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Assessing CITES non-detriment findings procedures for *Arapaima* in Brazil

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Summary

Arapaima are listed as endangered fishes according to the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), thus their international trade is regulated by non-detriment finding (NDF) procedures. The authors critically assessed Brazil's regulations for NDF procedures for *Arapaima* using IUCN's checklist for making NDFs, and found that those regulations cannot ensure the sustainability of *Arapaima* populations. *Arapaima* are among the largest fishes in the world, migrate short distances among several floodplain habitats, and are very vulnerable to fishing during spawning. They are threatened mainly by overfishing. The fishery is largely unregulated because government regulations on size, season, and even moratoriums on capture have been very poorly enforced. *Arapaima* remain poorly understood and the taxonomy and geographical distribution of the genus remain uncertain. There are no data on catch levels or status of wild populations, although available information suggests they are in decline. Brazil's NDF procedures for specimens originating in the wild are inadequate as they rely on 'technical opinion reports', which do not necessarily require scientific evidence. Furthermore, Brazil's NDF procedures exempt the need for NDF reports on 'captive' specimens; however, 'captive' specimens originating in the wild and raised in captivity can be exported because regulations do not specify that they must be 'captive-bred'. Six suggestions are offered to improve the reliability of NDF procedures for *Arapaima* in Brazil, emphasizing the utility of participatory monitoring and adaptive harvesting to strengthen much needed harvest control capacity in other tropical fisheries.

Introduction

Aquatic living resources are being degraded worldwide to the point that international policy and institutional arrangements have been established to curb the situation. The most prominent of these arrangements is the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), which attempts primarily to curb threats to biological species caused by international trade. One approach promoted by CITES has been the use of non-detriment finding (NDF) procedures. NDF procedures essentially require proof that the level of exports and associated harvesting is non-detrimental to the survival of the species in the wild or to their role in the ecosystem (Rosser and Haywood, 2002). Unfortunately, however, non-detriment finding (NDF) procedures have not been very effective worldwide. According to Rosser and Haywood (2002), 'current problems in making non-detrimental findings result mainly from lack of capacity and resources to implement monitoring schemes across the wide range of species in international trade.' Consequently, the CITES Secretariat has been seeking to improve existing NDF procedures: in 2008 an international workshop on the topic included a series of case studies covering various regions and taxa worldwide. The present study was developed for that workshop, contributing to the implementation of more effective NDF procedures for tropical fishes.

Tropical fishes are affected by the same broad range of conservation issues as most other taxa in the world. However, they are also affected by issues typical of developing countries where they tend to occur; they deserve attention because these countries comprise about two-thirds of the world. Conserving tropical fishes and their fisheries is especially difficult because they tend to be marked by high biological diversity and poor biological understanding, large geographical areas and scarcity of human and financial resources, and rapidly growing human populations and affluence (Berkes et al., 2001; Castello et al., 2007; Ruddle and Hickey, 2008).

This paper focuses on *Arapaima* spp. in Brazil. *Arapaima* are exceptional fishes from tropical South America and have been exported from Brazil since 1975 (BioTrade Facilitation Programme, 2006; CITES, 2008). *Arapaima* are among the largest freshwater fishes, growing to 3 m in length and 200 kg; they are highly specialized, obligate air-breathers that typically surface every 5–15 min to gulp air; and they have supported important regional fisheries. This paper focuses on the floodplains of the Amazon River where *Arapaima* have been studied the most and covers much of their range where they are (and were) abundant.

Methods

We tested the hypothesis that existing information and resource management schemes for *Arapaima* in Brazil allow for reliable NDF procedures. The analysis primarily followed the application of IUCN's checklist for making NDFs (Rosser and Haywood, 2002). This methodology relies on the assessment of 26 issues related to the species of interest (see Appendix I). These issues have been chosen to allow for 'easy qualitative checks that permit a basic assessment of the confidence with which an NDF may be made by scientific authorities' (Rosser and Haywood, 2002). The checklist was designed to require educated guesswork, as there is great difficulty in meeting hard criteria for sustainable use of many species, and it is practically impossible to extrapolate quantitative data from the few species that have been

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studied. To apply the checklist to *Arapaima*, we followed two steps: first, we reviewed the literature on *Arapaima* related to biology, population status, management, protection, conservation incentives, population monitoring, and harvesting control; second, we assigned scores from 1 to 5 to all issues assessed, with high scores related to presence of requirements of sustainable harvests, and low scores to uncertainty, lack of management capacity, or non-sustainability. This was done considering the information for the whole of Brazil, but not for small regions where information may be atypically good (e.g. Mamirauá Reserve in Amazonas State). The scores were plotted on a radar graph for ease of interpretation.

We supplemented this analysis with a critical assessment of Brazil's NDF procedures. This was done because individual countries design and implement NDF following advice given by their own scientific and administrative authorities. Information on Brazil's NDF procedures was obtained directly from the website of the Brazilian Institute for Environment and Renewable Resources (IBAMA) and through direct contact with IBAMA's personnel. However, we could not find specific data for cases where NDF reports have been made for *Arapaima*, because such data currently are not publicly available. Thus, our assessment was made for the entire area of Brazil considering the application of Brazil's regulations using the available information on the species. We sought to identify possible ways through which exports of *Arapaima* from Brazil potentially could be detrimental to their survival in the wild.

Results and discussion

The general characteristics of the *Arapaima* appear to allow for sustainable exploitation. However, we found that it is practically impossible to produce reliable NDF for the species in Brazil because of lack of monitoring and management capacity, scarcity of information on various topics, and deficiencies in Brazil's NDF procedures. Details follow.

Biology and ecology

Taxonomy. It is widely held that *Arapaima* is a monotypic genus, including only *A. gigas* (Schinz in Cuvier, 1822). However, there have been no species-level taxonomic analyses since Günther (1868) put the three species described by Valenciennes (in Cuvier and Valenciennes, 1847) into the synonymy of *A. gigas* without presenting any analysis or rationale. Our own study of populations in Brazil and Guyana (Fig. 1) and examination of *Arapaima* specimens preserved in several large international collections (including type materials in Paris and London, and non-types in Manaus and several US museums) suggests that all four nominal taxa are valid. At present, we can map approximate distribution of the genus *Arapaima* (Fig. 1), but distributions of the four previously described species remain unknown. Hrbek et al. (2005, 2007) studied variation in DNA for *Arapaima* from seven regional fish markets in the Amazon basin, covering a very large geographical area, including the Mamirauá Reserve, and inferred that their samples came from a single, panmictic population. However, those results cannot refute Valenciennes' four-species hypothesis because a taxonomic analysis was not done (i.e. they did not examine type materials or morphology of sampled specimens). Previous studies have shown that some Amazonian fish genera have both widespread, common species as well as localized or rare species (e.g. *Cichla monoculus* vs many localized taxa; Kullander and Ferreira, 2006). The present uncertainty on the taxonomy and geographical distribution of *Arapaima* highlights the urgent need for additional studies as well as caution in translocations of individuals.

Life history. The majority of the existing information stems from one area no greater than 1000 km^2, the Mamirauá Reserve, Amazonas State, Brazil, which represents less than 1% of the total distribution of the species (Fig. 1). *Arapaima* make short, seasonal migrations among all eight habitats of the Amazon River floodplain (based on Castello, 2008a,b). Most *Arapaima* inhabit lakes and channels during low-water periods, roughly from September to January each year. At that

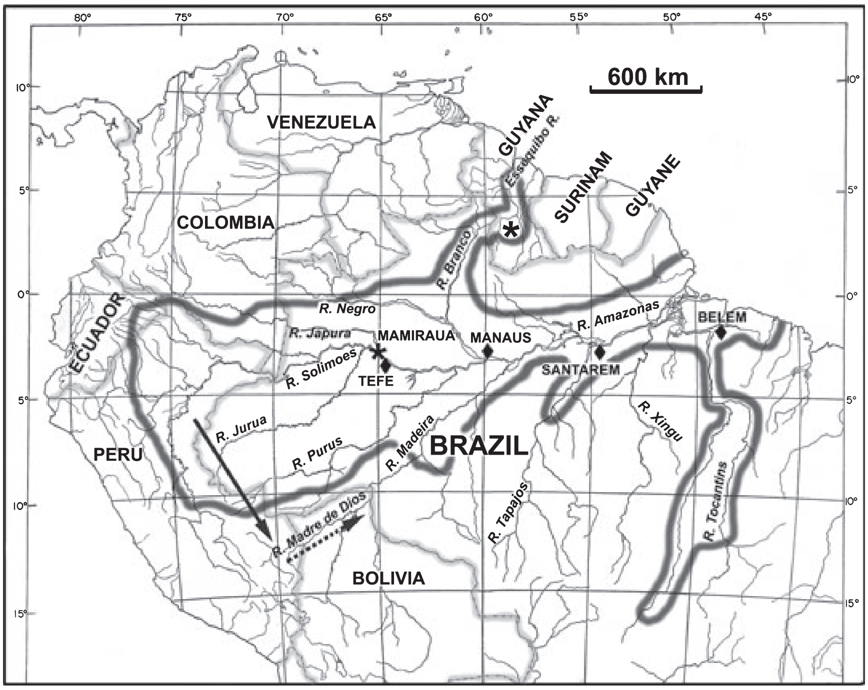

Fig. 1. Best available information on geographic distribution of *Arapaima* genus in northern South America (dark grey boundary). Stars = study areas. International boundaries shown as light grey bands; diamonds mark cities mentioned in the text. Solid arrow = a translocation of cultured *Arapaima* above waterfalls and rapids of Madeira River, Peru; dashed arrow = subsequent downstream spread of breeding populations into Bolivia. Distribution boundary line = synthesis of published accounts, museum records, personal communications from colleagues and, where data were lacking, a Google Earth search for suitable lagoon habitats below physical barriers such as river rapids

time, the adults form pairs and reproduce between December and May each year (Queiroz, 2000). Both sexes build their nest in the margins and banks of lakes, temporary lakes, and connecting channels during rising water levels. The males protect their young by staying very close to them for about 3 months, feeding in the food rich environment of flooded forest. 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.

Growth and reproduction. *Arapaima* are relatively long-lived fishes 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, 2009). In Mamirauá, total lengths of up to 285 cm have been confirmed (L. Castello, pers. obs.), and female *Arapaima* mature sexually at about 1.68 m in total length (Queiroz, 2000; Arantes, 2009). Data indicate that *Arapaima* populations show great growth potential when juveniles and individuals engaged in reproduction are protected (Castello, 2007). For one studied population at the Mamirauá Reserve, total number of individuals more than 1 m long increased from about 2350 in 1999 to 20, 650 in 2006 (Castello et al., 2009). Similar trends were observed in other areas (Arantes et al., 2006, 2007). Aspects of fecundity and fertility of *Arapaima* remain unclear (Lowe-McConnell, 1964; Lüling, 1964; Neves, 1995).

Habitat. *Arapaima* inhabit most low-gradient (i.e. lowland) aquatic ecosystems of the Amazon and Essequibo basins, including (flooded) forests, rivers, lakes, and coastal drainages, usually up to the first major rapids or waterfall on a river (Fig. 1). There are commercially viable populations of *Arapaima* in degraded floodplains such as those in the Lower Amazon (McGrath et al., 1993), suggesting some degree of capacity to adapt to habitat or environmental changes.

Role in the ecosystem. *Arapaima* are large-bodied predators, and thus probably help regulate the stability of their ecosystems. They are primarily piscivorous, and their prey are generally abundant, small-bodied, detritivorous and omnivorous fishes (Sánchez, 1969; Queiroz, 2000). However, there are no studies on the ecosystem roles of *Arapaima*.

Global population size. It is impossible to estimate the population size of *Arapaima* in their entire range. Through a genetic analysis, Hrbek et al. (2005, 2007) estimated that the total population of *Arapaima* in an area greater than 100 000 km^2 in the Amazon basin was around 150 000 individuals. We believe such an estimate is unrealistically low because censuses made in the Mamirauá Reserve show that there are well-managed *Arapaima* populations with over 50 000 individuals in areas of less than 500 km^2 (Arantes et al., 2006, 2007). Population census data from managed and non-managed areas also show that population densities vary greatly depending on management activities, from 0 to 200 individuals per ha (L.C., unpubl. data), making it difficult for extrapolation of population census data to larger areas.

Current global population trends. Global population trends of *Arapaima* are likely decreasing in the entire Amazon basin. In the 1800s and early 1900s, *Arapaima* were the most important fishery of the Amazon (Veríssimo, 1895), but landings and size of captured individuals were reduced drastically by the 1950s (Isaac et al., 1993; Fig. 2). Data from localities in the Central and Lower Amazon regions show predominance of juveniles (Fig. 2), a common sign of overexploitation. The most complete and longest time-series of data available for *Arapaima* are weight data of sun-dried, boneless fillets landed in Manaus, the largest city of the Amazon (Fig. 2). Such time series data illustrate the paucity of data, although the accuracy of the data is questionable. Landing data from Manaus city may be biased due to underreporting of catches by fishers or lack of monitoring activities (Castello et al., 2009). Similarly,

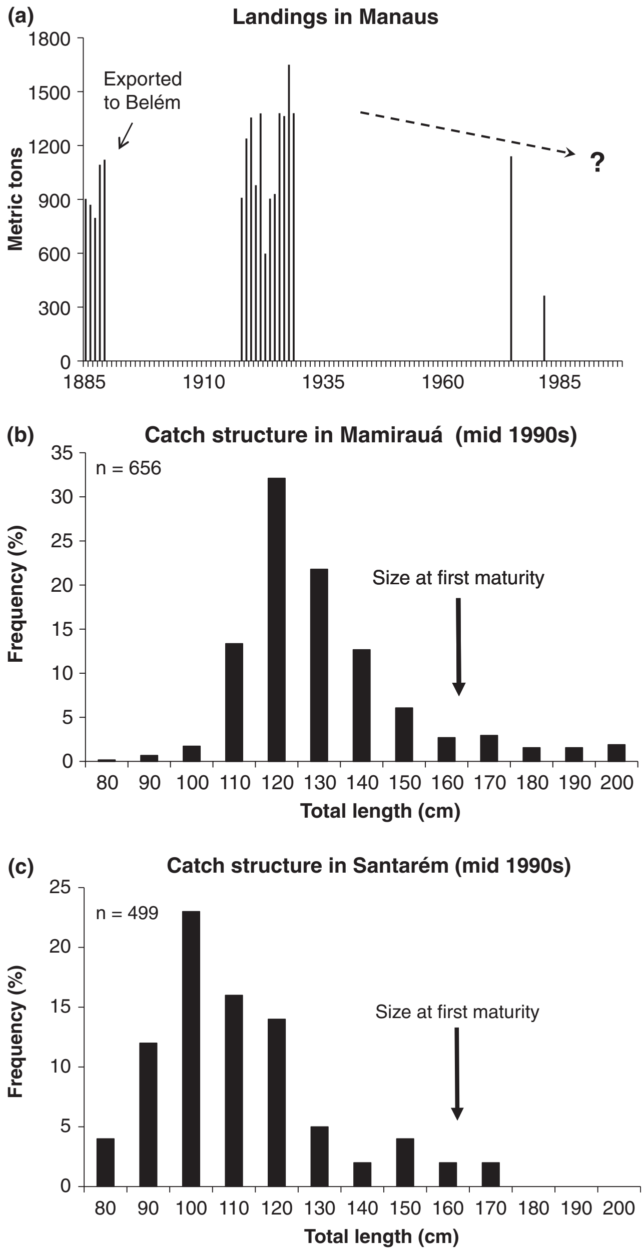

Fig. 2. Main data on landings and catch structure of *Arapaima* in Brazil. Top panel (a) data summary of *Arapaima* landings in Manaus (see map, Fig. 1). Data between 1889–1893 from Veríssimo (1895), refer to total exports from rural areas, State of Amazonas where Manaus is located, to the city of Belem (Fig. 1). Data for 1930s from Pereira (1954); 1979 and 1986 data summarized by Isaac et al. (1993). Middle (b) and bottom (c) panels = catch structure of *Arapaima*, Mamirauá Reserve and Santarém, respectively. Mamirauá data from Castello (2007); Santarém data estimated from analysis of dried tongue bones (Martinelli and Petrere, 1999). Size at first maturity from Queiroz (2000), consistent with more recent data (Arantes, 2009)

catch structure data from Mamirauá Reserve and Santarém city may be biased due to gear selectivity or underreporting of catches. There are no additional data on *Arapaima* populations, but reversal of that apparent resource decline trend is unlikely given lack of significant changes with respect to the principal causes of overfishing, at least at the appropriate spatial and temporal scale.

The only analysis of population trend done for *Arapaima* was by Queiroz and Sardinha (1999), with results in line with our above suggestion. Through a virtual population analysis, Queiroz and Sardinha (1999) concluded that fishing mortality rates at the Mamirauá Reserve (Fig. 1) in the early 1990s were exceedingly high and threatened the population with stock collapse. That population analysis was for an area of 562 km^2. Compounding the problem of data scarcity is the fact that the inherent variability of fish population dynamics in ecosystems such as the Amazon floodplains remains largely unknown. Therefore at present it is difficult to judge whether any observed population trend (or prediction, as in the case of Queiroz and Sardinha, 1999) is a natural or human-caused phenomenon.

Exceptions to the above-suggested trend include community-based conservation efforts. Several riverine communities are undertaking conservation activities related to *Arapaima* (McGrath et al., 1993; Castello et al., 2009), as their relatively small-ranging migrations make them suitable for small-scale management efforts. However, there are no data on the numbers of communities effectively conserving *Arapaima*, thus the geographical extent of these efforts remains unclear.

Conservation status. *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 is now '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.' *Arapaima gigas* is the only South American freshwater fish listed in CITES Appendix II. The conservation status of *Arapaima* in Brazil has not been rigorously assessed; they were not included in Brazil's recent list of threatened species commissioned by the Ministry of Environment.

Main threats. The principal threat appears to be overfishing, even though habitat degradation and by-catch are also issues of concern. Overfishing appears to be rampant in the entire region, except in a few local communities where they are being conserved with varying degrees of success. However, a lesser-known threat is long-distance translocation of specimens by aquaculture enterprises (L.C., pers. obs.), a process that threatens to homogenize the genetic pool and even possibly extirpate locally adapted races or species. Following a translocation by Peruvian authorities, *Arapaima* recently colonized areas of Bolivia for the first time (Fig. 1).

Management

Management measures. Government attempts to manage the *Arapaima* fishery in the Brazilian Amazon have been largely ineffective. IBAMA implemented a minimum catch length of 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 n° 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), the State of Amazonas in 1996, and the State of Acre in 2008. But illegal fishing of *Arapaima* is so widespread that most *Arapaima* are now probably caught and traded illegally. Enforcement of the above management regulations is extremely poor because IBAMA lacks human and economic resources to do so effectively (Castello et al., 2009). Until 1999, the office of IBAMA in Tefé (Fig. 1), for example, was staffed by just eight agents, did not even possess a boat, and was responsible for an area of 251 000 km^2 (about the size of Italy).

A new management regulation implemented in 2004 in the State of Amazonas promoted a potentially promising strategy of management for *Arapaima*. The regulation exempted the existing ban for fishers that census their *Arapaima* populations, and was developed because of previous work done at the Mamirauá Reserve. Research in Mamirauá showed that expert fishers can assess accurately the *Arapaima* populations 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. This methodology was used in a system in which local fishers assess *Arapaima* populations each year, then collaborate with the Mamirauá Institute and IBAMA to use the data in determining fishing quotas for the next year (Viana et al., 2004). In this system, the Mamirauá Institute provides institutional and technical assistance to local fishers, IBAMA oversees management actions and approves (or not) legal permits for the annual fishing quotas, and the fishers are responsible for complying and enforcing management regulations. Due to lack of information fishing quotas to date have been determined based on trial-and-error and educated guesses. Nine years of experimentation have shown that where this management model was implemented, fishers' profits more than doubled, fishers engaged in the process, and *Arapaima* populations recovered rapidly (Viana et al., 2004; Castello et al., 2009). Those population trends were compared to neighboring populations that remained stable at low densities, suggesting that the observed trends were the result of local management efforts (Castello et al., 2009). Incorporation of that management system into regional legislation in 2004 was followed by rapid dissemination. Whereas in 1999 only four riverine communities used it to manage *Arapaima*, more than 100 communities in the State of Amazonas now use it (including two regional cities). Similar legislation has been established in the State of Acre in Brazil in 2008, and in Guyana in 2006.

Monitoring system. Lack of information on population levels and associated harvests has been a major issue impeding sustainable management of *Arapaima* (Castello, 2004). Conventional mark-recapture methods are prohibitively difficult due to costs, labor, and the enormous geographic areas involved; monitoring of landings is practically impossible because of the decentralized and illegal nature of the trade. In many instances, reported landings can be as little as one-fifth of the actual *Arapaima* catch. Effective monitoring of the catch can be made in riverine communities, but requires much effort in developing trust with fishers.

Utilization, trade, and harvest

Utilization and trade. Most wild *Arapaima* are harvested by local fishers, commercialized through middlemen, and consumed in regional urban centers. *Arapaima* are key food resources because their air-breathing behavior makes them vulnerable to expert fishers who use harpoons and can choose the larger individuals. Also, a high proportion of their body (Bard and Imbiriba, 1986) is boneless, tasty meat that can be iced or salt-dried for future consumption or commercialization.

Harvest. Most harvesting of wild *Arapaima* is done during the dry season roughly between September and January each year when water levels in the floodplains are low and fish densities high (Veríssimo, 1895). Fishing is done using gillnets and/or harpoons. Gillnets are now widely used and harpoon usage is likely decreasing. Harpooning, however, is the most traditional fishing method (at least since the early 1800s) and preferred by expert fishers. Other fishing methods such as hook and line and traps are also used. Another (probably much smaller) source of harvest is the collection of young wild *Arapaima* to supply increasing numbers of (often large) aquaculture enterprises. Because the technology to breed *Arapaima* is in its infancy, most aquaculture enterprises depend on continuous collection of wild specimens. Cultured *Arapaima* are now routinely commercialized in most large urban centers in the Amazon. However, official data on such harvests and translocations are not available.

Brazil's NDF procedures

Application of IUCN's checklist for making NDF and assessment of Brazil's regulations for NDF procedures show that there is insufficient information to produce reliable NDFs and that certain regulatory deficiencies undermine the potential quality of NDF reports. Thus, the case of *Arapaima* in Brazil illustrates some of the deficiencies of NDF procedures worldwide.

IUCN's checklist for making NDF. Application of IUCN's checklist for making NDF for *Arapaima* in Brazil showed the most problematic area as being the management of the harvest (Fig. 3). Factors related to the biology and management of *Arapaima* received the highest scores (Fig. 3, right side), a result of the apparent biological adequacy to harvesting and existence of management regulations. However, factors related to status, control, monitoring, incentives, and protection received the lowest scores (Fig. 3, left side), a result of lack of enforcement and monitoring schemes as well as widespread illegal fishing.

We note that IUCN's checklist for making NDFs is intended to serve even when considerable guesswork is necessary (Appendix I), although the results can obviously vary among users. However, we suspect that our colleagues working in the more data-rich regions of the globe may be inclined to assign scores that are even lower than those assigned by us in the present study. Our conclusion that it currently is impossible to make reliable NDFs is likely conservative.

Brazil's NDF procedures. Brazil's regulations concerning NDF procedures for CITES species in Appendix II are detailed in Decreto Lei N^{o} 3,607 from 21 September 2000. Article 8 therein is the only regulation concerning NDF. As noted above, *Arapaima* is the only CITES Appendix II fish in Brazilian freshwaters. This law establishes that the 'scientific authority' must issue a technical opinion report attesting that the export will not undermine survival of the species, and that such a report must be submitted to the 'administrative authority'. This technical report requirement is exempted for specimens raised in captivity (Article 17). 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 two problems with those procedures. First, it would be nearly impossible 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 paucity of information on wild *Arapaima* populations. As we explained, there are critical uncertainties with respect to taxonomy, population size and trend, and total harvest. Also, existing schemes to monitor wild populations and manage associated harvests are wholly ineffectual. Previous exports may have been authorized despite lack of data, because there is no requirement for scientific evidence in the technical opinion reports. To our knowledge, the only area in Brazil with sufficient information for issuing an NDF report is the Mamirauá Reserve (Fig. 1), where since 1999 an annual census is taken of well-managed populations of *Arapaima* under intensive study (Castello et al., 2009). Second, Brazil's NDF procedures cannot ensure that *Arapaima* specimens are

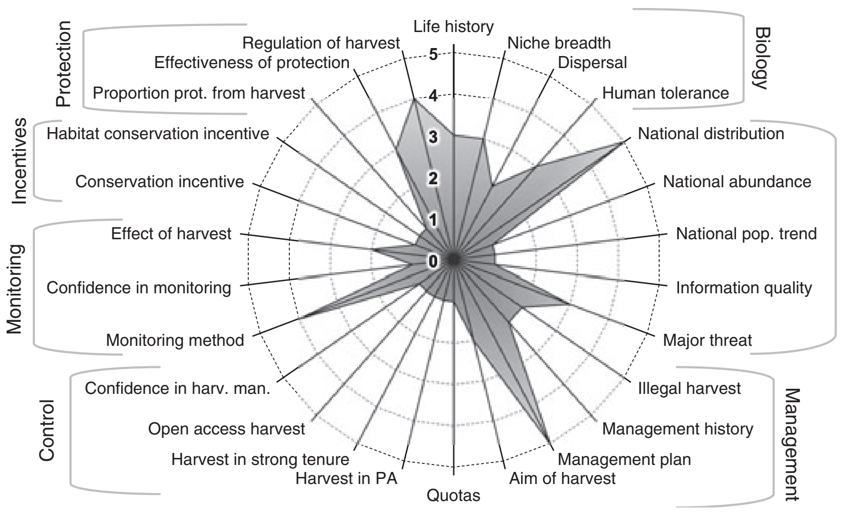

Fig. 3. Radar graph of factors affecting management of *Arapaima* in Brazil. See Appendix I for data

exported legally without detriment to wild populations, because Article 17 does not specify that exported specimens have to originate from a 'captive bred' population (i.e. self-sustaining population). Under present regulations, aquaculture enterprises in Brazil can collect *Arapaima* from the wild to subsidize 'captive' populations, in fact routinely done for use in exports. 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 may also passively supply 'captive' populations with wild *Arapaima*. This seemingly unlikely scenario is quite possible in floodplains of the Amazon where water levels vary seasonally by up to 15 m and where cages or pens are rarely used in aquaculture. Fortunately, these issues have recently begun to be addressed by IBAMA through routine inspections of aquaculture enterprises to ensure that *Arapaima* are captive bred (José Dias Neto, Coordenador geral de Gestão de Recursos Pesqueiros, IBAMA, Brasilia, pers. comm.).

Toward reliable NDFs

Our analysis has shown that there is potential for sustainable harvests of *Arapaima* in Brazil, and hence NDF, but such potential is not being achieved because of deficiencies in NDF procedures and lack of management capacity. Therefore, we suggest six recommendations to improve NDF procedures in Brazil. (i) *Arapaima* listing in CITES Appendix II could be based on the genus name to provide urgently needed protection to all possible species therein, at least until the taxonomy is better resolved and the status of each taxon is evaluated. (ii) Adaptive management strategies for *Arapaima* that use a yearly census (Castello, 2004; Arantes et al., 2007) to determine yearly harvest quotas of sexually mature individuals could improve future NDF report reliability. The counting of *Arapaima* when combined with catch monitoring, which we suggest can be done, provides a useful framework that addresses current weaknesses and focuses on strategic data. (iii) NDF reports prepared by scientific authorities and submitted to administrative authorities for licensing of exports of CITES species could be based on IUCN's checklist for NDF procedures. (iv) All documents used in licensing of exports of CITES species could be publicly available, as CITES species are a matter of public concern. (v) NDF report exemptions for cultured CITES species could be based on evidence that captive populations are self-sustaining and independent of wild populations. (vi) Greatly increased attention of governments worldwide to promote the study and monitoring of key fish resources such as *Arapaima*. Even the most elaborate system for making NDF procedures cannot overcome the impossibility of assessing fish resources for which there are no data. In the preceding list we have identified various knowledge gaps and deficiencies in monitoring and management activities that could be targeted in future efforts.

Lack of management capacity of *Arapaima* (Fig. 3) can be strengthened through intensive monitoring of wild populations combined with adaptive harvesting. Sound monitoring of harvested populations is most important because the effects of harvesting on wild fauna and flora most often are manifested by population decline (Walters, 1986), although obviously many other issues are key for the survival of any species. Participatory monitoring and management of *Arapaima* populations, as in the Mamirauá Reserve, can be very useful because *Arapaima* populations can be counted with accuracy, precision, and cost-effectiveness unparalleled in fisheries. Counts of *Arapaima* by experienced fishers have been shown to vary by 10–30% in the actual numbers of individuals (Castello, 2004; Arantes et al., 2007) and are about 200 times faster and less expensive than abundance estimates obtained through mark-recapture methods (Castello et al., 2009). Thus, annual harvests can be determined rather safely if based on continuous monitoring and assessment of population trends. However, this strategy can only work if population monitoring is reliable and harvest control is effective (i.e. minimal illegal harvesting). This is key, as was investigated and noted earlier (Castello, 2004, 2007; Arantes et al., 2006, 2007; Castello et al., 2009). Yet increasing numbers of government and non-governmental organizations have been promoting the use of population counts of *Arapaima* with little attention given to the quality of monitoring or regulation enforcement.

For improving the preparation of NDF procedures in other tropical developing countries, we highlight the utility of resource use approaches that are synergistic and participatory. The management system for *Arapaima* at the Mamirauá Reserve has been effective largely because the Mamirauá Institute, IBAMA, and local fishers have been collaborating in such a way that has overcome issues of lack of monitoring and management control capacity. There is increasing recognition worldwide that similar resource use approaches have already become essential elements of the fisheries management paradigm worldwide (Berkes et al., 2001; Castilla and Defeo, 2005; Orenzans et al., 2005) and in Brazil (Castello, 2008c). They could now be increasingly incorporated in broad-ranging arrangements such as CITES and NDF procedures.

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Appendix I

Questions related to main factors affecting *Arapaima* harvesting regime. Response values represent scores from 1 to 5 given to specific questions. Meanings of questions explained in Rosser and Haywood (2002).

Biology

Life history: What is the species' life history? 5) High reproductive rate, long-lived; 4) High reproductive rate, short-lived; 3) Low reproductive rate, long-lived; 2) Low reproductive rate, short-lived; 1) Uncertain

Ecological adaptability: To what extent is the species adaptable (habitat, diet, environmental tolerance etc.)? 5) Extreme generalist; 4) Generalist; 3) Specialist; 2) Extreme specialist; 1) Uncertain

Dispersal efficiency: How efficient is the species' dispersal mechanism at key life stages? 5) Very good; 4) Good; 3) Medium; 2) Poor; 1) Uncertain

Interaction with humans: Is the species tolerant to human activity other than harvest? 5) No interaction; 4) Pest ⁄ Commensal; 3) Tolerant; 2) Sensitive; 1) Uncertain

Status

National distribution: How is the species distributed nationally? 5) Widespread, contiguous in country; 4) Widespread, fragmented in country; 3) Restricted and fragmented; 2) Localized; 1) Uncertain

National abundance: What is the abundance nationally? 5) Very abundant; 4) Common; 3) Uncommon; 2) Rare; 1) Uncertain

National population trend: What is the recent national population trend? 5) Increasing; 4) Stable; 3) Reduced, but stable; 2) Reduced and still decreasing; 1) Uncertain

Quality of information: What type of information is available to describe abundance and trend in the national population? 5) Quantitative data, recent; 4) Good local knowledge; 3) Quantitative data, outdated; 2) Anecdotal information; 1) None

Major threats: What major threat is the species facing (underline following: overuse ⁄ habitat loss and alteration ⁄ invasive species ⁄ other: and how severe is it? 5) None; 4) Limited ⁄ Reversible; 3) Substantial; 2) Severe ⁄ Irreversible; 1) Uncertain

Management

Illegal harvest or trade: How significant is the national problem of illegal or unmanaged harvest or trade? 5) None; 4) Small; 3) Medium; 2) Large; 1) Uncertain

Management history: What is the history of harvest? 5) Managed harvest: ongoing with adaptive framework; 4) Managed harvest: ongoing but informal; 3) Managed harvest: new; 2) Unmanaged harvest: ongoing or new; 1) Uncertain

Management plan or equivalent: Is there amanagement plan related to the harvest of the species? 5) Approved and co-ordinated local and national management plans; 4) Approved national ⁄ state ⁄ provincial management plan(s); 3) Approved local management plan; 2) No approved plan: informal unplanned management; 1) Uncertain

Aim of harvest regime in management planning: What is harvest aiming to achieve? 5) Generate conservation benefit; 4) Population management ⁄ control; 3) Maximize economic yield; 2) Opportunistic, unselective harvest, or none; 1) Uncertain

Quotas: Is the harvest based on a system of quotas? 5) Ongoing national quota:based on biologically derived local quotas; 4) Ongoing quotas: ''cautious'' national or local; 3) Untried quota: recent and based on biologically derived local quotas; 2) Market-driven quota(s), arbitrary quota(s), or no quotas; 1) Uncertain

Control

Harvesting in Protected Areas: What percentage of the legal national harvest occurs in State-controlled Protected Areas? 5) High; 4) Medium; 3) Low; 2) None; 1) Uncertain

Harvesting in areas with strong resource tenure or ownership: What percentage of the legal national harvest occurs outside Protected Areas, in areas with strong local control over resource use? 5) High; 4) Medium; 3) Low; 2) None; 1) Uncertain

Harvesting in areas with open access: What percentage of the legal national harvest occurs in areas where there is no strong local control, giving de facto or actual open access? 5) None; 4) Low; 3) Medium; 2) High; 1) Uncertain

Confidence in harvest management: Do budgetary and other factors allow effective implementation of management plan(s) and harvest controls? 5) High confidence; 4) Medium confidence; 3) Low confidence; 2) No confidence; 1) Uncertain

Monitoring

Methods used to monitor the harvest: What is the principal method used to monitor the effects of the harvest? 5) Direct population estimates; 4) Quantitative indices; 3) Qualitative indices; 2) National monitoring of exports; 1) No monitoring or uncertain

Confidence in harvest monitoring: Do budgetary and other factors allow effective harvest monitoring? 5) High confidence; 4) Medium confidence; 3) Low confidence; 2) No confidence; 1) Uncertain

Utilization compared to other threats: What is the effect of the harvest when taken together with the major threat that has been identified for this species? 5) Beneficial; 4) Neutral; 3) Harmful; 2) Highly negative; 1) Uncertain

Incentives

Incentives for species conservation: At the national level, how much conservation benefit to this species accrues from harvesting? 5) High; 4) Medium; 3) Low; 2) None; 1) Uncertain

Incentives for habitat conservation: At the national level, how much habitat conservation benefit is derived from harvesting? 5) High; 4) Medium; 3) Low; 2) None; 1) Uncertain

Protection

Proportion strictly protected: What percentage of the species' natural range or population is legally excluded from harvest? 5) $>15\%$; 4) 5-15%; 3) $<5\%$; 2) None; 1) Uncertain

Effectiveness of strict protection measures: Do budgetary and other factors give confidence in the effectiveness of measures taken to afford strict protection? 5) High confidence; 4) Medium confidence; 3) Low confidence; 2) No confidence; 1) Uncertain

Regulation of harvest effort: How effective are any restrictions on harvesting (such as age or size, season or equipment) for preventing overuse? 5) Very effective; 4) Effective; 3) Ineffective; 2) None; 1) Uncertain