

Potential threat of the international aquarium fish trade to silver arawana *Osteoglossum bicirrhosum* in the Peruvian Amazon

Marie-Annick Moreau and Oliver T. Coomes

Abstract Silver arawana *Osteoglossum bicirrhosum* are increasingly popular on the international aquarium fish market, but the routine killing of mouth brooding adults to collect juveniles for the trade may threaten wild populations. We describe the aquarium trade and fishery for silver arawana in the Peruvian Amazon. This is the first such report on the species for South America, and is based on field interviews with trade participants and fishermen, and on a review of government statistics. The regional trade is large, expanding and valuable (over 1 million juveniles worth USD 560,000 exported in 2001), of considerable economic importance to the rural poor,

and in urgent need of research, monitoring and management. Outright bans on arawana fishing are likely to be ineffective and to destabilize an export fishery that provides significant part-time employment for the rural poor and substantial foreign earnings. Experimental studies are called for that compare the impacts on arawana yields of alternate fishing techniques, such as catch and release of brooding males, as a basis for developing more effective management schemes in Amazonia.

Keywords Amazonia, aquatic conservation, arawana, ornamental fish, Osteoglossidae, Peru.

Introduction

The global trade in aquarium fishes is a little studied yet valuable wildlife industry, estimated to have generated 3 billion USD in retail sales of fishes alone in 1999 (Olivier, 2001). Collection of wild fishes for the trade is known to have negative effects on certain species, as demonstrated by local population extinctions of freshwater aquarium species in South-east Asia (Banister, 1989; Ng & Tan, 1997) and declines in at least two South American species (Chao & Prada-Pedros, 1995; Crampton, 1999). The Asian arawana *Scleropages formosus* is one of only a few aquarium fishes whose international trade is restricted under CITES; it was listed on Appendix I in 1975 as a response to over-collection of juveniles and adults. Since the CITES listing trade in its close relative, the silver arawana of South America *Osteoglossum bicirrhosum*, has increased steadily (Tello & Cánepa, 1991; Ministerio de Pesquería, 2001).

O. bicirrhosum is one of only seven extant species of bony-tongue fishes (Family Osteoglossidae). Osteoglossids are restricted to tropical regions of Africa, Asia, Australia and South America, with *Arapaima gigas* and *O. ferreirai*, in addition to *O. bicirrhosum*, from South America (Moyle & Cech, 2004). Apart from *O. ferreirai*,

found only in the Rio Negro, the South American osteoglossids are widespread, occurring in the Amazon basin, the western Orinoco and the Rupununi and Essequibo systems of the Guianas, although not above cataracts (Goulding, 1980). Silver arawana (also called arowana or arowhana in English, *arahuana* in Spanish and *aruanã* in Portuguese) are found primarily in flood-plain lakes, where they are able to tolerate low oxygen levels (Val & de Almeida-Val, 1995). As water levels rise with the annual floods, arawana move laterally into the flooded forests (Lowe-McConnell, 1975). The fish is relatively sedentary, however, not engaging in migrations along the main river channels (Bayley & Petrere, 1989). It is a long, laterally compressed fish (maximum length of c. 1 m) covered in large, iridescent, bony scales, and is distinguished by its two chin barbels and a large, upwardly angled mouth (Goulding, 1980). A slow-swimming predator, arawana stay in well lit surface waters along the shoreline, feeding primarily on insects and spiders that fall in the water (Goulding, 1980). The species also eats crabs, fishes and snakes, and has earned the name water monkey for its habit of jumping out of the water to catch insects, birds on low branches, and even bats (Goulding, 1980).

Adult arawana spawn at low water, as flood waters are beginning to rise (Goulding, 1980). According to fishermen, juveniles (*alevinos*) become available c. 2 months later. Fecundity is extremely low, with females carrying relatively few, large eggs at spawning (180–210; Goulding, 1980; Val & de Almeida-Val, 1995). The male arawana provides parental care to the eggs and young,

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gathering the eggs in a special pouch in its mouth after fertilization. After the eggs hatch, the male continues to keep the larvae entirely in its mouth for up to 3 weeks (Schaller & Dorn, 1971). Only once the *alevinos* are 25–40 mm long and have absorbed their yolk-sac are they released from the male's mouth for occasional feeding, returning at the first sign of danger (Schaller & Dorn, 1971; Goulding, 1990). At 4–6 weeks young are left to fend for themselves (Goulding, 1990). Silver arawana are thought to reach sexual maturity after 2 years (Lowe-McConnell, 1975), with hobbyist web sites reporting that the fish can live for up to 20 years in captivity.

Silver arawana are seen as good luck symbols in Asian households and businesses, a belief that stems from the species' resemblance to the Asian arawana. In the 1970s Chinese and Japanese businessmen keeping the Asian arawana began associating the red and deep gold colouration of some specimens with the traditional colours of prosperity, sparking an Asian boom in the species' trade (Ng & Tan, 1997). International restrictions on the sale of Asian arawana followed, leading traders to develop captive breeding initiatives (Ng & Tan, 1997), to obtain wild specimens by illegal means (Matsumura & Milliken, 1984), and to shift to replacement species. The silver arawana serves this last purpose, having the same general shape as Asian arawana, a metallic colour associated with money, and the ability to eat prodigiously and grow rapidly in captivity, taken to symbolise wealth accumulation. The fish is also appreciated outside Asia for its size, graceful movements and prehistoric appearance. Juveniles are the preferred targets of trade, as they can be held and shipped at higher densities, and so at lower costs, than adults. In North America, based on an October 2005 internet search of aquarium fish retailer and hobbyist sites, silver arawana larvae with yolk sacs retail for 10–20 USD, 10–20 cm juveniles for 25–65 USD, and adults for 100 USD or more, depending on size.

Although the silver arawana shares many of the life history characteristics that make the Asian arawana vulnerable to overexploitation, i.e. late maturity, low fecundity and mouth-brooding, there is limited monitoring of the species and few trade controls in place. Here we argue, based on observations from the Peruvian Amazon, for the need to develop research and management plans for the silver arawana because of its vulnerability and regional economic importance. To our knowledge this is the first account of the conservation status, trade and fishery of *O. bicirrhosum*.

Study area

The Peruvian Amazon is a key supply region of *O. bicirrhosum* to international aquarium markets, with silver arawana also exported (probably in smaller quantities) from Brazil (64,750 individuals exported from

Manaus in 2003; N.L. Chao, pers. comm), Colombia and Guyana. Peru's Amazonian fish trade is centered on the city of Iquitos, capital of the Department of Loreto (Fig. 1). With >300,000 inhabitants Iquitos is the largest urban area in the Peruvian Amazon and the main market for most of the commodities produced or extracted in the region (Barham *et al.*, 1999; Kvist *et al.*, 2001). Iquitos is at the hub of an extensive river transportation network but lacks roads to the rest of Peru and commercial flights to international destinations. In 2001, 28 aquarium fish firms were established, drawing in supplies from at least 21 major rivers and exporting >9 million fishes (officially worth 2.5 million USD free-on-board, i.e. cost of goods before freight, packing and duties) to national and international clients in 24 countries, via Lima (Ministerio de Pesquería, 2001). The local export industry was first established in the 1950s, supplying small fishes (e.g. the neon tetra *Paracheirodon innesi*) primarily to North American markets, but declined precipitously in the late 1970s as a result of increasing competition from captive-breeders abroad (Hanek, 1982). The industry has experienced a resurgence since the early 1990s, due to local firms re-orienting their exports towards larger, higher-value species (including silver arawana) for Asian clients.

Few legislative controls are in place for the region's ornamental fisheries, and none relate specifically to the silver arawana. The main piece of national legislation on Peruvian Amazon fisheries (Reglamento de Ordenamiento Pesquero en la Amazonía Peruana, Ministerial Resolution No. 147-2001-PE) requires all fishermen of ornamental fish to be licensed, calls on collectors and traders to minimize mortality in transport and holding, and bans collection from the wild and sale of the fry and juveniles of 41 species also deemed to be important to the commercial food fishery. Silver arawana is not included on this list.

Methods

Data came from fieldwork conducted by MAM and a local research assistant in June–September 2002 as part of a study of the organization and livelihood role of the Peruvian Amazon aquarium fish trade. Semi-structured interviews (consisting of a set of open ended questions) were held with 12 representatives of 10 Iquitos export firms selected to reflect the range, both in size (i.e. trade volume and value) and market orientation (i.e. selling to national clients only, North America only, or more internationally) of export companies in the city. Initial information on firms' trade volumes and shipping destinations was obtained from the Ministry of Fisheries (Department of Loreto office). We also conducted fieldwork in and around the rural town of Requena, an

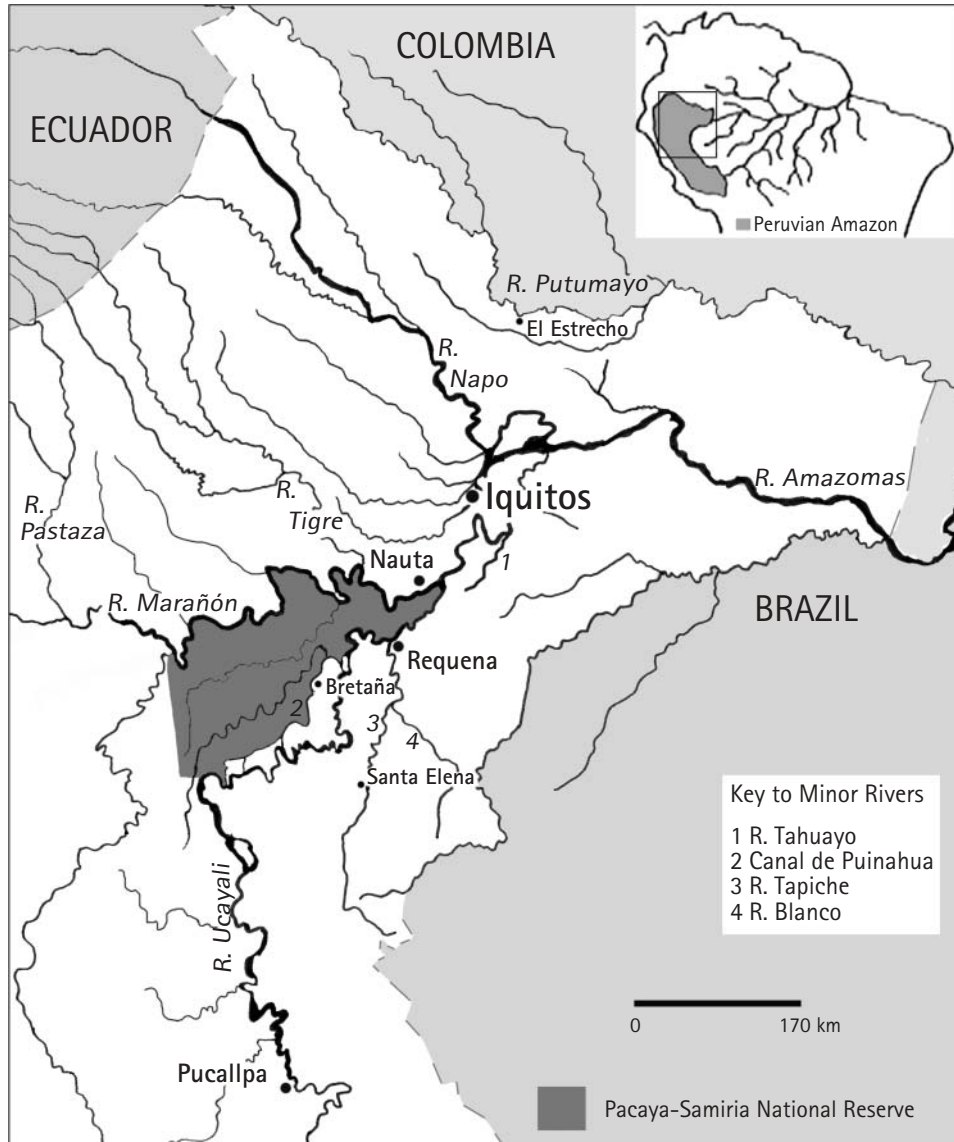


Fig. 1 The Peruvian Amazon showing key rivers and towns in the silver arawana trade.

important transit point on the Río Ucayali in ornamental fish supply networks. We interviewed two intermediary arawana traders established in Requena, one suggested to us by export firm representatives in Iquitos as a major supplier, and the other encountered on site. Additional information on the arawana fishery was collected in the course of a socioeconomic study of rural household participation in the ornamental fish trade, involving residents from the villages of San Juan (Río Tapiche, $n = 10$) and Isla Verde (Río Ucayali, $n = 26$), both located within 50 km by river of Requena (village names have been changed to preserve informants' anonymity). Households were selected for inclusion in the survey based on their livelihood means (making their living from natural resources and not salaried), length of establishment in the community (>6 months), and their

constitution as a family (an adult couple with at least one child). The study sample included 21 arawana fishermen, with an additional five arawana fishermen interviewed in the neighbouring village of San Miguel (Río Tapiche).

Descriptions of fish catches, fishing techniques and income earned are as reported to us by fishermen and traders, and could not be directly verified. Although interviews occurred 7–8 months after the start of the 2001–2002 arawana fishing season, recall bias is expected to be minimal as quantitative information asked of informants was straightforward (arawana are caught and sold in precise numbers) and associated with a vivid, punctual experience (fish are sold at high prices over a short fishing period). While no direct evidence is available to indicate whether 2001–2002 was a representative year for the fishery, none of the respondents, including fishers,

traders and government officials, indicated that the flood regime, prices or other market conditions were aberrant for the study year.

Documentary sources are used to complement the field data. Aquarium fish export figures compiled for the years 2000 and 2001 were obtained from the Ministry of Fisheries (Loreto). Export companies in Iquitos must obtain a permit from the Ministry prior to each aquarium fish shipment by completing a Certificado de Procedencia, with information provided on the forms summarized annually by the Ministry. The annual summary reports list, inter alia: the units and value of fishes received at firms, exported nationally and internationally by fish trade name and firm, the total units and sales value of aquarium fish exports by country and city, and export destinations. Although Ministry officials are meant to verify information provided by firms through inspections of shipments prior to regional export, interviewed exporters reported that most boxes went unchecked and that officials were usually unable to accurately identify fishes. Species identifications provided on certificates are therefore generally inaccurate, reflecting the poor state of knowledge of taxonomy in the trade, but also the purposeful mislabeling of fishes to export restricted species. Exporters also under-declare the value to reduce taxes paid on shipments, and under-declare the shipment volumes in anticipation of clients' deductions from the final payment for fishes arriving dead at destination (to avoid paying taxes on fishes that they will never receive payment for). This under-declaration in export trade may be at least 20% (Soregui & Montreuil, 1998). Here, export volumes are presented for the national and international trade combined, but export values are for the international trade only, due to the suspiciously high national export value figure reported in the 2001 statistics.

Trade volumes and values prior to 2000 were obtained from Hanek (1982), Tello & Cánepa (1991) and Soregui & Montreuil (1998), who obtained export statistics from the Ministry of Fisheries (Loreto). The currency conversion used here is 1 USD = 3.47 PEN.

Results

Scale and organization of the regional trade

In Peru exports of silver arawana for the aquarium trade have increased more than 100-fold since 1978, the earliest date for which data are available, from 0.07% of total regional trade volume to 11% in 2001 (Tello & Cánepa, 1991, Table 3; Ministerio de Pesquería, 2001). Increases in arawana exports parallel the increasing importance of Asian markets to the regional aquarium fish trade. In 1981 only 0.03% by volume of Iquitos' aquarium fish

exports was destined for Asia, compared to 19.8% in 2001 (Hanek, 1982; Ministerio de Pesquería, 2001). Arawana are a minor target of Peru's commercial food fishery, unlike in Brazil where the species is targeted by both commercial and subsistence fishermen. Peruvian Ministry of Fishery statistics indicated that arawana represented <1% of annual commercial fishery landings in Iquitos over 1980–1989 (Flores *et al.*, 1990) and was not among the 14 most popular species (in terms of quantities landed) harvested commercially in the Department of Loreto over 1986–1995 (de Jesús & Kohler, 2004). Prices for arawana as a comestible fish are low as other, more preferred fish are available on the market.

In 2001 aquarium export firms in Iquitos officially sold just over one million arawana juveniles to international clients at an average unit price of 0.55 USD, for a declared export value of 559,615 USD free-on-board. Actual trade volumes and values are probably higher (by at least 20%, see Methods). Arawana is the most commercially important species to the Peruvian Amazon aquarium trade, representing 42% of declared total international export value in 2001. The next most economically important species (the red tail catfish or *peje torre*, *Phractocephalus hemiliopterus* and the tiger-striped catfish, *Merodontotus tigrinus*) each account for only 5% of export value. Arawana is also the second most important species in the trade by total export volume, after the small armoured catfish *Otocinclus* sp. (29% of volume).

Arawana are unusual in the regional trade in that they fetch a relatively high unit price while being exported in large quantities (Fig. 2) and therefore export firms compete intensely for supplies. Most other species of aquarium fish are delivered to firms in Iquitos through a network of independent intermediaries (*proveedores* or *acopiadores*) who receive little or no financial support from exporters apart from the loan of holding boxes. During the supply season for arawana juveniles (October to April), however, some firms provide intermediaries with loans of fishing gear (even boat motors) and cash advances for equipping fishing expeditions and/or for purchasing arawana from local fishermen. Expeditions for ornamental fish occur year-round, but their number increases markedly in the arawana season as intermediaries organize their own group trips or sponsor another fisherman (*armador*) to do so. Up to 12 men participate as contract labourers on an expedition and are generally paid by the piece, at approximately half the price received by the fishing group leader from the sale of the catch. Intermediaries can also be bypassed entirely, with firms sending boats staffed with company buyers (*corredores*) to the fishing grounds, purchasing arawana directly from independent fishermen rather than risking that supplies delivered to Iquitos by intermediaries are too few to satisfy local demand among export firms.

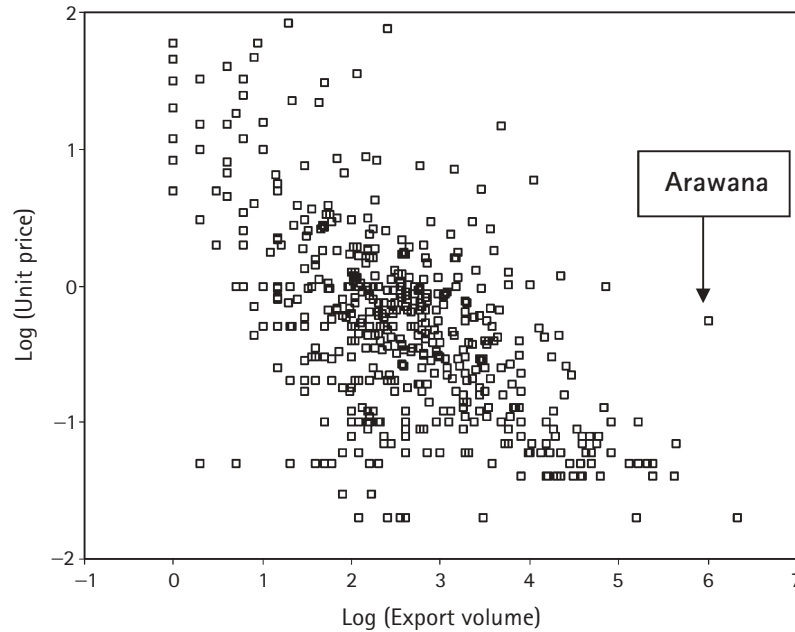


Fig. 2 Export price vs export volume, on logarithmic scales, showing the position of silver arawana relative to other aquarium fish varieties exported from the Peruvian Amazon in 2001 ($n = 502$).

Characteristics of the fishery

The principal fishing areas for silver arawana in the Peruvian Amazon are reported by informants to be the Tapiche and Blanco rivers, and the Río Ucayali in the area of the Puinahua canal and the Pacaya-Samiria National Reserve Area (Fig. 1). The towns of Breña, Santa Elena and Requena are key arawana trading outposts on these rivers, with *c.* 50 intermediaries established in Requena alone during the arawana season.

Reports of the organization of fishing trips and methods differed significantly between our study communities. Community members in Isla Verde describe fishing for arawana in small, kin-based groups (typically with 2–5 male members of the extended family), although at least once per season there is a communal fishing trip in which all willing male villagers participate. On communal trips villagers share in the boat and fishing gear provided by wealthier participants and split profits. To catch arawana, fishermen set large gill nets (*arahuaneras*, 10–12 cm stretched mesh size, 50–115 m long, 3–4 m deep) at the surface, retrieving by hand any adult arawana caught as it tries to swim through the net. Brooding adults are forced to release their young into plastic buckets, and are then released outside the net. Experienced fishermen reported that captured fish often bear scars from previous encounters with the gill net, suggesting that some released males survive to breed again.

Villagers living in San Juan and San Miguel, like many others in the area of Requena, regularly join expeditions to reach fishing grounds further up the Tapiche and

Blanco rivers. Expeditions set *arahuanera* nets to trap adult fishes, but will shoot or spear adults caught in the net before retrieving their juveniles, so as to ensure that the powerful, high-jumping fish do not get away, or swallow and kill their young in panic (see also Goulding, 1990, for a description of Brazilian fishermen killing male arawana prior to collection of young). Where gillnets are not available or cannot be used (e.g. in flooded forest) fishermen seek out arawana from their canoes, or from the vantage point of overhanging tree branches, and shoot or spear them. Arawana fishermen in San Juan and San Miguel who do not join expeditions, but instead collect small numbers of the fish independently, close to their village, also kill any adults encountered.

Such contrasts in arawana fishing practices probably reflect differences between property regimes on the fishing grounds of the Pacaya-Samiria National Reserve and Tapiche/Blanco rivers. Although the Reserve is public property the regional government has a duty to protect its natural resources and to promote the participation of local communities in sustainable use activities (Curichimba, 1998; Durand & McCaffrey, 1999). In the case of Isla Verde, villagers have the right to deny outsiders access to 36 lakes of the Reserve located near their community, and are allotted a harvest quota of arawana from these lakes, reported by a community leader to be 6,000 juveniles in 2001/2002, in exchange for participation in monitoring and guarding duties. A formal system of guardposts and patrols is meant to further limit outsiders' exploitation of the Reserve, with trespassers risking confiscation of their fishing gear. Under these conditions, arawana represent a defensible and

renewable resource to villagers, providing an incentive for using catch-and-release fishing methods. The reality may be less ideal than reported by fishermen because, in practice, the size of the Reserve, the limited staff and financial resources, and corruption, makes enforcement of regulations and management plans difficult. However, reports of fishing methods were consistent among interviews with different villagers and among repeat conversations with the same informants in Isla Verde, and corresponded to accounts of local arawana fishing methods given in a neighbouring village as part of an unrelated study (M. Manzi, pers. comm.). This would suggest that catch-and-release methods are in common (though perhaps not exclusive) use in Isla Verde.

In contrast to villagers living within or near the Reserve, fishermen established on the Río Tapiche compete for arawana resources on open-access fishing grounds. In addition to having no government presence, the upper reaches of the Tapiche and the Blanco rivers have few permanent settlements due to a lack of land suitable for agriculture (Bennett *et al.*, 2001), precluding community controls on resources. Informants frequently remarked that there were 'more fishermen than fish' on the fishing grounds, explaining that if they did not kill adult arawana encountered, someone else would.

According to informants the preferred season for fishing arawana in the supply zone of the Ucayali/Tapiche-Blanco rivers and the Reserve begins in late October or early November, as flood waters are rising and adult males have begun to brood hatched, viable young. Fishermen continue fishing arawana until early or mid-February, as waters approach peak levels (in March/April). Informants cited the increased difficulty in finding brooding adults (because fishes disperse into the greatly expanded flood zone) and falling prices (due to increase of supply of fish from other fishing zones) as reasons for stopping fishing. The first juveniles of the season are typically sold by independent fishermen to buyers in the fishing zone for 0.86–1.15 USD each, with prices dropping to 0.14–0.29 USD by January. On a good night of fishing, informants reported catching 2–3 mouth brooding males (known as *madres*), each having 90–200 juveniles. The reported maximum may be inflated, however, given reports of females only carrying up to 210 ova at spawning (Goulding, 1980; Val & de Almeida-Val, 1995). Intermediaries in Requena reported selling 3,000–15,000 juveniles per season (i.e. over 4 months), noting that supplies depended primarily on fishermen's luck in encountering brooders.

Fishing for arawana also occurs outside the main supply area. Closer to Iquitos, arawana are collected on a small scale from floodplain lakes of the upper Tahuayo river (J. Penn, pers. comm.). Exporters also seek supplies from further afield, following the spawning cycle of the

arawana as this coincides with the flood pulse. The first arawana shipments of the year come from the upper Ucayali (near Pucallpa, c. 1,100 km up-river from Iquitos) where waters begin to rise in September, peaking in February/March (C. Abizaid, pers. comm., based on data from the Dirección General de Transporte Acuático, Ministro de Transporte y Comunicaciones regional office at Pucallpa) and the last supplies for the season from the Río Putumayo (along Peru's border with Ecuador and Colombia) (Fig. 1). According to one fisherman/trader interviewed in Requena, his father is one of only two intermediaries permanently established on the Putumayo, although others travel there during the arawana season, basing themselves in El Estrecho, and he typically brings in 30,000–40,000 arawana juveniles over the fishing season. Given the distances involved, export firms with sufficient financial resources fly in the fish from these minor fishing zones, or send speedboats to collect them. International buyers also respond to the differential timing of the flood pulse along the Amazon River and its tributaries throughout the arawana's range in the basin, shifting their supply sources between Peru, Colombia and Brazil as juveniles become available in each country. Iquitos exporters generally do not keep arawana in stock out of season, as they are expensive fish to feed and because space in their facilities is limited.

Economic importance to rural households

The silver arawana fishery exerts a strong draw on rural fishermen in our study communities. For most households (64% of surveyed households in Isla Verde, 69% in San Juan), participation in the aquarium trade is restricted to the collection of arawana and juveniles of the *peje torre* only, the latter a relatively high-value (and easily caught) species whose preferred fishing season overlaps with that of arawana, and is readily bought by arawana traders. Households in our study villages are poor (mean annual income of 2,395 and 4,780 USD in the Isla Verde and San Juan samples, respectively), and arawana make a significant contribution to the income of many, though not all, households (Table 1). The capture of a single mouth brooding male represents cash earnings of 12–230 USD (depending on the market price and size of brood), whereas the daily wage in Isla Verde and San Juan is only 2–3 USD, and the mean annual daily household agricultural earnings are 2.80 and 4.20 USD, respectively. Kvist *et al.* (2001) similarly note that collection of arawana for the aquarium trade brings high daily incomes to villagers in their two study communities of the Pacaya-Samiria National Reserve, creating strong economic incentives for people to participate.

The attraction of arawana for rural villagers is due not only to its high price but also to the circumstances

Table 1 Participation rates, catches, earnings and economic reliance on the silver arawana fishery for sample households in Isla Verde and San Juan, Peruvian Amazon, 2001–2002. Catches and earnings are as reported by fishermen over a 1-year recall period (July 2001–July 2002), and as such are approximate (see Methods).

Characteristic	Isla Verde	San Juan
Village level		
Participation rate in the arawana fishery (% of village sample households)	90	48
Participation rate in the <i>peje torre</i> fishery (%)	80	46
Participation rate in the fishery for other ornamental fish (not including arawana or <i>peje torre</i>) (%)	10	35
Total annual village arawana catch (no. of juvenile fish)	9,230	27,950
Total annual village arawana earnings (USD)	5,271	14,942
Total annual village earnings for all economic activities (USD)	26,348	124,286
Household level		
Mean annual arawana earnings per participating household (USD) \pm SD (range)	586 \pm 575 (3–1,816)	1,149 \pm 959 (43–2,738)
Mean household economic reliance on arawana (% of annual income) \pm SD (range)	20.7 \pm 16 (1–47)	13.2 \pm 8.6 (2–32)
No. of village sample households	10	26

surrounding the fishery. Firstly, the arrival of large numbers of traders to arawana fishing grounds gives fishermen easier access to the aquarium fish market and competitive pricing among buyers that favour fishermen. Capital and financial inputs associated with the trade also increase opportunities for fishermen, as more expeditions are organized by intermediaries. Secondly, the arawana season coincides with the time of year when rural people are largely freed from other livelihood tasks (most agricultural lands are submerged, and food fish are too widely dispersed in the flooded forest to allow efficient fishing) and so have household labour to spare. Finally, the promise of receiving cash for the household is a major draw. Expedition fishermen commonly described arawana fishing as ‘thrilling’, and said that the fish ‘smells of money’.

Discussion

The Peruvian Amazon’s trade in silver arawana is large and growing, with local exporters confident that demand for the species will continue to increase as connections to the Asian market develop further. Firms in Iquitos are becoming more adept at directly marketing their fish to Asian clients, with at least five companies employing Asians in management positions, and some reportedly attracting direct investment from Japan and Taiwan. High demand for the species can be met by a large pool of potential fishermen as the rural poor are attracted to silver arawana not only for its economic value but also for the ease with which buyers can be found and the convenient timing of the fishery with respect to other livelihood activities. The trade has expanded to areas distant from Iquitos, an indication that supplies within

the usual fishing zone may be insufficient to meet current demand. The practice of killing reproductive adults and taking all their juveniles for the trade, as reported by informants on the Río Tapiche, is probably more common in the Peruvian Amazon than the catch-and-release method described by informants living within the Pacaya-Samiria National Reserve. Over most of their range in Peru silver arawana represent an essentially open-access resource, limiting the incentive to preserve reproductive males. The 20,600 km² Reserve is one of the largest protected areas in the Peruvian tropical lowlands, but represents only 3.7% of the region’s area (based on figures in Kvist & Nebel, 2001), and is inadequately protected. The major trading centres for the species are located outside protected areas, and each season receive an influx of fishermen and buyers that compete intensely for arawana.

The killing of reproductive males for the aquarium trade may threaten the fishery’s long-term sustainability. The species’ life-history characteristics (including unusually low fecundity) make it unsuited to heavy exploitation, with a minimum population doubling time of 4.5–14 years (Froese & Pauly, 2004), and as a predatory species high in the food web population size is limited in comparison to other fish species. Two osteoglossid species with similar biological traits are already listed on CITES to protect wild populations from collection for the aquarium and food fish trades, i.e. the Asian arawana and the *paiche* or *pirarucu* of Amazonia *A. gigas* (on Appendix II since 1975). No similar international trade restrictions are in place for the silver arawana, and little information is available on the status of wild populations in Peru or elsewhere in South America. *A. gigas* is categorized as Data Deficient on the IUCN Red List (IUCN, 2004), but *O. bicirrhosum* has yet to be evaluated.

Determining whether the aquarium fish trade poses a threat to Peru's wild silver arawana is a challenge, particularly in the context of the region's limited human and financial resources. Research to determine whether stocks are declining, as seems likely given the current levels of offtake, would need to be conducted over several years and in different fishing areas, and would need to determine whether exploitation for the aquarium trade is the primary cause of any decline or whether other factors (e.g. direct fishing for food fish, bycatch capture by other fisheries and habitat degradation/destruction) also act singly or jointly to reduce fishing yields (see Gerstner *et al.*, 2006, for an example from Peru). A more general approach, and one that could be more immediately applied to management, would be to determine experimentally the effect on arawana yields of different fishing techniques (e.g. with and without the killing of reproductive males) within selected fisheries that have a degree of resource ownership. Potential research sites include the Pacaya-Samiria National Reserve and the lakes of the upper Tahuayo river, where community-based initiatives to manage arawana stocks (through taxing catches) are already in place (J. Penn, pers. comm.). If results show that yields improve under certain fishing regimes, the next step would be to disseminate good practices to other communities.

Sustainable use of silver arawana populations should be the guiding management principle for this species. To ban the trade outright (particularly in the absence of supporting data on the conservation status of the species) would deny an important source of income to the rural poor, destabilize an export industry that is estimated to directly employ up to 14,000 people in Peru (M.-A. Moreau, unpubl. data) and that provides important foreign earnings to Amazonian countries, and would probably shift exploitation pressure to other vulnerable Amazonian aquarium fish species (e.g. the *peje torre* and river stingrays). Enforcing trade restrictions may be difficult in any case: representatives of firms reported that *A. gigas* juveniles continue to be exported illegally from Iquitos, either by exporters bribing officials or purposefully mislabeling shipments. Exporters in Brazil set self-imposed quotas on silver arawana exports in 2002/03 (300,000 juveniles), and the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis closed the fishery for the 2005/2006 season between 15 November and 15 March (Mendonça, 2005). Yet exporters must still contend with the purported large-scale smuggling into Colombia for onward export of ornamental fishes caught in Brazil (Chao & Petry, 2004) including arawana (N. Chao, pers. comm.).

Management efforts at the export level in the Peruvian Amazon could be usefully focused on increasing the government's capacity to monitor the trade accurately

(through better training of officials) and obtaining exporters' cooperation in supporting sustainably managed fisheries. Any management initiatives must, however, be based on a firmer understanding of the nature of the fishery and of the long-term consequences of the trade in silver arawana for both the resource and the resource users.

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