primarily found in the portion of the Mekong River shared by Thailand, Lao PDR and Cambodia.

6.11 *Hucho taimen* (Distribution: China, Kazakhstan, Mongolia, Russia)

H. taimen is a large, predatory salmonid native to the Caspian and Arctic drainages in Eurasia (Volga, Pachora, Yenisey, Lena) and the Pacific drainage in Mongolia, Russia, and China (Amur). *H. taimen* is listed as endangered (category 1) in the European part of Russia, endangered in China, and endangered in Mongolia (Ocock et al. 2006). Previously abundant in large areas of Russia, Mongolia, and China, *H. taimen* populations have declined significantly in most parts of the range. Large adult fish, in particular, are scarce. For example, 50 years ago on the lower Amur, 11 kg fish were commonplace whereas nowadays even a 5 kilogram fish might be considered a large catch. In western Russia, including the Volga and Pechora, *H. taimen* has disappeared from most reservoirs and dammed rivers where they once occurred. In Siberia, there are still some relatively healthy stocks but in many areas (Angara, Pyasina, Anabar, Olenyok, Vilyi, upper Aldan, Khroma) *H. taimen* has become rare due to over-fishing and habitat degradation. In Mongolia, fish have disappeared from rivers near town centers and downstream of mining areas. Healthy populations still occur in more remote areas but these populations are vulnerable as mining, overgrazing, and fishing become more common in Mongolia. In China, populations have declined significantly due to pollution and over-harvest. *H. taimen* occurs exclusively in freshwater, migrating in autumn and spring. Migration distances have not been well studied but long distance movements and home range shifts have been documented in Mongolia (Gilroy et al. 2010). *H. taimen* stocks are likely shared between Russia, China, and Mongolia and would benefit from a CMS Appendix II listing to improve monitoring and management.

6.12 Species assemblages that may benefit from CMS Listing

There are several species assemblages (groups of related migratory species) that would likely benefit from listing on CMS. These are groups of fish that contain many threatened species, occur in areas with many transboundary issues, or both. These groups include sturgeon, salmon (as previously mentioned), sawfish (Pristiformes), freshwater stingrays (Himantura spp.) anguillid eels (Anguillidae), shad (Alosinae), and large, migratory pimelodids and characids of South America, pangasiid catfish of Southeast Asia (most notably the Mekong River), mahseer (*Tor spp*. and related species), Alestiidae of the Lake Chad basin and cichlids of the East African Great Lakes.

7 Discussion

7.1 Options for management of transboundary freshwater fish

The importance of international agreements and cooperation is well recognized for marine species (Barston 1995, FAO 1995). Many marine species are migratory and cross international boundaries or enter the high seas. The need for similar agreements for freshwater species, while often no less important or urgent, has been slow to be recognized. This may be, at least in part, because management of inland waters (and freshwater biodiversity) has historically been viewed as a sovereign issue (Beard *et al.* 2008). Nonetheless, systems of transboundary governance and cooperation are urgently needed for many species where fish stocks migrate across an international border or fish stocks are shared in international inland waters (Valbo-Jorgenson et al. 2008). In such cases, migratory, freshwater fish are particularly susceptible to a wide range of threats: overfishing (which often occurs at rearing and spawning sites, as well as migration corridors), loss of habitat, loss of connectivity between critical habitats, and alteration of the river itself (e.g. water quantity, quality, flow, and temperature, etc.).

The IUCN Shark Specialist Group (2007) and Coates et al. (2000) provide excellent reviews of the management options for transboundary fish stocks, including options that exist for cooperation using international frameworks and agreements. Notably, the Convention on Migratory Species is the only global agreement specially designed to facilitate management and conservation of transboundary migratory species. While the importance of international cooperation to protect and manage transboundary species is widely accepted (Dillon and Wikramanayake 1997, Lorenz et al. 2001), CMS does face a number of limitations, particularly the lack of recognition in a number of important regions for migratory species (e.g. North America, Southeast Asia, Brazil, etc.). Nonetheless, non-CMS member countries can participate in regional agreements that are developed under the auspices of CMS and there

may also be opportunities for CMS to operate in collaboration with other international agreements, such as the Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the IUCN Red List Programme, regional river basin groups, such as the Mekong River Commission, and other international organizations like the Food and Agriculture Organization (FAO).

7.2 The Convention on Biological Diversity

The CBD was signed by 150 member countries at the Rio Summit in 1992 and is designed to promote sustainable development and protect biodiversity. As of 2011, 193 countries are party to the convention, and others, such as the United States, have signed the convention but not ratified it. The CBD makes specific reference to management of transboundary biodiversity, stating in Article 3 that parties "ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of their national jurisdiction". With regards to collaboration between CMS and CBD, Coates et al. (2000) states "the Secretariat of the CMS envisages a greater role of the Convention in co-operation and co-ordination with other related conventions, particularly the Convention on Biological Diversity (CBD)".

7.3 The Convention on International Trade in Endangered Species of Wild Fauna and Flora

CITES was signed by 80 parties in 1973 to protect wildlife against over-exploitation, and to prevent international trade from threatening biodiversity. As of 2011, 175 countries are party to the convention, a legally binding agreement that helps protect many transboundary species through reduction of overexploitation driven by international trade. In the case of freshwater fish, all CMS species are also listed on CITES, so this would appear to be an opportunity for collaboration to improve the management of the freshwater fish species. CITES has moved forward to promote regional agreements and activities aimed at improved management, control of illegal trade, and aquaculture of several sturgeon species (Valbo-Jorgensen et al. 2008). These agreements include:

Heilongjiang/Amur River: China-Russia Fishery Committee
Caspian Sea: Commission on Aquatic Bioresources of the Caspian Sea
NW Black Sea and Lower Danube: Meeting of the CITES Management Authorities of Countries of the Northwest Black Sea and Lower Danube River
Azov Sea: Ukrainian-Russian Sea of Azov Joint Fisheries Commission

7.4 The Mekong River Commission / the Mekong Agreement

Regional river basin agreements like the Mekong Agreement, and the supporting Mekong River Commission, are important tools for the management of transboundary rivers and lakes. Such agreements usually stipulate international cooperation, such as the Mekong Agreement which states "that Parties shall co-operate in all fields of sustainable development, utilization, management, and conservation of the water and related resources of the Mekong River Basin, in a manner to optimize the multiple use and mutual benefits of all riparians and to minimize the harmful effects that might results from natural occurrences and man-made activities" (Coates et al. 2000). Partnerships with regional river basin agreements, like the Mekong River Commission, can stimulate additional information gathering, research, and management efforts with relatively little expense.

7.5 The IUCN Red List Programme

The IUCN Red List Programme administers the IUCN Red List, one of the best sources of information on the global conservation status of freshwater fish. IUCN organizes workshops and expert input to evaluate the extinction risk of hundreds of species each year. These evaluations are relevant to CMS because they can be used as a starting point to identify species of unfavorable conservation status. IUCN also has access to a global network of fish experts. These experts have the most up to date information on the ecology and conservation status of freshwater fish species.

7.6 The FAO Code of Conduct for Responsible Fisheries

The FAO Code of Conduct for Responsible Fisheries deals mainly with good practice and policy development for freshwater and marine fisheries (FAO 1995). Many sections of the code are relevant to transboundary fish stocks and could be used as a framework by CMS parties to develop management guidelines for specific species, regions, and fisheries. The sections with transboundary implications include Article 6.12 and Article 7.1.3 among others.

Article 6.12 – "States should ... cooperate at sub-regional, regional and global levels ... to promote conservation and management, ensure responsible fishing and ensure effective conservation and protection of living aquatic resources throughout their range of distribution, taking into account the need for compatible measures in areas within and beyond national jurisdiction".

Article 7.1.3 – "For transboundary fish stocks, ... the States concerned ... should co-operate to ensure effective conservation and management of the resources. This should be achieved, where appropriate through the establishment of a bilateral, sub-regional or regional fisheries organization or arrangement".

8 Conclusions

While each case is unique, it is clear that the management/conservation status of many freshwater fish species - on every continent with transboundary rivers - could be improved through international cooperative efforts. Critically Endangered species, like migratory sawfish and the migratory catfish *P. sanitwongsei*, would benefit from an Appendix I listing that leads to the reduction of harvest. An Appendix II listing is perhaps more appropriate for widespread fisheries species like the migratory characids and catfish of South America. Rivers like La Plata and the Amazon in South America, and the Mekong in Southeast Asia, would also clearly benefit from more broad scale, guild or species group level management actions, since scientists from each region regularly call for increased international efforts to improve management of migratory stocks (Agostinho et al. 2007, Carolsfeld et al. 2003, Coates et al. 2000, Vasquez et al. 2009). In the Aral Sea Basin and Lake Chad basin, the deteriorating health of the ecosystem makes it imperative that any species level efforts are linked with efforts to improve the condition of the environment.

Partnerships with regional river basin agreements, like the Mekong River Commission in South East Asia, and global organizations such as CITES and IUCN may facilitate additional information gathering and management efforts with relatively little expense. In the case of the Mekong River Commission for example, a transboundary framework already exists for the sustainable management of the river, but little focus is placed on individual migratory species. Likewise, the IUCN Red List Programme holds workshops worldwide to assess the conservation status of freshwater fish, but IUCN does not necessarily have the resources to gather specific information on transboundary migrations. Using the IUCN expert network, and regular Red List workshops, it would probably be possible to gather the information needed for CMS listing. Such partnerships should be explored in addition to the formal CMS listing process.

This review also highlights the importance of several generic measures to improve the management and conservation status of migratory fish.

- Develop baseline information on current and historical abundance of migratory fish

  Current and historical abundance information is needed to determine conservation status and set management targets. Baseline information is critical to listing on the Convention of Migratory Species because without baseline information, it is very difficult to establish a management need. Collaboration with groups like IUCN is likely the most efficient way to obtain this information because they are already collecting similar data.

- Improve knowledge of migratory fish ecology

  Knowledge of migratory fish ecology is needed to understand and predict how activities such as harvest, dams, and habitat degradation impact fish stocks. Data on freshwater fish migrations is sorely lacking and it cannot be emphasized enough that the migratory species identified in this report is not comprehensive. Rather, it focuses on species where information exists to make an assessment of whether or not the species meets the criteria for CMS listing.

- Address problems created by damming

  Dams fragment fish habitat, alter flows, disrupt spawning cues, block spawning migrations, and slow downstream dispersal. In areas where dams have already been built, populations of many migratory species have declined or been extirpated. In regions now considering building additional dams, such development will likely disrupt the life cycle of migratory fish. There is an urgent need to address the problems created by dams, by either restoring river processes that have been disrupted by existing dams or planning future constructions to minimize impact. The maintenance of environmental flows is essential for biodiversity protection (Postel and Richter 2003).

- Reduce habitat degradation, including pollution

  In the case of transboundary migratory species, habitat degradation in one area (e.g. a nursery ground or spawning site) can have international ramifications. Activities designed to control land-based pollution, prevent of deforestation, prevent degradation of wetlands, reduce fish overexploitation, and control spread of invasive species will improve ecosystem health in transboundary water bodies.

- Initiate transboundary monitoring and management programs in partnership with other management frameworks, including regional migratory fish workshops and data sharing

  Proper management of transboundary fish stocks requires international cooperative management because the actions of one country can impact fish stocks in another. Likewise, data on fish stocks and fish ecology from one country may aid in migratory fish management and conservation in another country. CMS is one framework that is designed to facilitate such exchange.

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