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WG 8 – Fishes
CASE STUDY 1
Arapaima spp
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ASSESSING CITES NON-DETRIMENT FINDINGS PROCEDURES FOR *ARAPAIMA* IN BRAZIL

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I. Background information on the taxa

1. BIOLOGICAL DATA

1.1 Scientific and common names

1.2 Distribution

The current ignorance on the taxonomy of arapaima undermines NDF determinations. A recent taxonomic analysis by Stewart and Watson (In Review) shows that *Arapaima gigas*—which should be studied here—has not been found in the wild; instead other *Arapaima* species have been found, including undescribed ones. Today we do not know if A. gigas is extant or extinct simply because there are few or no recent collections from key areas. Stewart and Watson's study was based on comparisons of all extant type materials, available non-type materials in several museums, and detailed observations on reference populations in Mamirauá Reserve, Brazil, and the Essequibo River basin, Guyana (Figure 1). Stewart and Watson (In Review) found that all four species recognized by Valenciennes in 1847 (in Cuvier & Valenciennes 1847) are valid (Figure 2). Valenciennes (in Cuvier & Valenciennes 1847) re-described *A. gigas* and described three new species (*A. mapae, A. agassizii* and *A. arapaima*). Subsequently, Günther (1868) put the latter three species in synonymy of *A. gigas* without

presenting any analysis, and his unstudied opinion remains the sole basis for conventional wisdom that *Arapaima* is a monotypic genus. Hrbek *et al*. (2007; 2005) studied variation in DNA for *Arapaima* in seven locations in the Amazon including the Mamirauá Reserve, and inferred that their samples came from a single, panmictic population. However, the results of Hrbek *et al*. cannot refute Valenciennes' four-species hypothesis because they did not do a taxonomic analysis (i.e., they did not examine type materials or morphology of sampled specimens). Furthermore, no voucher specimens were preserved, so a retrospective taxonomic analysis is not possible.

Stewart and Watson (In Review) also found that only one of the four arapaima species was represented in museums by materials collected after the original description. *A. arapaima* have been found at three localities in the central and lower Amazon (Figure 1), but *A. gigas, A. mapae*, and *A. agassizii* still are known only from their holotypes. The taxonomy of *Arapaima* is unknown even in areas where Arapaima have been most studied, such as the Mamirauá Reserve (Figure 1); there an undescribed species has been found (D.J.S., personal observations).

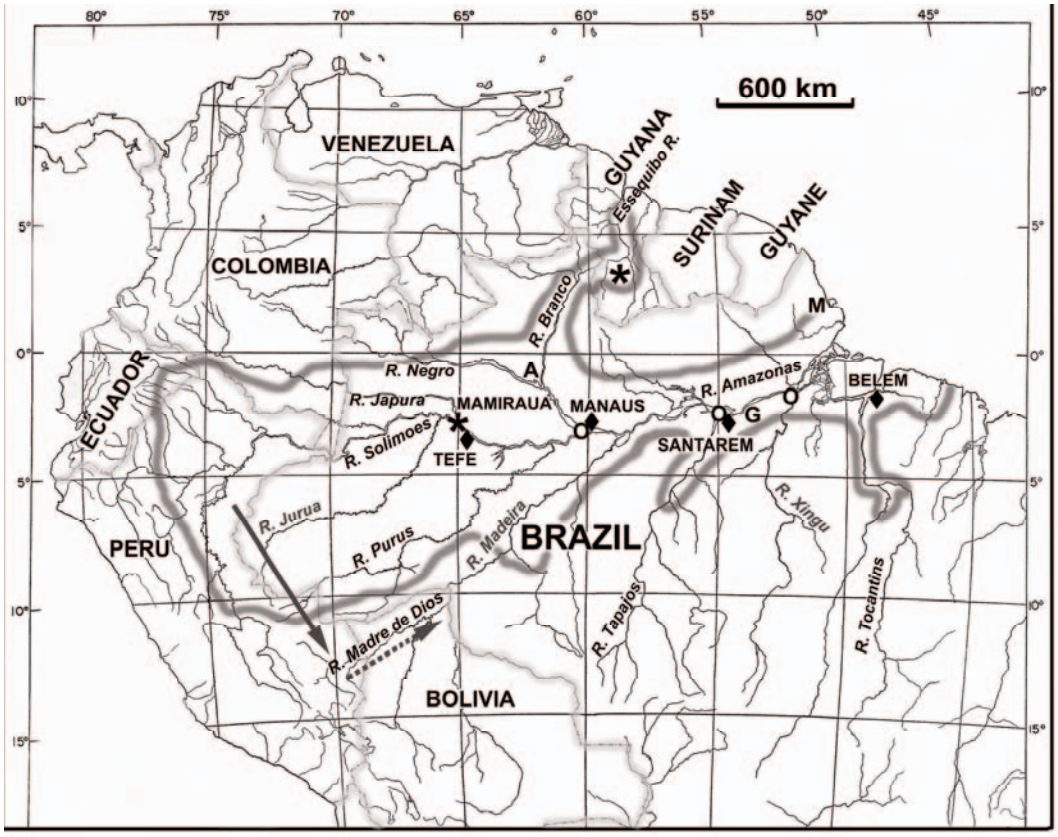

Figure 1. Geographic distribution of the genus Arapaima in northern South America (dark grey boundary). Suspected type localities for three nominal species (i.e., a best guess based on historical information) are marked as follows: A = *A. arapaima*; G = *A. gigas*; and M = *A. mapae*. Open circles mark localities for non-type museum specimens of *A. arapaima* that D.J.S. has studied; stars mark two reference areas where arapaima populations recently have been studied in detail. International boundaries are shown as light grey bands, and diamonds mark cities mentioned in the text. The solid arrow indicates a translocation of cultured arapaima to southern Peru, and dashed arrow indicates subsequent downstream spread of breeding populations into Bolivia. The distribution boundary line represents a synthesis of published accounts, museum records, personal communications from various colleagues and, where data otherwise were lacking, a search for suitable lagoon habitats below physical barriers using Google Earth.

The following is a synopsis of the described species and what little is known about their distributions; a few diagnostic features are indicated in Figure 2.

- *Arapaima gigas* (Schinz, in Cuvier 1822); common names: arapaima (English), pirarucu (Portuguese), paiche (Spanish). Known only from the holotype (MHNH a-8837, 203 cm SL, dried and stuffed mount in Paris); type locality is unknown, but presumably it was collected in the lower Amazon near Santarem, Brazil (Figure 1), in about 1787 (Valenciennes, in Cuvier & Valenciennes 1847; Ferreira 1903).
- *Arapaima mapae* (Valenciennes, in Cuvier & Valenciennes 1847); no common name. Known only from the holotype (MHNH a-8836, 203 cm SL, dried and stuffed mount in Paris); type locality is uncertain, but we think it may have been collected in Lago Amapá in Amapá State, Brazil, in about 1837 (Figure 1).
- *Arapaima agassizii* (Valenciennes, in Cuvier & Valenciennes 1847); no common name. Today, known only from detailed osteological drawings of the holotype (which was destroyed during World War II, Kottelat 1988). This species was collected by J. B. Spix between 1817 and 1820 in the Brazilian Amazon, but no precise locality was reported (Spix & Agassiz 1829-31).
- *Arapaima arapaima* (Valenciennes, in Cuvier & Valenciennes 1847); no common name. Originally described based on three syntypes, but one of those now is lost and another is an incomplete skeleton. There is only one extant, intact syntype, and that can provide a basis for stabilizing the nomenclature (i.e., MNHN b-2202, 59.0 cm SL, alcohol specimen in Paris, collected by 'Schomburgk'). Type locality for the Paris specimen is uncertain, but we suspect it came from the Negro/Branco basin because many of Schomburgk's collections stem from there (Kullander & Stawikowski 1997), and *A. arapaima* has

been found in the central and lower Amazon (Figure 1). So far, we have not found this species in the Essequibo basin. Present conservation status of *A. arapaima* is unknown because the most recently collected specimen is from 1909 (Stewart and Watson, In Review).

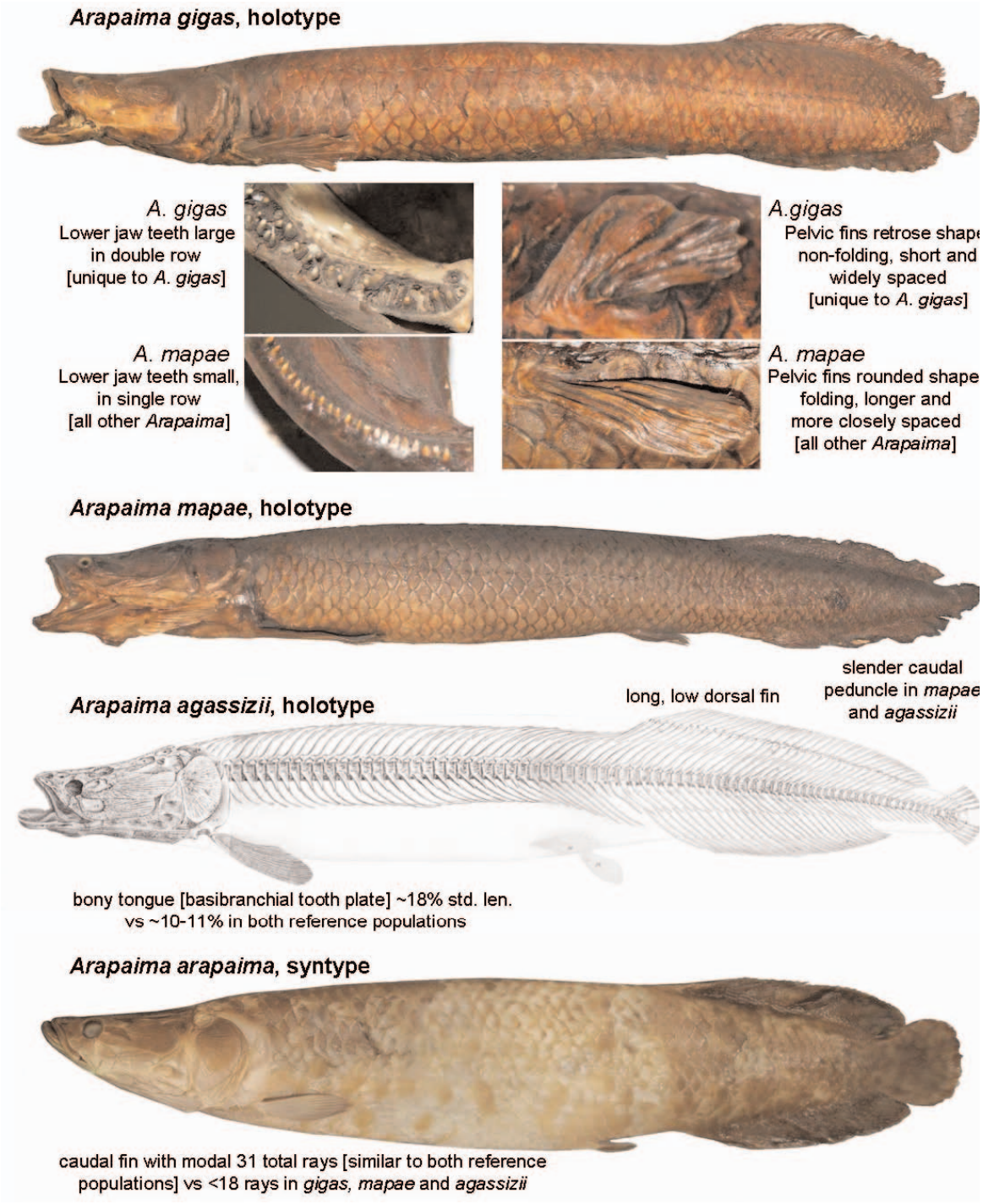

Figure 2. Comparison of type specimens of the four species of *Arapaima* described by Valenciennes (in Cuvier and Valenciennes 1847). Selected diagnostic characters are indicated; they are either features unique to a particular species or are statistical outliers ($p < 0.05$) when compared to samples from reference populations in Guyana and/or Brazil (Stewart and Watson, In Review). There are many more diagnostic characters for each species, but it is not feasible to present all details here.

1.3 Biological characteristics

1.3.1 *General biological and life history characteristics of the species*

The majority of the existing information of the biological and life history characteristics of arapaima stem from one area no greater than 1,000 km^2, the Mamirauá Reserve, which represents less than 1% of the total distribution of the species (Figure 1). The arapaima are characterized as being "sedentary", which means that they do not conduct long migrations (Isaac *et al*. 1993). Instead, arapaima seasonally make complex lateral migrations among all eight habitats of the Amazon River floodplains. The following summary of migratory and reproductive activities is based on Castello (2008a; 2008b) unless referenced otherwise. Most arapaima inhabit lakes but also can be found in rivers and connecting channels during low water levels, roughly from September to January every year. At that time, the adults form pairs, and the peak of the reproductive activities appear to be from December to May every year (Queiroz 2000). In Mamirauá, there is a one-to-one sex ratio, and female arapaima mature sexually at about 1.68 m in total length (Queiroz 2000). Both sexes of adult arapaima collaborate to build their nest in the margins and banks of lakes, temporary lakes, and connecting channels during rising water levels (Queiroz 2000). They take from 3 to 5 days to build their nests, spawn immediately after the nests are ready, and the young hatch from 3 to 5 days after the adults spawn (Fontanele 1948). After the larvae hatch, most females leave (personal observations), and some may reproduce again in the same season (Queiroz 2000). The males protect the young by staying very close to them, usually no farther than 1 m away. The males protect and guide the young by swimming slowly through the food-rich environments of flooded forest during the following weeks. The arapaima and young migrate to increasingly higher habitats in flooded forests and remain there during high water levels. The male arapaima care for their young for about 3 to 4 months (Isaac et al. 1993). As water levels decline, adult arapaima separate from their young, and they all migrate back to lower habitats of flooded forests. With further decline in water levels, they migrate to connecting channels and lakes.

Existing data on fecundity and fertility of arapaima (Lowe-McConnell 1964; Lüling 1964; Neves 1995; Queiroz 2000) are unclear for purposes of understanding the regenerative capacity of wild populations. However, protecting the reproduction of arapaima is key to sustainable harvesting. The arapaima are very vulnerable when they are engaged in reproductive activities because the male will not escape in the presence of fishing (Castello 2008b). Furthermore, the spawning habitats of arapaima are easily accessible to people as they build their nests along the aquatic pathways fishers use to move within and between their communities (Castello 2008b). The arapaima build most of their nests on forested levees in locations that are shallow (i.e., 1-2 m deep) and sandy at the margins of the forests surrounding temporary or permanent lakes and their immediate connecting channels (Castello 2008b). The nests of arapaima are cooking-pan like holes in the substrata, measuring about 57 cm in diameter and 16 cm deep (Castello 2008b).

When the reproductive activities of arapaima are protected, their populations show great growth potential (Castello *et al*. In Review-a). Populations of arapaima have increased rapidly at the Mamirauá Reserve where fishing targets only adult individuals and is not done during the reproductive season. For the case of one population that has been monitored for nine years now, total number of individuals more than 1 m long has increased from about 2,350 in 1999 to 20,650 in 2006 (Castello *et al*. In Review-a). Similar trends have been observed in other managed populations at the Mamirauá Reserve (Arantes *et al*. 2006).

The arapaima are relatively long-lived fish of fast body growth. Arapaima will grow to 70-100 cm in length and about 10 kg in weight in their first year of life, and about 160 cm and 45 kg in 3-4 years (Arantes *et al*. In Review). In Mamirauá, arapaima as old as 10 years have been recorded (Queiroz 2000), and total lengths of up to 285 cm (L.C., personal observations). However, body growth and population growth rates appear to depend on harvesting regimes. A recent analysis suggested that fishing selectivity (which generally selects fast-growing individuals of any given age class) could significantly lower average body growth rates of heavily exploited populations, decreasing mean length-at-age by an average of 27 cm and, hence, delaying age-at-first reproduction by one year (Castello *et al*. In Review-a).

1.3.2 *Habitat types*

Habitats occupied by arapaima appear to include most low-gradient (i.e., lowland) aquatic ecosystems of the Amazon and Essequibo basins, including (flooded) forests, rivers, and lakes. They have also

been found in small, coastal drainages both north and south of the Amazon delta (Figure 1). Their distribution encompasses both rainforest and savannah habitats, and waters that may be clear, black or white/muddy. The arapaima perform seasonal migrations among all habitats of the várzea floodplains, and that is evidence that they have great capacity to exploit the temporal and spatial heterogeneity of that ecosystem (Castello 2008a). Furthermore, commercially viable populations of arapaima thrive in degraded floodplains such as those found in the Lower Amazon (McGrath *et al*. 1993), and that indicates capacity to adapt to habitat/environmental changes.

However, arapaima appear to be poor swimmers, at least in comparison to other fishes known to be long-distance migrants in the Amazon. Arapaima are absent upstream of most rapids and waterfalls, and observations at Mamirauá revealed a strong preference for quiet or slow-moving waters (Castello 2008a). As a general rule, arapaima occur in all large tributaries of the Amazon basin up to the first major rapids or waterfall, but presence of accessible lake habitats also seems to be critical for their occurrence (D.J.S., personal observations in Ecuador). The Tocantins basin is an exception where apparently they occur upsteam of natural barriers in the lower basin.

1.3.3 *Role of the species in the ecosystem*

The arapaima are large-bodied predators, so they probably help regulate the stability of their ecosystems. However, there are no studies on the ecosystem roles of the arapaima, and there are probably very few areas where present populations attain maximum possible densities. The arapaima are primarily piscivorous, and their prey are generally abundant, small-bodied detritivorous and omnivorous fishes (Queiroz 2000; Sánchez 1969). Their guts, however, are about 1.8 times body length, suggesting omnivory, and it is not unusual to find plant materials in the stomach along with ingested fishes (D.J.S., personal observations).

1.4 Population:

1.4.1 *Global population size*

Unfortunately, we believe that presently it is impossible to estimate the size of the population of arapaima in its entire range, even through educated guesses. Hrbek *et al*. (2005) estimated through genetic analysis that the total population of arapaima in an area greater than 100,000 km^2 in the Amazon basin was around 150,000 individuals. However, we believe such an estimate is unrealistically low because censuses made in the Mamirauá Reserve in the State of

Amazonas, Brazil, show that there are well-managed arapaima populations with over 50,000 individuals in areas of less than 1,000 km^2 (Arantes *et al*. 2006). Population census data from managed and unmanaged areas also show that population densities vary greatly depending on management success, from 0 to 200 individuals per ha (L.C., unpublished data). Thus, extrapolation of those population census data to larger areas is not likely to provide a reliable estimate of overall abundance. An approach to lower uncertainties about global population sizes could be extrapolating based on the characteristics of the areas across the species range: areas managed vs. un-managed; levels of fishing intensity; proximity to urban centers, etc. A similar procedure was adopted for the Napoleon fish in Indonesia with some interesting results.

1.4.2 *Current global population trends*

___increasing _X_ decreasing ____stable ____unknown

Global population trends of arapaima likely are decreasing in the Amazon basin. There are no time-series data on population indexes such as catch or catch per unit of effort for the arapaima. The most complete and long time-series data available for the arapaima are weight data of sun-dried, boneless fillets landed in Manaus, the largest city of the Amazon. Such time series data show the scarcity of data on arapaima (Figure 3). However, recent data from the 1990's on catch structure in localities in the Central and Lower Amazon regions (in Mamirauá and Santarém, respectively; Figure 1) show predominance of juveniles, a common sign of resource overexploitation (Figure 3). Moreover, there have been no significant changes in the last few decades with respect to the principal causes of overfishing of arapaima, such as lack of compliance with management regulations and increasing demand for fish brought about by human population growth. So, there is no reason to believe that there has been reversal of the historical trend of decline (Figure 3). In the 1800's and early 1900's, arapaima were the most important fishery of the Amazon (Veríssimo 1895), but arapaima landings and the average size of captured individuals started to decrease drastically by the 1950s (Isaac et al. 1993). Today, the scarce data available indicate the arapaima are overfished in most of the Amazon, and may be threatened with extirpation in some regions (Goulding 1980; Isaac *et al*. 1993; Isaac et al. 1998). Arapaima landings now rarely are accounted for in landing statistics because most of the catch is illegal or severely reduced.

In the Essequibo River basin of Guyana, heavy over-exploitation between about 1970 and 2000 nearly extirpated arapaima. A popula-

tion census in early 2001 revealed only about 450 individuals over 1 m in length, and half of those were immature (Castello 2001b). Conservation efforts since then have led to slow but seemingly steady increases, but much of the recovery has been in protected or remote areas, while areas accessible by road have had little or no recovery (D.J.S., personal observations).

1.5 Conservation status

1.5.1 *Global conservation status* (according to IUCN Red List)

___Critically endangered ___Near Threatened
___Endangered ___Least concern
___Vulnerable _X_Data deficient

Arapaima were listed in the IUCN Red List as 'vulnerable' in 1986 and 1988, and then as 'insufficiently known' in 1990 and 1994 (World Conservation Monitoring Centre 1996). The Red List criteria and category today is "data deficient", which means that "there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status" (World Conservation Monitoring Centre 1996).

1.5.2 *National conservation status for the case study country*

There are no published documents on the conservation status of arapaima in Brazil. The recently developed list of national threatened species in Brazil does not list arapaima (http://www.mma.gov.br/port/sbf/fauna/index.cfm). However, it is routinely stated that arapaima are threatened with extinction. There certainly is reason for concern as in the last 12 years three states in Brazil have banned arapaima fishing due to suspicion of (severe) overexploitation (see below).

1.5.3 *Main threats within the case study country*

___No Threats
___Habitat Loss/Degradation (human induced)
___Invasive alien species (directly affecting the species)
_X_Harvesting [hunting/gathering]
___Accidental mortality (e.g. Bycatch)
___Persecution (e.g. Pest control)
___Pollution (affecting habitat and/or species)
_X_Other __Translocation of specimens threatens to homogenize genetic pool
___Unknown

The principal threat to the conservation of arapaima is overfishing. Habitat loss and degradation and by-catch (e.g., especially of juveniles in gillnets) probably also are issues of concern, but no information exists on their possible impacts. Translocation of specimens, sometimes over several hundred kilometers, is routinely done by aquaculture enterprises, and it threatens to homogenize the genetic pool and even extirpate locally adapted races or species. The magnitude of annual translocations of arapaima in Brazil is unknown but likely to be significant. For example, alevines of arapaima collected in the wild for just one aquaculture enterprise in the State of Amazonas numbered more than 200,000 annually (L.C., personal observations). Elsewhere, arapaima have been introduced above the water falls and rapids of the Madeira River in Peru (by Peruvian authorities), and now are dispersing downriver and colonizing in Bolivia (Castello 2001a).

2. SPECIES MANAGEMENT WITHIN THE COUNTRY FOR WHICH CASE STUDY IS BEING PRESENTED.

2.1 Management measures

Government attempts to manage the arapaima fishery in the Brazilian Amazon have been largely ineffective. The regional environmental agency (IBAMA) implemented a minimum length of catch (1.5 m) in 1986 (Portaria nº 14-N, de 15 de fevereiro de 1993) and a closed season (December-May) in 1991 (Portaria Normativa no 489 de 05 de Março de 1991). IBAMA also banned the arapaima fishery in the State of Tocantins in 1990 (Portaria Normativa de 23 de Março de 1990), in the State of Amazonas in 1996, and in the State of Acre in 2008. There are other relevant regulations of the arapaima fishery in Brazil, but they do not differ substantially from these because they tend to address regional peculiarities.

However, illegal fishing of arapaima is so widespread that most arapaima now probably are caught and traded illegally. Enforcement of the above management regulations is extremely poor because IBAMA lacks human and economic resources to do it effectively (Bayley & Petrere Jr. 1989). The field office of IBAMA in Tefé (Figure 1), for example, is staffed by just eight agents, is responsible for an area of 251,000 km^2 (about the size of Italy), and did not even possess a boat until 1999 in a region where all surface transportation is by boat (Crampton *et al*. 2004).

A new management regulation implemented in 2004 in the State of Amazonas promoted a potentially promising strategy of management for arapaima. That regulation exempted the existing ban by allowing fishers to harvest fishing quotas of arapaima provided they con-

duct population censuses. The idea of managing arapaima like this originated in the Mamirauá Reserve. Previous work done there showed that expert fishers can assess accurately the populations of arapaima by counting individuals at the moment of aerial breathing (Castello 2004). Accuracy of the counts was assessed through direct comparison with mark-recapture and total catches. The counts of arapaima made by the fishers are used in a management system whereby every year local fishers assess the population of arapaima and, in collaboration with the Mamirauá Institute and government, use the data to determine fishing quotas for the next year (Viana *et al*. 2004). Fishing quotas have been determined to this date based on trial-and-error and educated guesses (based on estimates of sustainable production of arapaima in Peru; Viana *et al*. 2004), as more detailed information on sustainable harvests of arapaima still is being investigated. Most fishing quotas determined have used a rule of thumb of harvesting between 20 and 30% of the number of adult arapaima counted in the managed area in the previous year (Castello *et al*. In Review-a), and this rate previously has been shown to be close to sustainable (Gulland 1977). Nine years of experimentation with this management system have shown that, where this management model was implemented, fishers' profits more than doubled, arapaima populations recovered rapidly, and fishers engaged in the process (Castello *et al*. In Press; Viana et al. 2004). Incorporation of that management system into regional legislation in 2004 was followed by rapid dissemination. Whereas in 1999, only four riverside communities used it to manage arapaima, today more than 100 communities in the State of Amazonas are using it (including two regional cities). Regulations similar to this now have been established in the State of Acre in 2008, as well as in Guyana in 2007. If one or more additional states adopt this management system in Brazil, it could become the dominant form of management.

However, that "count before you catch" management system lacks consideration of the accuracy of the counts and sustainability of the populations. The only existing regulation requires that fishers have data on counts of the arapaima population from which a harvest quota will be set. Consequently, a recent analysis found no evidence of resource conservation in the more than 100 communities in the State of Amazonas where it was implemented (Castello et al. In Press). That does not mean the management system is ineffective. There is evidence of successful management of arapaima in the Mamirauá Reserve (Castello et al. In Press). Rather, it means that now it is impossible to determine if that management system is effectively conserving wild populations of arapaima in the whole state of Amazonas. The main

problem is lack of data on accuracy of the counts, fishers' behavior, and impact of fishing quotas on arapaima populations (Castello *et al*. In Review-b).

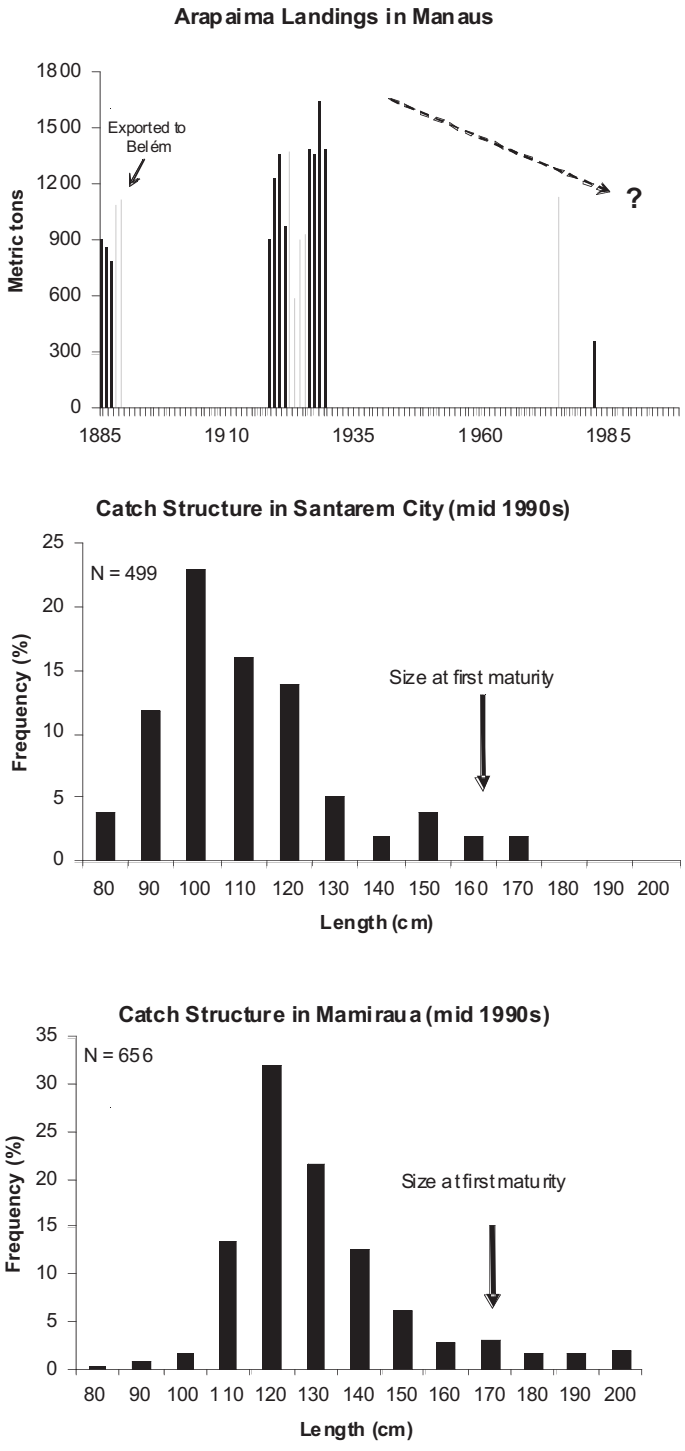

Figure 3. Main data available on landings and catch structure of arapaima in Brazil. The top panel summarizes existing data on landings of arapaima in Manaus (see map, Figure 1). Data for years between 1889-1893 are from Veríssimo (1895) and refer to total exports from the rural areas of the State of Amazonas, where Manaus is located, to the city of Belem (Figure 1). Data for the 1930s are from Pereira (1954) and for 1979 and 1986 are from SUDEPE summarized by Isaac et al. (1993). The middle and bottom panels present catch structure of arapaima at the Mamirauá Reserve and Santarém (Figure 1). Data for Mamirauá are from Castello et al. (In Review-a); data for Santarém are estimated from analysis of dried tongue bones (Martinelli & Petrere (1999). The size at first maturity indicated is from Queiroz (2000) and is consistent with more recent data (Arantes *et al*. In Review).

2.2 Monitoring system

Lack of information on population levels and associated harvest has been a major issue impeding sustainable management of arapaima (Castello 2004). Conventional mark-recapture methods are prohibitively difficult due to the costs, labor, and the enormous geographic areas involved, and monitoring of landings is practically impossible because of the decentralized and illegal nature of the trade (Bayley & Petrere Jr. 1989). In many instances, reported landings can be as little as one-fifth of the actual arapaima catch. Effective monitoring of the catch can be done in riverside communities, but it requires much effort in developing trust with fishers. So, relatively reliable catch data such as those presented in Figure 3 are very rare. Those two figures include all published data on catch structure of arapaima to date, and the Santarém data were reconstructed from dried tongue bones, not actual measurements of fishes. Now, with inclusion of counts of arapaima made by local fishers into regional legislation, it could be possible to collect data on wild populations in large areas, but further progress on that front still is needed.

3. UTILIZATION AND TRADE FOR RANGE STATE FOR WHICH CASE STUDY IS BEING PRESENTED.

3.1 **Type of use** (origin) **and destinations** (purposes)

The overwhelming majority of arapaima trade involves harvest of wild populations in rural areas by local fishers and commercialization with middlemen, who transport them to urban centers for human consumption inside Brazil. The arapaima are key fishery resources for human consumption for two reasons. They are large and air-breathing, so fishers can visually select large individuals and each individual contributes much to the catch in weight. An arapaima at the minimum length limit of 1.5 m weighs about 45 kg (Arantes et al. In Review). Another reason is that, unlike most fishes, 56% of their body weight is meat (Bard & Imbiriba 1986) that can extracted in the form of (generally) one single boneless fillet, that is either iced or salt-dried by the fishers themselves for commercialization. Other uses of arapaima exist and include commercialization of the following (roughly in order of importance; Table 1): scales for handicrafts and nail files, tongue bones for grating *guaraná* seeds, and skin for leather production. All other bony parts of arapaima (i.e., head and skeleton) sometimes also are commercialized for human consumption. More recently, a few sport fishing businesses have been established, but the impact of these probably is insignificant compared to that of commercial fishing because most sport-fishing enterprises practice catch and release.

3.2 Harvest

Increasing numbers of (sometimes large) aquaculture enterprises have been established "promising to save the species from extinction", and they may represent a significant source of wild harvests of arapaima. This issue is of concern because the technology for breeding arapaima in captivity is poorly known, making most of the existing aquaculture enterprises dependent on continuous collection of wild specimens. There are a handful of enterprises that do breed arapaima, but that breeding is unpredictable (i.e., it occurs but technicians involved cannot routinely replicate it). Legal permits are required to harvest the young from the wild and transport them to aquaculture facilities, but data on such harvests and translocations are not available. Arapaima are suitable for aquaculture because they grow fast (but only on a fish-based diet) and tolerate poor water quality (e.g., anoxia). Cultured arapaima now are routinely commercialized in most large urban centers in the Amazon. However, data on total trade of cultured arapaima also are missing. Small numbers of cultured arapaima also are exported as aquarium fishes, perhaps mostly for exhibition in large public aquaria.

Most harvesting of wild arapaima for consumption is done during the dry season between roughly September and January every year, when water levels in the floodplains are low and fish densities are high (Goulding et al. 1996; Veríssimo 1895). Fishing is done using either or a combination of gillnets and harpoons. Gillnets now are widely used and use of harpoons likely is decreasing. However, harpooning is the most traditional fishing method (at least since the early 1800's) and is preferred by expert fishers who use their harpooning skills to obtain rather high catches. Harpooners probably also capture relatively more very large individuals. For example, only about 10% of all fishers in the Mamirauá Reserve are specialized in arapaima, yet they produce between 50 and 60% of the total catch of arapaima (Queiroz & Sardinha 1999). Other fishing methods also are used such as hook and line and traps.

II. Non-detriment finding procedure (NDFs)

The case of arapaima in Brazil illustrates some of the deficiencies of current NDF procedures. Brazil has been exporting arapaima since 1975, and yet application of both Brazil's current regulations for NDF procedures and IUCN's checklist for making NDF show that there is no evidence for or against assertions that the harvests were sustainable.

In making this assessment, we could not find specific data for cases where NDF reports have been made, nor did we have access to details of any export of arapaima from Brazil because such data currently are not publicly available. Thus, the assessment that follows was made in general terms. It is based on Brazil's current NDF regulations, the best information available on arapaima in Brazil reviewed above, and our educated guesses about the likelihood of making reliable NDF. We considered the available information on arapaima for the whole of Brazil, but not for the Mamirauá Reserve because the situation in Mamirauá is atypically good.

Brazil's NDF Procedures

Brazil's regulations concerning NDF procedures for CITES species in Appendix II are relaxed, and these are detailed in Decreto Lei No 3,607 from September 21, 2000. Article 8 of that Decreto Lei is the only regulation concerning NDF. It establishes that the 'Scientific Authority' must issue a technical opinion report attesting that the export will not undermine the survival of the species[1], and that such report must be submitted to the 'Administrative Authority'. There are two relevant exemptions to the requirement for such a technical report. One is for cases of borrowing, donation, or inter-exchange with no commercial purposes between scientists or scientific institutions (Article 16). Another is for the case of specimens that were raised in captivity (Article 17). The Decreto Lei 3,602 also has several other regulations on CITES species in Brazil, but most of those focus on administrative procedures, conditions of transport of specimens, etc.

There are at least two problems. First, we believe that it is very difficult for any Scientific Authority to be able to issue a technical opinion report showing evidence that the export will not undermine the survival of the species, as required by Decreto Lei 3,602, because there is a severe lack of information on wild arapaima populations. As we explained in the preceding review sections:

1. the taxonomy of arapaima currently inhabiting Brazilian waters is largely unknown, so geographical distribution of each species also is unknown;
2. there are no data (or expert consensus opinions) on the numbers of individuals in wild populations or their trends;

[1] This sentence is based on the best translation possible of the original version in Portuguese: "emissão de parecer, pela Autoridade Científica, atestando que a introdução não prejudicará a sobrevivência da espécie".

3. there are no data on numbers or sizes of individuals presently being harvested legally or illegally;
4. the dominant management scheme is largely ineffective due to lack of resources;
5. the dominant monitoring scheme based on recording market landings is inadequate;
6. there is widespread illegal fishing;
7. trade is done to satisfy increasing local demand, irrespective of regulations.

This lack of information exacerbates the historical difficulty of estimating sustainable harvests of fish populations. Fisheries science in general has done a poor job of determining sustainable harvests, as evidenced in part by worldwide overfishing (Pauly *et al*. 2002). To our knowledge, the only area in Brazil that may have sufficient information for issuing a NDF report is the Mamirauá Reserve (Figure 1), where well-managed growing populations of arapaima have been censused annually since 1999 and studied intensively (Castello *et al*. In Press).

Second, we believe that Brazil's NDF procedures cannot prevent that arapaima specimens are exported legally without detriment of wild populations because Article 17 does not specify that exported specimens have to originate from a captive *bred* population[2] (i.e., self-sustaining population). It may well be that exports of arapaima from Brazil originating from captivity were exempted from NDF reports, and that those exports were not detrimental to wild populations. However, under the present regulations, aquaculture enterprises in Brazil can collect alevines, juveniles, and even adult arapaima from the wild to subsidize "captive" arapaima populations. Such collection of specimens in the wild is done routinely (in many but not all aquaculture enterprises) because of lack of technology to breed the arapaima in captivity. Furthermore, Article 17 is unclear about the definition of the term captivity. Aquaculture enterprises may have facilities that are naturally connected to surrounding water bodies, and such connections also may passively supply "captive" populations with wild arapaima. This seemingly unlikely scenario is quite possible in floodplain ecosystems such as that of the Amazon River where water level variations are as high as 15 m seasonally. Cages or pens rarely are used in aquaculture in the Amazon.

Fortunately, the lack of specificity of Brazil's NDF procedures with respect to the origin of arapaima specimens is being addressed. The

[2] This is because the terms used have multiple interpretations. The terms used specify that the specimens are 'criado' in captivity. The term criado in English can mean raised, bred, or originated.

Administrative Authority now routinely inspects aquaculture enterprises to ensure that arapaima are captive bred (José Dias Neto, personal communication[3]). Such inspections can do much to promote the reliability of NDF. It is believed that most aquaculture enterprises of arapaima in the area of the Brazilian Amazon do not comply with Brazil's legal requirements for aquaculture and thus are not authorized to do exports (José Dias Neto, personal communication3). However, we have been unable to identify any legal formalization of this procedure as well as methodological details, so it is impossible for us to assess here its efficacy.

IUCN's Checklist for Making NDF

Our above suggestion that Brazil's NDF procedures for arapaima are problematic are reinforced by application of IUCN's checklist for making NDF. We applied IUCN's checklist for making NDF to arapaima and found that it is impossible to certify that exports of arapaima are non-detrimental to the survival of the species, mostly because of weak management capacity and data deficiencies. We assessed qualitatively a total of 26 issues or questions related to seven main factors affecting the harvesting regime of arapaima. We assigned scores from 1 to 5 to all issues or questions, with high scores being related to presence of requirements of sustainable harvests, and low scores to uncertainty, lack of management capacity, or un-sustainability. A complete list of the issues and questions investigated with related scores is shown in Appendix 1, and details of IUCN methodology are found in the original publication (Rosser & Haywood 2002).

We found that most factors affecting the management of the harvesting regime fell in cautionary or problematic areas (Figure 4). These findings are consistent with the situation of the genus Arapaima in Brazil. Factors related to the biology and management of arapaima received the highest scores (right-side of Figure 4), as a result of the biological adequacy to harvesting and existence of management regulations. However, factors related to status, control, monitoring, incentives, and protection received the lowest scores (left-side of Figure 4), as a result of lack of enforcement and monitoring schemes and widespread illegal fishing. If an attempt were made to create a radar plot for each of the four previously described species (Figure 2), such plots would look considerably more barren, representing the epitome of 'data deficient'. In sum, it seems that the case of arapaima in Brazil shows that there is potential for sustainable harvests, and hence NDF,

[3] Coordenador geral de Gestão de Recursos Pesqueiros, IBAMA, Brasilia, Brasil.

but such potential is not being achieved mainly because of lack of management capacity.

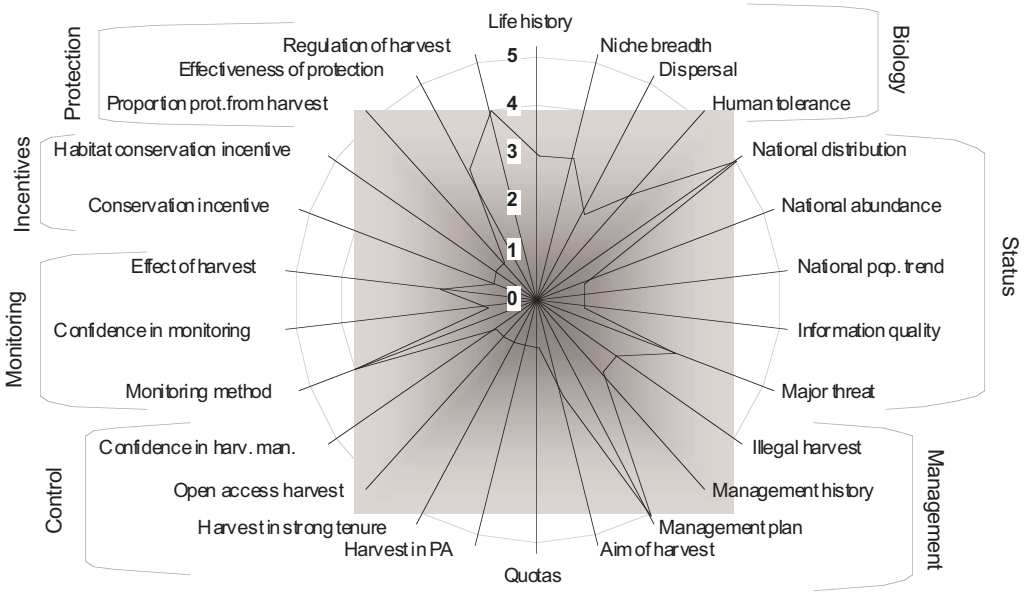

Figure 4. Radar plot of the factors affecting the management of arapaima in Brazil. See Annex 1 for data.

Towards Reliable NDFs

We believe that many of the problems currently affecting the preparation of NDF reports for arapaima in Brazil can be overcome through intensive monitoring of wild populations combined with adaptive harvesting, as is done at the Mamirauá Reserve (Figure 1). Sound monitoring of harvested populations is the most important because the effects of harvesting on wild fauna and flora most often are manifested through population declines (Walters 1986), although obviously there is a wealth of other issues that are key for the survival of any species. In fact, the utility and importance of population monitoring has been poorly appreciated. This is evidenced by the case of cod in Newfoundland, which has been one of the most intensely studied and managed fisheries of the world, and which collapsed partly because of problems in monitoring (Walters & Maguire 1996).

Monitoring of arapaima populations can be very useful for making NDF reports because arapaima populations can be censused with accuracy, precision, and cost-effectiveness that are unparalleled in fisheries. Counts of arapaima done by experienced fishers have been shown to vary by 10-30% around the true numbers of arapaima in lakes (Arantes *et al*. 2007; Castello 2004). Furthermore, counts of arapaima

have been estimated to be about 200 times faster and less expensive than estimates of abundance calculated with conventional mark-recapture methods (Castello *et al.* In Press). Thus, arapaima populations that are monitored annually through count-based censuses are ideal for assessing the effects of harvesting. The detrimental effects of (over)harvests should cause declines in population numbers in subsequent years. We believe that five or more years of count-based monitoring of arapaima populations is a minimum to provide a reliable base- or trend-line to assess the effects of harvesting, given that arapaima attain first maturity at 3-5 years of age (Arantes et al. In Review).

However, conducting sound monitoring of arapaima populations requires addressing several issues, most of which currently are not being addressed in Brazil. The first is the need to ensure that only fishers that can count arapaima accurately are involved in population censusing. Castello (2004) showed that fishers use a combination of visual and acoustic cues to count the arapaima when they surface to breath atmospheric air, and that the skills necessary to do accurate counts depended on the knowledge and experience of the fishers. Arantes *et al*. (2007) showed that there is great variation among fishers with respect to their capacity to count the arapaima accurately, and they proposed a cost-effective method to assess fishers' counts based on total catches done using large seine nets. Because of these findings, most fishers involved in arapaima censusing at the Mamirauá Reserve have undergone quantitative assessments of their counts (Castello et al. In Review-b).

The second issue is the need to ensure the authenticity of the censuses. At the Mamirauá Reserve, technicians of the Mamirauá Institute accompany the fishers to prevent possible cheating. Even though the technicians do not have the expertise needed to assess the accuracy of the counts, it is believed that their presence during census work minimizes possible biases.

The third issue is the need to ensure that the counts include all individuals in the population. Counts are done in small "quadrats" of 2 ha in area at maximum, and the time taken at each "quadrat" is 20 min. So census workers must move steadily to minimize errors due to possible movements of the arapaima in the aquatic habitats being surveyed. Field experience has shown that short-term movements of arapaima within relatively small aquatic habitats such as lakes (<10-100 ha) cause little to no effect on the counts. But such population censuses can be under- or over-estimated by thousands of individuals if census workers do not account for the regular seasonal migrations that arapaima perform within and among various habitats of Amazonian

aquatic ecosystems (Castello 2008a). Accounting for effects of such migrations on a population census requires site-specific knowledge and agility on the part of the involved fishers (Castello 2007). Census work also needs to account for possible changes in spatial distribution of the population that occur because of inter-annual changes in water levels and changes in population densities. At the Mamirauá Reserve, arapaima densities in any specific site changed from year to year, and new habitats became inhabited as the population grew.

Lastly, any attempt to conserve and sustainably manage a population of an economically valuable species such as the arapaima necessarily must address the high probability of un-accounted harvests by outsiders (i.e., poaching). Vigilance systems are routinely used by community-based arapaima fisheries in Brazil to help protect the fish populations, and they are key to preparing reliable NDF reports.

Challenges Found in this Assessment

The following main challenges were involved in the preparation of this case study:

1. Lack of data specific to cases where licenses for export of CITES Appendix II species were issued.
2. Difficulty in accessing existing information necessary to make NDF following IUCN's checklist. Most of it is scattered in published and unpublished reports in several languages.
3. Difficulty in evaluating conservation status of various nominal species. There are very few arapaima specimens preserved in museums that have useful locality data, and vast areas, including entire river basins, have no preserved materials to study. Clearly, not knowing how many species are present or the distribution of each makes it impossible to truly evaluate population status or sustainability of harvests.

RECOMMENDATIONS

The following recommendations likely can improve the reliability of NDF procedures in Brazil:

1. Listing of *Arapaima* in CITES Appendix II could be based on genus name to give urgently needed protection to all species within, at least until the taxonomy is better resolved and status of each taxon is evaluated. There is no evidence that any of the exported specimens are *A. gigas* (i.e., based on study of aquarium specimens deposited in various US and European museums).
2. Adaptive management strategies for arapaima that use yearly population counts (Arantes *et al*. 2007; Castello 2004) to determi-

ne yearly harvest quotas of sexually mature individuals, as done in Mamirauá and as suggested above, could tremendously improve the reliability of future NDF reports. The counting of arapaima when combined with monitoring of the catch, which we suggest can be done, provides a useful framework that addresses current weaknesses and focuses on strategic data.

3. NDF reports prepared by Scientific Authorities that are submitted to Administrative Authorities for licensing of exports of CITES species could be based on IUCN's checklist for NDF procedures. In particular, we emphasize the usefulness of annual population monitoring in determining non-detriment effects to wild populations.
4. All documents used in licensing of exports of CITES species could be made available publicly as CITES species are a matter of public concern.
5. Exemption of NDF report for cultured CITES species could be based on evidence that captive populations are self-sustaining and independent of wild populations.

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