Biodiversity and Conservation **00:** 1–17, 2004.

Marine Ornamental Trade in Brazil

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Received 21 October 2003; accepted in revised form 13 April 2004

Key words: Aquarium reef trade, Brazil, *Condylactis gigantea*, Local extinction, Marine ornamentals, Reef fish

Abstract. Brazil is one of the five leading exporting countries of tropical aquarium fishes in the world, and the interest in marine ornamental organisms has increased substantially there from the mid to the late 1990s. About 120 reef fish species are currently harvested in Brazil's ornamental trade. Among the 75 most harvested species, 26 (34.7%) are endemic, eight (10.7%) are rare, and six (8.2%) are estuarine-dependent species. Fifty-five species (75.3%) have complex reproductive strategies and/or parental care. In quantitative terms, the top 10 species comprises 62% of the species exported from Brazil to the USA and the European Community. The most harvested reef invertebrates include about 65 species. The most representative groups are crustaceans with 15 species (23%), and molluscs and stony corals with 10 species (15.4%) each. Among these, 15 (23%) are endemics, nine (13.8%) are rare species, and seven (10.8%) are important reef builders. A case of local extinction of the giant anemone *Condylactis gigantea* is reported. To alleviate ecological impacts a series of urgent measures is suggested, including the creation of specific laws for marine ornamental harvesting and improving law enforcement to prevent illegal trade in Brazil.

Introduction

The global aquatic ornamental trade, including both freshwater and marine organisms as well as aquarium products, was worth about one billion US dollars in 1993 (Chapman et al. 1997). The marine portion accounts for 10–20% of the total value of the ornamental industry (Andrews 1990), comprising 4–10% of the fishes traded (Biffar 1997; Sadovy and Vincent 2002). Nearly all marine aquarium fish and invertebrate species are still harvested from the wild (Friedlander 2001; Wood 2001a), and the increase in collection rates leads us to dispute the sustainability of the marine ornamental trade. Due to the highly selective nature of this activity and to the large numbers of individuals collected, the potential for over-exploitation is high (Wood 1985, 2001a; Sadovy and Vincent 2002).

The global import value of marine fish and invertebrates for the aquarium trade is estimated to be US$ 24–40 million annually (Wood 2001a). Overall, this figure has apparently remained fairly stable in recent years. The USA is the main import market for aquarium species (marine and freshwater), followed by the European Community and Japan (Davenport 1996; Wood 2001a). Currently, as many as 24 million reef fishes belonging to about 1470 species are currently collected yearly to supply private and public aquaria around the world (Wabnitz et al. 2003). Marine ornamental species come from about 80 countries, the most important suppliers being Indonesia and the Philippines, but Brazil, the Maldives, Vietnam, Sri Lanka and Hawaii (USA) also supply impressive numbers (Wood 2001a; Sadovy and Vincent 2002).

During the last 5 decades, the Brazilian coast has experienced intense industrialisation and chaotic urban development, seriously affecting all coastal ecosystems including reef systems (Leão and Dominguez 2000). Other human economic activities have direct impacts on reefs, one of which is the harvesting of organisms for the ornamental trade. However, very few reports are available on this activity in Brazil (IBAMA 2000; Monteiro-Neto et al. 2000, 2003). The country is one of the five leading exporting countries of tropical aquarium fishes in the world (freshwater and marine), with exports worth US$ 3.5 million in 2000 according to the Brazilian Trade Ministry (Ministério do Desenvolvimento, Indústria e Comércio Exterior – http://www.mdic.gov.br). Even though most of the trade focuses on freshwater fishes, the interest in marine aquarium organisms has greatly increased in the last few years (Monteiro-Neto et al. 2000, 2003). In this paper the current knowledge on the marine ornamental trade in Brazil is synthesised for the first time, including selected data on the most harvested species. The most urgent management and conservation measures for these renewable resources are suggested.

Ornamental reef trade in Brazil

There are no official statistics on the ornamental marine trade in Brazil. The Global Marine Aquarium Database (GMAD – http://www.unep-wcmc.org/marine/GMAD) is one of the few sources of information. Although numbers are clearly underestimated (see below), the database is a useful tool to identify trends on fish and invertebrate organisms exported from Brazil to the USA and the European Community. For example, according to the GMAD, Brazil alone supplies one-third to almost half of the combined North American and European trade of many reef fish species (e.g. the angelfishes *Pomacanthus paru*, *Holacanthus tricolor*, *H. ciliaris*). However a huge discrepancy in numbers is found. For example, in contrast to the nearly 2200 French angelfish (*Pomacanthus paru*) reported in the GMAD as imported by the United States and Europe, export figures reported by Monteiro-Neto et al. (2003) for this species for the Ceará State only are over 10 times higher (22,969 – data come from the same years, 1995–2000). The general fish imports increased threefold from 1995–1997 to 1999–2000 according to GMAD, but exports from the Ceará State increased six- to eightfold in the same period.

About 120 reef fish species are currently in the aquarium trade in Brazil (IBAMA 2000; Monteiro-Neto et al. 2003; authors' personal observations 2003), and we present herein a list of the most harvested ones (Table 1, Appendix 1). In quantitative terms, species that rank among the most imported by the USA and the European Community are also found to rank among the most important species traded at four Brazilian States that we have information on (Table 1). In the Ceará State (NE Brazil) the top 10 species made up 72% of the total trade between 1995 and 2000 Monteiro-Neto et al. 2003). The same 10 species comprises 62% of the species exported from Brazil to the USA and the EU (Table 1).

For the number of species richness in the trade, the most representative families are wrasses (Labridae: nine species), damselfishes (Pomacentridae: eight), and angelfishes (Pomacanthidae) and butterflyfishes (Chaetodontidae) with five species each (Appendix 1). Among these four families, 26 species (34.7%) are endemics with five species still scientifically undescribed (''new species''). Eight (10.7%) are rare species, and six (8.2%) are estuarine-dependent species. Fifty-five species (75.3%) present particular reproductive strategies and/or parental care.

The most harvested reef invertebrate organisms in Brazil comprise about 65 species (Appendix 2). The most representative groups are the crustaceans with

Table 1. The most important reef fish species in the aquarium trade at four Brazilian States

Species	GMAD[a]	Ceará[b]	Pernambuco[c]	Bahia[c]	Espírito Santo[c]
Hippocampus spp.[d]	1	3	1	5	5
Gramma brasiliensis[d]	2	5	2	4	1
Holacanthus ciliaris	3	1	3	2	2
Centropyge aurantonotus[d]	4	8			4
Pomacanthus paru	5	2		3	7
Elacatinus figaro[d]	6	7		1	
Holacanthus tricolor	7	6	4		3
Acanthurus coeruleus	8	10			
Bodianus pulchellus	9				6
Pomacanthus arcuatus	17	4			
% of total trade	62%[e]	72%	NA	NA	NA
Year	1999–2001	1995–2000	1998–1999	2000	1999

The ranking of species at all sites follows that of the imports by the USA and EU from Brazil. Sources: (a) Global Marine Aquarium Database (http://www.unep-wcmc.org/marine/GMAD); (b) Monteiro-Neto et al. (2003); (c) IBAMA (2000); (d) Endemic to the Brazilian marine biogeographic province or to Brazil's coast plus the southern tip of the Caribbean; (e) The goldentail moray (*Gymnothorax miliaris*) figures in the top 10 GMAD list but was here excluded from the analysis because it was considered to represent an unusual shipment in the year 2000, since it is not among the top species in neither Brazilian State nor in other years searched in the GMAD; NA = data not available.

15 species (23%), and mollusks and stony corals with 10 species (15.4%) each. Among these species 15 (23%) are endemics, nine (13.8%) are rare species, and seven species (10.8%) are important reef builders. Only large gastropods are listed in Table 2, ■Au: Table 2 not provided, please check.■ but an equally important (if not larger) and specialised market is maintained by amateur and professional malacologists. This trade promotes intense gathering of several smaller gastropods and bivalves (R. Absalão, personal communication 2002).

Main harvesting areas

The six Brazil's States in which marine ornamentals are most heavily harvested are presented here from north to south along the coast, and briefly discussed below (Figure 1). In the northeast coast, the Ceará State is the major export site, the dealers receiving the production from neighbour States. A total of 199,304 reef fishes were traded through Fortaleza (main Ceará city) market from 1995 to 2000 (Monteiro-Neto et al. 2003). However, the Ceará State is also an important collecting ground, heavily harvested places including the "Pedra da Risca do Meio", a Marine Protected Area (Nottingham et al. 2000). The neighbouring Rio Grande do Norte State recently started to harvest seahorses, mostly from mangrove channels (Dias et al. 2002). Still in the northeast, the Pernambuco State suffers from severe overexploitation of reef organisms due to the easy access to the coastal fringing reefs (B.P. Ferreira, personal communication 2002). In the east, the Bahia State has four exporting facilities, the Baía de Todos os Santos being an important collection area close to main city, Salvador. There are 25 wholesalers licensed by the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) in these four northeast States (Figure 1).

In the southeast, the Espírito Santo State leads the harvesting of marine organisms. These are principally extracted from the many coastal islands, submersed rocky reefs and extensive calcareous algae (rhodoliths) beds. This state is the main producer of 'live rock', with 29 licensed wholesalers. Also in the southeast, the São Paulo State exported 184,070 fishes through 14 wholesalers between 1998 and 2000, according to official data. However, it has the distinction of being the only Brazilian State that created official rules for the ornamental trade, such as the establishment of collecting quotas and minimum standards for handling and transport of reef fishes (IBAMA 2000). There are 35 wholesalers licensed by the IBAMA in these two southeast States (Figure 1).

Harvesting methods

Inadequate and poorly adapted vessels from conventional and/or artisanal fisheries are largely used for collection of marine ornamentals. The boats are generally equipped with old 'narghile' gear (surface demand), usually in bad

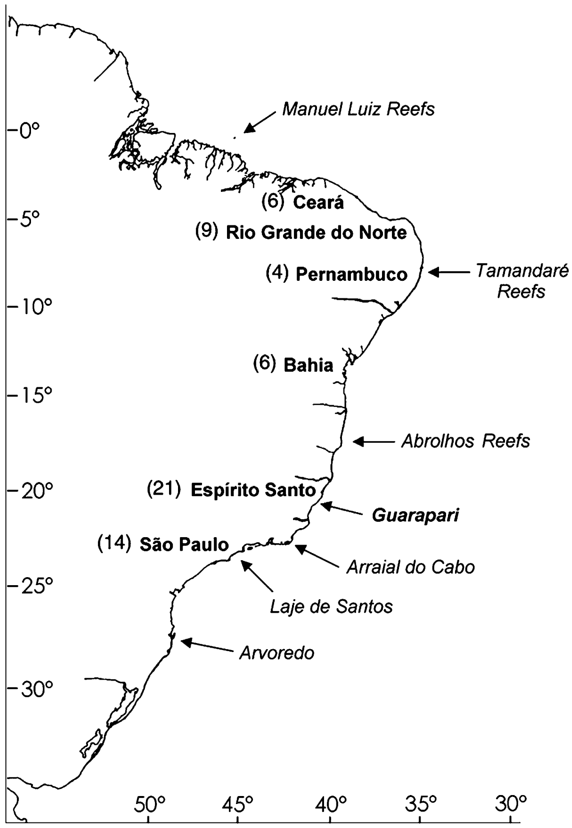

Figure 1. Main harvesting areas and sites sampled along the Brazilian coast. Main harvesting areas shown inside the continent with number of licensed wholesalers; sites sampled along Brazilian coast indicated with arrows; Guarapari Islands (collection site of data in Figure 2) shown in bold.

condition. The crew is often composed of three people, one controlling the air compressor and the other two diving (Nottingham et al. 2000). Hand nets are the main gear used for harvesting while underwater. At shallow sites, small-mesh cast-nets are sometimes used (small hand nets are used in tide pools, and cast-nets are used in mangrove systems). Invertebrates harvested for the ornamental trade are collected with hand nets or by hand. Those taken for the souvenir trade are pulled out manually (e.g. coral heads) or with the aid of iron bars (JLG personal observations 1991–1998). With few exceptions fishes are inadequately handled and stored. Poor water quality and handling, along with accompanying stress and disease are the causes of high mortality rates (see Wood 2001a; Sadovy and Vincent 2002). Mortality immediately after collection and in holding tanks prior to exportation is estimated to be at least 30–40% (JLG personal observations 1995–2003).

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Among the most harvested reef fishes for the aquarium trade in Brazil, nine species (12%) are also harvested for food or are caught as a by-catch by trawling. Six other species (8%) are subject to three different harvesting methods (Appendix 1). Twenty species (26.7%) are considered to suffer high harvesting pressure from the aquarium trade, based on their importance ranking in the trade (Table 1), price and/or rarity.

Among the reef invertebrate species, 14 (21.5%) are harvested by at least two different markets, aquarium and curio trade, 12 of which are considered to suffer from high pressure from one of these types of harvesting (Appendix 2). Five species (7.7%) are also caught as a by-catch product from trawling activities.

The impacts of harvesting

The effects of removing ornamentals on ecological processes are largely unknown. For example, angelfishes may represent a true 'keystone guild' (Hill 1998) and their effect on community structure might be greater than their numbers (abundance) suggest. Thus, the possible effects of widespread angelfish harvesting on reef communities should be seriously considered.

The fire corals (*Millepora* spp.) provide a good illustration of how collecting affects the physical structure of the reef. Collectors sometimes inadvertently break coral while attempting to corner a fish or prevent its escape (Wood 2001a). For example, the yellowtail damselfish *Microspathodon chrysurus* (Appendix 1) tends to dwell close to branching colonies of fire corals (*Millepora* spp.) and retreats within the branches when threatened, in a fashion similar to that recorded for the Indo-Pacific three-stripe damsel *Dascyllus aruanus* (Edwards and Shepherd 1992). In Brazil, extensive damage to the coral colony is frequently done while harvesting the yellowtail damselfish, as the corals are often deliberately smashed and fishes hiding amongst the branches are 'shaken out' into plastic bags.

Despite a dispersal phase at the planktonic larval stage, most coral reef fishes are rather sedentary after settlement and have a relatively small home range (Leis 1991; Friedlander 2001). Moreover, self-recruitment is considered important in some species (e.g. Leis 2002). Site fidelity is a serious problem when heavy harvesting is exerted on a small area for a long time, a problem aggravated by the selective removal of a few target species. We expect harvesting pressure to be lower in areas away from the coast, due to the progressive access troubles (local scale), and at marine protected areas along the coast (regional scale). To test this hypothesis, densities of angelfishes (Pomacanthidae, a highly targeted fish family by the ornamental trade) were censused at three sites with progressively greater distances from the coast near Guarapari, Espírito Santo State in SE Brazil. Replicated visual transects (20 m long and 2 m wide = 40 m^2) using SCUBA diving were performed in each site from January to April 2001 (details in Floeter 2003). Densities of the smaller size classes (juveniles and sub-adults) were greater at progressively greater distances from the coast (Figure 2). The trend we found is consistent with our suggestion that harvesting is greater in coastal areas and that it has the potential to reduce the overall abundance of the harvested species at local scales. These results are not to be confounded with natural variation due to habitat characteristics (authors' personal observations), since we also found that the larger size classes of these fishes (adults usually not targeted by the trade) were present in approximately equal numbers at the three sites, a strong indication that these species would be found in similar numbers at all sites were not for harvesting trade. The differences in Figure 2 exemplify the greatest pressure exerted upon the small size classes (more suitable for the trade).

On a larger scale pattern, we recorded differences in the relative abundance of the French and the grey angelfishes (*Pomacanthus paru* and *P. arcuatus*, respectively) along the Brazilian coast (Figure 3). Although a decrease in abundance with increasing latitude is expected for this spongivore-herbivore genus (Harmelin-Vivien 2002; Ferreira et al. 2004), sites that are not protected by marine reserves show much lower abundances than would be predicted by their latitudinal position.

Endemic species that present very restricted distribution ranges or small populations are especially vulnerable to local extinction (Hawkins et al. 2000). Even ornamentals from remote reefs or oceanic islands are not free from harvesting. For example, heavy collecting severely reduced the endemic

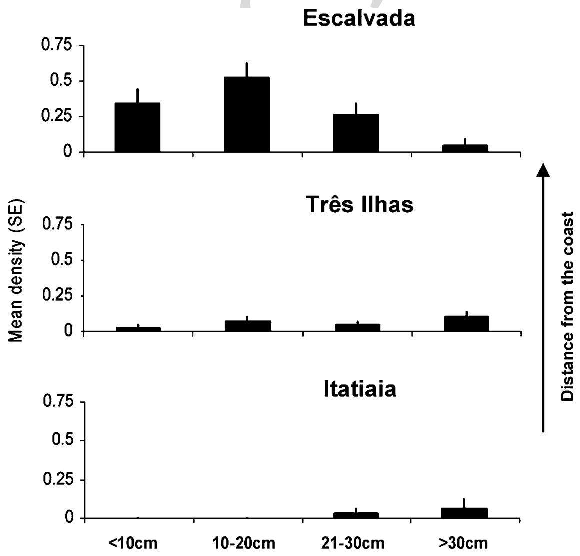

Figure 2. Angelfish (Pomacentridae) mean densities and standard error in four size classes at three island sites near Guarapari (Espírito Santo, SE Brazil). Fish were censused in strip transects of 20×2 m (Itatiaia, N = 39; Três Ilhas Archipelago, N = 72; Escalvada Is., N = 55). Distance from the coast: Itatiaia = 0.5 km, Três Ilhas = 3.5 km, Escalvada = 11 km.

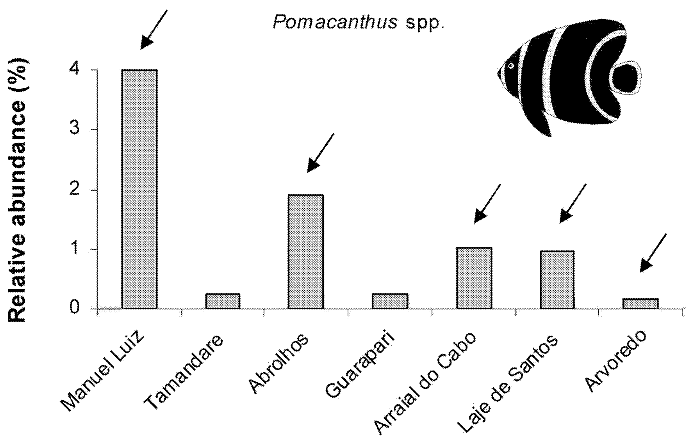

Figure 3. Relative abundance of French and grey angelfish (*Pomacanthus* spp.) along the Brazilian coast. Refer to Figure 1 for site locations and latitudes. Sites with arrows are marine protected areas. For site descriptions and details on sampling methods see Ferreira et al. (2004).

populations of the angelfish *Holacanthus clarionensis* at the Revillagigedos island group off the Pacific coast of Mexico (cf. Wood 2001b). Hobbyists frequently favour rarities and/or oddities (e.g. hybrids, distinctive colour morphs or deep-water species), as indicated by the high prices quoted for less readily available species (Sadovy and Vincent 2002). The unique colour morphs (e.g. wholly blue, yellow, or white) of the queen angelfish *Holacanthus* '*ciliaris*' from St. Paul's Rocks are currently the target of such specialised market in Japan (Luiz-Júnior 2003), achieving prices up to US$ 8900 (Hiroyuki Tanaka, personal communication 2004). If concentrated harvesting of endemic species will continue, and if the risk of extinction of these species will be increased by harvesting, current harvesting practices may well lead to decreased phylogenetic diversity in the long run.

Species with particular reproductive traits (including parental care) are the bulk of ornamental reef fish trade (75.3%). Sea horses (*Hippocampus* spp.), long-time favourites of aquarists, are additionally dried in large scale for the souvenir trade, use in folk medicine (Costa-Neto 1999; Warmolts 2000), and even witchcraft (authors' observations). About half of the male sea horses harvested for souvenir trade and traditional medicine in NE Brazil carry eggs in their brood pouch (Rosa, personal communication 2002). Intense harvesting is especially problematic for species with parental care since such exploitation may severely deplete or even wipe out local populations due to low recruitment rates. Additionally, the sea horses suffer greatly from habitat (estuaries and mangroves) pollution or destruction (e.g. landfill for human settlement).

Intensive harvesting may disrupt inter-specific associations such as cleaning symbiosis (review in Côté 2000). The conspicuous colours and small size of reef cleaners, instrumental in their cleaning role on the coral reef (Côté 2000), are their most sought-after features for the aquarium trade. Of the ca. 25 species of cleaner fishes and eight cleaner shrimps known from Brazil's coast, all the shrimps and at least 15 fish species are regularly harvested for the ornamental trade (Appendix 1 and 2). The two best studied cleaners in Brazil are the barber goby (*Elacatinus figaro*) and juvenile French angelfish (*Pomacanthus paru*), both of which clean numerous and varied client assemblages, from small herbivores to large carnivores (Sazima et al. 1999, 2000) including several economically important species for reef fisheries (groupers, snappers, jacks). A continuous harvesting of cleaner fishes and shrimps, as presently practised in Brazil, may cause an unbalance on the reef's inter-specific associations (e.g. Limbaugh 1961; Bshary 2003; Grutter et al. 2003). Specialised cleaners generally survive for a short time in aquariums due to their distinctive feeding habits, and thus experience a high turnover in the ornamental trade (Wabnitz et al. 2003; authors' personal observations). Harvesting pressure should be alleviated on all life phases of these specialised cleaners, as well as on the juvenile phase of the less specialised ones (Wood 2001b; Monteiro-Neto et al. 2003).

Effects of over-harvesting on ornamental organisms: a study case

Due to inadequate knowledge, and little understanding of local processes, effects of over-harvesting of ornamental organisms are unknown. The Arraial do Cabo region in Rio de Janeiro, SE Brazil, encompasses about 1500 km^2 of rocky shores and was declared a Managed Resource Protected Area in 1997. Before 1997 the ornamental trade strongly affected the region for more than 2 decades. Among the ornamental invertebrates found in Arraial do Cabo, the giant anemone *Condylactis gigantea* provides an example of the effects of over-exploitation. Its abundance before 1990 was about 1–2 individuals per 10–15 m^2 (CELF, personal observations prior to 1990). Each anemone (up to 40 cm wide) may harbour up to 10 cleaner shrimps. Giant anemones occur as solitary individuals, are oviparous and dioecious with a 1:1 sex ratio. They have lecithotrophic planktonic larvae with a presumably short life span in the plankton, and low fecundity (Jennison 1981; Chiappone et al. 2001). This anemone seems to be unable to sustain even a very low level of exploitation due to Allee effects, i.e. individuals became too sparse to achieve significant fertilisation success. At the peak of harvesting (in the early 1990s), about 100 individuals of the giant anemone were taken a day from the Arraial do Cabo reefs. After the collapse of ornamental marine resources in Arraial do Cabo, most collectors migrated northwards to the Espírito Santo State, where about 600 individuals are currently harvested each week (Afonso Jório, personal communication 2002). The last individual of *C. gigantea* in Arraial do Cabo was recorded about two years ago, despite continued, intense sampling effort (visual census sampling of approximately 6 h per week – CELF, personal observation 2000–2003). This may be the first documented case of local extinction of a relatively large marine organism due to over-exploitation by the ornamental trade in Brazil.

Conservation and management

There are no specific laws directed to the marine ornamental harvesting in Brazil and such laws are obviously needed to improve domestic fishery law enforcement as well as to prevent illegal trade. The following eight steps are suggested here as of foremost importance to support such law type: (1) Limit the number of licensed collectors and dealers; (2) Give priority to threat assessment of species subject to trade; (3) Establish species-based quotas; (4) Set size limits; (5) Promote adequate collecting methods and storage through the use of quality certifications; (6) Protect rare or key species; (7) Require monthly reports by the dealers; (8) Produce an illustrated guide of the most harvested species (Appendix 1 and 2) that would help officers and custom inspectors to recognise and monitor the trade. Stocks of target species need to be monitored on a reef-by-reef basis due to the variability in abundance of particular species at different localities.

The viability of current trade practices in Brazil should be disputed. Overall, there is a pressing need for basic information on the life history and population dynamics features of the organisms targeted by the marine ornamental trade. Combined with accurate trade data, such information is essential for making more informed decisions for a sustainable collection of marine ornamentals (Wabnitz et al. 2003).

The pressure exerted by the ornamental reef trade may be alleviated through public awareness and certification methods. A good model to follow is outlined in the Marine Aquarium Council's 'Core Ecosystem and Fishery Management Standard' (http://www.aquariumcouncil.org/), an international certification for the quality and sustainability of marine aquarium organisms trade. Model guidelines of this type, if adequately followed, fit well the suggestions made herein for the conservation and management of Brazilian ornamental species. Another important strategy for conservation is the establishment and enforcement of no-take areas, to protect stocks from the selective effects of ornamental and commercial harvesting (Bohnsack 1999). The limited home range and high degree of habitat specificity of many marine ornamental fish species would make the no-take zones a highly effective strategy for the management of these resources (Roberts and Hawkins 2000).

Acknowledgements

We express our most sincere thanks to D.A. Jório for historical information on the ornamental trade; UNEP-WCMC for providing data; J.-C. Joyeux, J. Van Tassell, N. Polunin, N. Dulvy, D. Vázquez, and I.R. Zalmon for critically reading the manuscript; B.M. Feitoza, C.L.S. Sampaio, T.L. Dias, I.L. Rosa (UFPB), M.E. Araújo and M. Nottingham (IMAT), B.P. Ferreira (UFPE/IBAMA – PE), S.M. Gandolfi, R. Absalão, L.J. Sik (IBAMA - ES), and H. Tanaka for unpublished data; V. Vidal, J. Yaber, C. Sazima, K.I. Gasparini, A.G. Floeter, R.C. Spindola, C.M. Musso, L.A. Rocha, N. Pimenta, W. Krohling, J. Gonçalves, R.B. Francini-Filho, R.L. Moura, A.P. Almeida, C. Bellini (TAMAR), J. Silva Jr. (Centro Golfinho Rotador), for helping in several ways; the Fundação O Boticário de Proteção à Natureza, Padi AWARE Foundation, IBAMA (CEPENE/CEPSUL), AVIDEPA, the Brazilian Navy, the IBAMA managers of Abrolhos and Fernando de Noronha National Marine Parks, the CNPq, FAPESP, FAEP-Unicamp, FINEP/PRONEX, UENF, and the National Center for Analysis and Synthesis for essential financial and other support.

Appendix 1. Reef fishes most harvested for the aquarium trade in Brazil, selected aspects of their biology, and harvesting methods (classification of fish families follows Nelson (1994))

Families and species	Reproductive biology[a]	Cleaning symbiosis	Harvesting methods
Ginglymostomatidae			
Ginglymostoma cirratum[b]	Internal fertilisation; live bearing		A, Sf, H
Narcinidae			
Narcine brasiliensis	Internal fertilisation; live bearing		A, T
Rhinobatidae			
Rhinobatus spp.	Internal fertilisation; live bearing		A, T
Zapteryx brevirostris	Internal fertilisation; live bearing		A, T
Muraenidae			
Gymnothorax miliaris			A
Ophichthidae			
Myrichthys breviceps			A
Myrichthys ocellatus			A
Bythitidae			
Stygnobrotula latebricola[c]	Live-bearer		A
Antennariidae			
Antennarius multiocellatus[b]	Nest guarding		A, T
Antennarius striatus[b]	Nest guarding		A, T
Ogcocephalidae			
Ogcocephalus vespertilio			A, T
Syngnathidae			
Hippocampus aff. *Erectus*[d,b]	Internal fertilisation; parental care		A+, S, T
Hippocampus aff. *Reidi*[d,b]	Internal fertilisation; parental care		A+, S, T
Microphis eigenmanni[d,b]	Internal fertilisation; parental care		A

Appendix 1. (Continued)

Families and species	Reproductive biology[a]	Cleaning symbiosis	Harvesting methods
Serranidae			
Epinephelus itajara[c,b]	Sex change, spawning aggregation		A, Sf, T, H
Liopropoma carmabi[c]			A+
Grammatidae			
Gramma brasiliensis[d]	mouth-brooder	occasional (J-A)	A+
Apogonidae			
Apogon americanus[d]	Mouth-brooder		A
Apogon planifrons	Mouth-brooder		A
Apogon pseudomaculatus	Mouth-brooder		A
Phaeoptyx pigmentaria	Mouth-brooder		A
Haemulidae			
Anisotremus moricandi[d]		Habitual? (J)	A, Sf, H
Anisotremus virginicus		Habitual (J)	A, Sf, H
Sciaenidae			
Equetus lanceolatus[c]			A+
Pareques acuminatus			A
Cirrhitidae			
Amblycirrhitus pinos			A
Chaetodontidae			
Chaetodon ocellatus	Spawning aggregation		A
Chaetodon sedentarius	Spawning aggregation	Occasional (A)	A
Chaetodon striatus	Spawning aggregation	Occasional (A)	A
Prognathodes brasiliensis[d]			A+
Prognathodes obliquus[d,c]			A
Prognathodes guyanensis[d]			A
Pomacanthidae			
Centropyge aurontonotus[d]	Sex change; harem		A+
Holacanthus ciliaris	Sex change	Occasional (J)	A+
Holacanthus tricolour	Sex change	Occasional (J)	A+
Pomacanthus arcuatus	Sex change	Habitual? (J)	A+
Pomacanthus paru	Sex change	Habitual (J)	A+
Pomacentridae			
Abudefduf saxatilis	Nest guarding	Occasional (J)	A
Chromis flavicauda[d]	Nest guarding		A+
Chromis jubauna[d]	Nest guarding		A+
Chromis multilineata	Nest guarding		A
Microspathodon chrysurus	Nest guarding	Occasional (J)	A+
Stegastes fuscus[d]	Nest guarding		A
Stegastes pictus[d]	Nest guarding		A
Stegastes variabilis	Nest guarding		A+
Labridae			
Bodianus pulchellus	Sex change; harem	Habitual (J), occasional (A)	A+
Bodianus rufus	Sex change; harem	Habitual (J), occasional (A)	A+
Halichoeres bivittatus	Sex change; harem	Occasional (J)	A
Halichoeres brasiliensis[d]	Sex change; harem	Occasional (J)	A

Appendix 1. (Continued)

Families and species	Reproductive biology[a]	Cleaning symbiosis	Harvesting methods
Halichoeres aff. *Cyanocephalus*[d]	Sex change; harem	Habitual (J)	A+
Halichoeres aff. *maculipinna*[d]	Sex change; harem	Occasional (J)	A
Halichoeres poeyi	Sex change; harem	Occasional (J)	A
Thalassoma noronhanum[d]	Sex change; harem	Habitual (J)	A
Xyrichtys novacula	Sex change; harem		A
Scaridae			
Scarus zelindae[d]	Sex change; harem		A, Sf
Sparisoma tuiupiranga[d]	Sex change; harem		A, Sf
Opistognathidae			
Opistognathus lonchurus	Mouth-brooder		A
Opistognathus sp. n.[d]	Mouth-brooder		A+
Labrisomidae			
Labrisomus cricota[d]	Harem; nest guarding		A
Labrisomus nuchipinnis	Harem; nest guarding		A
Malacoctenus sp. n.[d]	Harem; nest guarding		A
Blenniidae			
Ophioblennius trinitatis[d]	Nest guarding		A
Parablennius marmoreus	Nest guarding		A
Scartella cf. *cristata*[d]	Nest guarding		A
Gobiidae			
Elacatinus figaro[d]	Nest guarding; monogamous	Habitual (J-A)	A+
Microdesmidae			
Ptereleotris randalli[d]	Nest guarding		A
Acanthuridae			
Acanthurus coeruleus			A
Balistidae			
Balistes vetula	Nest guarding		A, Sf
Monacanthidae			
Cantherines macrocerus	Monogamous		A
Cantherines pullus	Monogamous		A
Ostraciidae			
Acanthostracion polygonius			A
Acanthostracion quadricornis			A
Tetraodontidae			
Canthigaster figueiredoi[d]	Monogamous		A
Diodontidae			
Cyclichthys spinosus[d]			A
Diodon holocanthus			A

(a) Reproductive biology associated with increased vulnerability to extinction; (b) Estuarine dependent; (c) Rare, defined as recorded in about 10% or less of dives at a given site, or dwelling in depths greater than 40 m (thus hardly available for collectors), or vagrant in a given area; (d) Endemic to the Brazilian Province or to Brazil's coast plus the southern tip of the Caribbean; Cleaning symbiosis: A = adult; J = juvenile; Harvesting methods: A = Aquarium trade; A+ = High pressure; S = Souvenir; Sf = Spearfishing; T = Trawling; H = Hook and Line.

Appendix 2. Invertebrates most harvested for the aquarium and souvenir trade in Brazil, selected aspects of their biology, and harvesting methods

Species	Biology	Harvesting methods
Cnidarians (Stony Corals)		
Favia gravida[a]	Reef builder	A, S
Madracis decactis		A
Meandrina braziliensis[a]		S, A
Montastrea cavernosa		S, A
Mussismilia braziliensis[a]	Reef builder	S, A
Mussismilia hartii[a]	Reef builder	S, A
Mussismilia hispida[a]	Reef builder	S, A
Porites branneri		S, A
Scolymia wellsi	Sand dweller	A
Siderastrea stellata[a]	Reef builder	A, S
Cnidarians (Fire Corals)		
Millepora braziliensis[a]	Reef builder	S+, A
Millepora alcicornis	Reef builder	S+, A
Cnidarians (Octocorals)		
Carijoa riisei		A
Heterogorgia uatumani[a]		A
Lophogorgia punicea[a]		A
Lophogorgia violacea[a]		A
Muricea flamma[a]		S, A
Muriceopsis sulphurea[a]		A
Phyllogorgia dilatata[a]		S+,A
Plexaurella grandiflora[a]		A
Plexaurella regia[a]		A
Cnidarians (Black Corals)		
Cirripathes spp.[b]	Deep reefs	S
Cnidarians (Sea Anemones)		
Actinoporus sp.		A
Alicia mirabilis		A
Bellactis ilkalysae	Shallow reefs	A
Condylactis gigantea [b]	Station for cleaners	A+
Discossoma spp.		A
Cnidarians (Zoanthids)		
Palythoa caribaeorum		A
Zoanthus spp.		A
Mollusks		
Cassis tuberosa		S, T
Charonia variegata[b]		S, T
Conus spp.	Venomous predator	A, S
Cyphoma macumba[a]		S
Cyphoma signatum		S
Cypraea zebra		S
Lyropecten nodosus		S
Octopus vulgaris	Key predator on crabs	A
Spondylus americanus		S+
Strombus gigas[b]		S+, T

Appendix 2. (Continued)

Species	Biology	Harvesting methods
Polychaetes		
Spirobranchus spp.		A
Crustaceans		
Brachycarpus cf. *biunguiculatus*	Cleaner?	A
Calcinus tibicen		A, T
Cinetorhynchus rigens		A
Dardanus venosus		A, T
Hoplometopus antillensis[b]		A+
Lysmata grabhami[b]	cleaner	A
Lysmata wurdemanni[b]	cleaner	A
Periclimenes aff. *pedersoni*[b]	Cleaner	A
Periclimenes aff. *yucatanicus*[b]	Cleaner	A
Petrochirus diogenes		A, S
Platypodiella spectabilis		A
Stenopus hispidus	Cleaner	A+
Stenopus scutellatus[b]	Cleaner	A
Stenorhynchus seticornis	Cleaner?	A+
Thor aff. *amboinensis*[b]	Cleaner?	A
Echinoderms		
Astrophyton sp.		A
Echinaster spp.		A
Echinometra lucunter	Key herbivore	S
Eucidaris tribuloides	Key herbivore	A+, S
Linckia guildingii		A
Meoma ventricosa		S
Narcisia trigonaria		A
Ophioderma spp.		A
Oreaster reticulatus		S+
Tripneustes ventricosus		S

(a) Endemic to the Brazilian Province; (b) Rare, defined as recorded in about 10% or less of dives at a given site, or dwelling in depths greater than 40 m (thus hardly available for collectors), or vagrant in a given area; Harvesting pressure: A = Aquarium trade; A+ = High pressure; S = Souvenir trade; T = Trawling.

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