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Status of the Marine Aquarium Fishery in Galle and Matara Districts

CENARA Reports: Marine Aquarium Fishery, south coast 2009

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Executive Summary

The marine aquarium fishery in Sri Lanka has been in existence for more than 70 years (Wabnitz et al., 2003). Presently this fishery is carried out in all coastal areas of the country except in northern coastal waters. All indigenous species are wild caught from reef areas. The current value of the marine aquarium sector of the ornamental fish industry is estimated to be about US \$ 4 to 5 million annually. Wood (1996) reported that about 250 species of fish and about 50 species of invertebrates are utilized by this industry. These numbers have increased in the recent past and at present about 330 species of fish and about 50 species of invertebrates are exported from Sri Lanka (De Alwis, 2007). Marine aquarium species are exported mainly to western countries. Three main operational components constitute the industry, namely fish collectors, suppliers and exporters. It is believed that about 1000 fish collectors, both scuba divers and snorkelers are engaged in this fishery island-wide. About half of them live in the southern coast within Galle and Matara Districts. The number of individuals that are engaged as aquarium keepers, packers, boat operators, compressor operators etc. is yet to be determined. Habitat damage to coral reefs due to fish collecting and over collection of aquarium species have been attributed to this industry (Wood, 1985; 1996; Mee, 1993; Beets, 1994). Some of these studies created the misconception that the collection of aquarium fish is the main cause of coral reef damage in the country, while the habitat quality was affected by a combination of natural and many human impacts extraneous to the activities of the marine aquarium fishery. The government of Sri Lanka introduced regulations to protect several species under the Fauna and Flora Protection Ordinance (GOSL, 1993) and the Fisheries and Aquatic Resources Act (GOSL, 1996). Because of the large number of species used by the industry it requires to be managed on the basis of individual species or species groups taking into consideration their ecological requirements, abundance and the rate of harvesting. However, the management authorities lacked information on the above aspects. The primary goal of the studies on the marine aquarium fishery of the CENARA project is to obtain the necessary data for adaptive management of the fishery.

The survey was conducted in March 2009 from Unawatuna in the Galle District to Polhena in the Matara District. Information derived from the coral reef monitoring studies of NARA (Rajasuriya and De Silva, 1988; Ohman, Rajasuriya and Svensson, 1998; Rajasuriya Ohman and Svensson, 1998; Rajasuriya, 2005) and reports from Wood (1985, 1996) were used to select the study area. The survey was designed using GIS and 150 sites were randomly selected within the two districts in a reef area of 61,768 square meters. Sampling was carried out by snorkeling and scuba diving. Data was collected using the Fish Belt Transect method to record the abundance of selected aquarium fish species and the Point Intercept Transect method to collect data on benthic cover and a two meter belt transect to record the abundance of large invertebrates. In addition, focused interviews were carried out with the primary stakeholders to obtain data on catch and effort and information about the fishery. A major difficulty was encountered in the collection of catch data as the collectors and suppliers were concerned about providing this information as they believed that the data will be used to ban the fishery or bring in various regulations and taxation.

The CENARA Data Systems Standard operating procedures were used to enter and analyse data. Abundance and the maximum sustainable yield for a total of 66 species were calculated and the total allowable catch (TAC) was estimated with 90% upper and lower confidence intervals.

Results show that the shallow coral reef habitats were highly degraded with a live hard coral cover of 23% in the Galle District and 21% in the Matara District respectively. The percentage of coral rubble was very high in both districts with 21% in Galle District and 22% in the Matara District respectively. The main causative factors of reef degradation were identified as the 1998 coral bleaching event and the impact of the 2004 tsunami coupled with various other human activities including the marine aquarium fishery, pollution and sedimentation due to poor landuse practices. The degradation of the habitat and the continued extraction appear to have a negative impact on several species. Some of the highly sought after species by the aquarium trade are in relatively low abundance, particularly the Powder blue surgeonfish (*Acanthurus leucosternon*), Orangespine unicorn surgeonfish (*Naso lituratus*) and some butterflyfish species (Chaetodontidae). Importantly, none of the presently protected species of aquarium fish were recorded and only 5 species listed under the restricted export category were recorded.

Holding facilities of some suppliers were not properly maintained with several species of fish kept together in relatively small containers and tanks. Stress and mortality can be avoided by improving these facilities with adequate space and by appropriate handling of the specimens. It was also observed that the collectors still use the banned 'moxy' net and that many snorkelers damage the little coral that is present on the fringing reefs. Only a few collectors had licenses and snorkelers in particular lacked the permits to fish. The main issues raised by the stakeholders were the increasing number of collectors leading to over-harvesting, some of the inexperienced collectors were causing habitat damage and the collection of large breeding sized individual specimens reduced the reproductive potential of the stocks. Problems related to the use of scuba in deep water are relatively low in the southern coast, nevertheless it is important to educate divers on this aspect.

As the marine aquarium fishery is directly affected by the quality of the reef environment, the fishery has to be managed taking into consideration all other impacts on the marine habitats. Therefore management has to be addressed not only with the stakeholders of the aquarium industry but with other users and abusers of the marine environment and the local government authorities that is responsible for pollution management and issuing of permits for coastal development. The main issues and management opportunities are listed below.

Issues]	Recommendations & Management opportunities
•	The study revealed that some species that are important for the industry are in low abundance as their TAC is very low. (Intense harvesting of these species may result in their populations falling below a recovery stage).	•	Discuss with all stakeholders and inform them of the current status of these species, especially in the light of serious habitat degradation. Harvesting should be carried out cautiously adhering to the 'precautionary principal' when harvesting species with low stock sizes.
•	None of the 'Protected species' were recorded	•	Retain the currently protected species in Part 1 of the schedule under the Fisheries and Aquatic Resources Act of 1996.
•	Only 3 species listed in the 'Restricted Export' category was recorded indicating that many other species are also uncommon.	•	Re-evaluate the status of these species with surveys conducted in the northwestern and eastern coastal waters. Consider the possibility of shifting very rare species listed in the 'Restricted Export' category to the 'Protected species' list whilst species that are not under threat of over-exploitation should be considered for de-listing. (This should be carried out with caution and by comparing the results of the

			studies in the east and northwestern waters).
•	Collection of very small size classes of fish. (This is harmful as small juveniles of many species do not survive in captivity).	٠	Discuss with the exporters and agree on minimum size classes.
•	Collection of very large size classes of fish. (These size classes are classified as 'extra-large' and are collected to cater to special orders for public aquaria. This is harmful as breeders are caught and exported. They are difficult to pack and travel poorly. Some tend to die during transit from collecting sites).	•	Discuss with the exporters. Discourage the export of breeders.
•	Use of moxy nets and other fishing methods that cause habitat degradation. Removal of corals to collect <i>Gobiodon citrinus</i> Over-exploitation of fish stocks Spear fishing, especially groupers that maintain the habitats of the scarlet shrimps (<i>Lysmata debelius</i>) and painted shrimps (<i>L. amboinensis</i>)	•	Implement the existing regulations. Strengthen the monitoring systems for illegal and destructive fishing. Include <i>Gobiodon citrinus</i> in the list of protected species in order to prevent fish collectors from damaging the coral habitat. Discuss with exporters and collectors and establish a 'code of conduct' using best practices to prevent habitat damage due to collecting. The fish collectors should be educated on the role of the groupers in maintaining the habitats of the reef shrimps (<i>Lysmata</i> spp.) and also of the fact that spear fishing is banned in Sri Lanka under the Fauna and Flora Protection Ordinance.
•	Inability to obtain catch data from the collectors and suppliers. (It is important to obtain catch data from different areas because species and abundance can vary depending on locations).	•	Catch data can be obtained from the record books maintained by every supplier. To obtain this data it is necessary to establish a system through the network of fisheries inspectors. A logbook can be supplied by the DFAR to each Assistant Director in charge of the different districts where the catch can be entered.
•	Lack of registration of fish collectors and their operational and gear licenses. Lack of registration of suppliers.	•	The network of fisheries inspectors of the DFAR in each district can be used to register all fish collectors. All the suppliers should also be registered although most are not actively engaged in collecting specimens. The registration of the suppliers should be linked to the data collection system.
•	Lack of suitable holding facilities and improper handling of specimens.	•	Conduct awareness programmes for suppliers on the proper maintenance of holding facilities. Conduct awareness programmes for collectors and suppliers on the proper handling of specimens. Develop a set of guidelines and best practices for holding facilities, handling and packing of specimens.
•	Habitat degradation due to natural causes such as coral bleaching, storms etc.	•	Improve the protection of coral reefs to enhance their resilience to perturbations.
•	Habitat damage and alteration due to human	•	Implement the existing regulations through the

activities such as destructive fishing, pollution etc. (Ecosystems recover from serious damage if they are resilient to perturbations and if chronic negative impacts are absent).	 relevant government organizations to prevent the use of destructive fishing methods and illegal activities such as coral mining and illegal construction. Seek the assistance of the Coast Guard Department to eliminate destructive fishing such as blast fishing. Conduct awareness programmes for all stakeholders including the local government authorities to impress that the health of the costal waters and reef habitats is critically important and that pollution from the towns and cities as well as other industries need to be managed.
• Lack of fish refuges to support breeding populations.	• Identify reef patches that can be set aside as fish refuges. This has to be done together with the primary stakeholders and the responsibility of caring for such areas should be vested with the primary stakeholders through the fisheries management committees.

Introduction

The marine aquarium fishery has been in existence in Sri Lanka since the 1930's (Wabnitz et al., 2003). The present value of the marine ornamental sector of the aquarium fish industry is believed to be about 40% -50% of the total

value of the ornamental fish sector which is about US \$ 9 million annually. Marine aquarium fish are collected by snorkeling and scuba diving in western, southern and eastern coastal waters of Sri Lanka. Aquarium fish collecting is carried out in the non-monsoon periods when the sea is calm and clear. Some fish collecting was done around the islands of the Jaffna Peninsula prior to 1985, but due to the internal conflict this area became out of bounds and collecting activities has not commenced yet. The southern coastal reefs are an important source of aquarium species such as butterflyfish (chaetodontidae), angelfish (Pomacanthidae), wrasses (Labridae), gobies (Gobiidae), damselfish (Pomacentridae), groupers (Serranidae), blennies (Blennidae), surgeonfish (Acanthuridae) and many species of invertebrates including the scarlet shrimps (*Lysmata debelius*) and painted shrimps (*L. amboinensis*).

The fishery in the southern coast is conducted during the calm season from October to March. Aquarium species are collected by snorkeling among shallow inshore reefs and by scuba diving on offshore reefs to a depth of about 40m. Over the years an increase in the number of species and volume has been recorded. Wood (1996) reported that about 250 species of marine fish and about 50 species of invertebrates were exported in the 1990's. In a recent study, De Alwis (2007) reported that about 343 species of reef fish and around 50 species of invertebrates are exported at present, but this number also includes species that are imported for re-export. The industry operates at three basic levels; namely, aquarium fish collectors, suppliers and exporters. Although a complete census of all the fish collectors have not been done, it is believed that there are about 1000 individuals engaged in this activity island wide. At present there are about 500 aquarium fish collectors in the southern coastal areas from Galle to Matara. The number of individuals employed as aquarium keepers, packers, boat operators, compressor operators etc. have not been determined. Habitat damage to coral reefs due to fish collecting and over collection of aquarium species have been attributed to this industry (Wood, 1985, 1996; Mee, 1993; Beets, 1994). The earliest comprehensive study of the marine aquarium fish industry in Sri Lanka was carried out by Wood (1985). Thereafter Mee (1993) and Beets (1994) followed with an overview of the industry. Wood (1996) published management needs for the industry in Sri Lanka, based on a study conducted with the National Aquatic Resources Research and Development Agency. All of these studies pointed out that there is a need to manage the marine aquarium fishery and recommended to establish a quota based management system for the industry and to establish no-take zones and to protect rare and vulnerable species.

The Department of Fisheries and Aquatic Resources is responsible for the management of the marine aquarium fishery. In addition the Department of Wildlife Conservation is responsible for the protection of rare and vulnerable species as well as the custodian of marine protected areas. Regulations were gazetted under the Fauna and Flora Protection Ordinance (GOSL, 1993) and the Fisheries and Aquatic Resources Act (GOSL, 1996) to protect and control the export of several species considered as rare and vulnerable to over-exploitation. Although there has been a need to manage the fishery there is a lack of information for the management of individual species. The abundance of species is directly affected by the changes that occur to habitats and fishing pressure as well as natural mortality. Hence management measures have to take into consideration the dynamism of the above aspects. The marine aquarium fishery study of the CENARA project is designed to obtain the required information for adaptive management of the fishery.

Materials and methods

Survey Design

Fringing reefs are common along the southern coast of Sri Lanka. They occur as a narrow belt of coral, sandstone/limestone and rock reef habitats (Swan, 1983; Rajasuriya and De Silva, 1988). The majority of these fringing reefs extend about 500m offshore. Beyond this area there are patches of rock and sandstone/limestone platform reefs. The selection of survey areas were based on studies carried out by by the coral reef monitoring programme of NARA (Rajasuriya and De Silva, 1988; Ohman, Rajasuriya and Svensson, 1998; Rajasuriya, Ohman and Svensson, 1998; and Rajasuriya, 2005) and reports from Wood (1985, 1996). As the majority of fish collecting is carried out in the inshore reefs the study area was restricted to the fringing reefs. Areas devoid of fringing reefs were excluded from the survey area. The survey area was dived into 4 sections; from Unawatuna to Habaraduwa (section A), from Midigama to Weligama (section B), Mirissa (section C) and from Bandaramulla to Polhena (section D) (Fig. 1).

The fringing reefs were further divided into two depth classes based on reef zonation. In the majority of these fringing reefs the back reef, reef crest and the upper reef slope extend from the shore to a distance of about 300m and the depth varied from 1 to 3m. The seaward reef slope extended approximately another 200m to a depth of about 10m. The survey was designed using GIS. The estimated total reef area in the Galle District was 28,445 square meters and 33,323 square meters in the Matara District. Using GIS, 150 randomly distributed sites were generated within the reef areas in Galle and Matara Districts. There were 73 and 77 sites in the Galle and Matara Districts respectively (Fig. 2).



Figure 1. Survey area from Unawatuna in Galle District to Polhena in the Matara District



Figure 2. Survey sites (sampling points) in Galle and Matara Districts.

Field sampling

The survey was carried out in March 2009. Each site was surveyed to collect three sets of data on the substrate, aquarium fish and megabenthos (large invertebrates). In addition site details such as depth, location on the reef, sampling time, current intensity and weather were recorded. Reef substrate was sampled using the Point Intercept Transect method (PIT) along a 50m tape laid on the reef. Substrate was recorded at 75 points along the 50m transect by dividing the transect into three 10m sections and by recording the substrate at 25 points in each section along the first, third and fourth sections of the transect (modified from English et al., 1997). Large invertebrates (Megabenthos) such as starfish, lobsters, large molluscs occurring within 1m on either side of the 50m long transect were also recorded.

Marine aquarium fish were recorded using the fish belt transect method (English et al., 1997) along the 50m transect used for the PIT covering an area of 250 square meters (2.5m on either side of the 50m tape).

A pair of divers collected data at each site. One diver collected substrate and megabenthos data while the other recorded the abundance of aquarium fish along the transect. Thirty minutes were allocated to complete each fish belt transect in order to standardize the time spent to record fish at each site. Two pairs of divers collected data at two sites simultaneously. Data was recorded on underwater slates and transferred to MS Excel data entry workbooks.

Species that are currently protected and exported under permits were given special consideration in the study (appendices 7 & 8). Their presence was noted even if they occurred outside the fish belt transect. Cryptic species such as gobies, blennies and some species that live in caves and ledges were recorded, however, their abundance may be affected by their cryptic behaviour. Similarly reef shrimps (*Lysmata debelius* and *L. amboinensis*) were not sampled in this study because they are highly cryptic and live in holes in the reef structures at a depth of 25 to 30m.

Moreover, it was impractical to sample *Lysmata debelius* and *L. amboinensis* due to limitations imposed by problems associated with scuba diving in deep water.

Sampling was carried out by snorkeling in shallow reefs less than 3m depth while all other sites were sampled using scuba. A total of 142 sites were sampled for aquarium fishes, substrate and megabenthos. Eight sites out of the 150 survey sites could not be sampled as they were in inaccessible locations such as the middle of rock outcrops or wave zones in the reef crest.

Collection of fishery data

Data was collected on the operational aspects of the fishery by focused interviews with fish collectors and suppliers at the village level and by interviewing several exporters. There was difficulty in obtaining catch and effort data as the fish collectors and suppliers were reluctant to provide this information as they believed that the data will be used to ban the collection of some species and that they might be subject to income tax. De Alwis (2007) also reported on the difficulty in obtaining catch data.

Data Analysis

The CENARA Data Systems Standard Operating Procedure (SOP) included MS Access queries to join the various worksheets in the Excel Data Entry workbook and to export the data for input into SPSS scripts where standing stock calculations were performed (CENARA Data Operations SOP, 2009).

The output from SPSS was entered into an Excel workbook for final formatting before being copied and pasted into this report.

Total Allowable Catch

The total allowable catch (TAC) for each species was calculated using the formula $TAC = MSY \times Estimated$ mortality of an exploited stock (estimated at 0.5). This calculation was adopted with the assumption that the populations of reef fish are under high collecting pressure at a time when the reef habitats are also highly degraded due to the combined impacts of the unprecedented coral bleaching event of 1998 and the impacts of the tsunami in 2004 coupled with anthropogenic impacts such as pollution and increased sedimentation due to poor land use practices. Thus the calculated TAC is highly conservative and designed to prevent the overexploitation of species. Although the TAC can be based on the standing stock, the upper or lower 90% CIs, in order to protect species with a low abundance the TAC should ideally be based on the lower 90% CI for each species as variations in the patterns of spawning, recruitment and predation can also affect the populations.

Results

Standing stock estimates

The standing stock presented in appendices 4 & 5 contain the abundance of the recorded species, the maximum sustainable yield (MSY) and the total allowable catch (TAC). A total of 66 species of aquarium reef fish were recorded divided among 20 families and 38 genera (Fig. 3). None of the marine fish species protected under the Fisheries and Aquatic Resources Act and the Fauna and Flora Protection Ordinance were recorded during this survey. Two species of butterflyfish (Chaetodontidae), one species of pygmy angelfish (Pomacanthidae) were the only 3 species that were recorded from a total number of 17 species listed in the 'Restricted Export' category in the Fisheries and Aquatic Resources Act of 1996.



Figure 3. Families, Genera and Species of aquarium fish recorded in Galle and Matara Districts.

Galle District

The abundance, maximum sustainable yield (MSY) and the total allowable catch (TAC) is given in appendix 4. The most abundant species in the Galle District were damselfish; *Neopomacentrus asyzron, Abudefduf vaigiensis* and *Pomacentrus similis* with an estimated abundance of 4,202,918, 2,276,756 and 1,931,662 individual fish respectively. The TAC for these three species of damselfish is 210,146 for *Neopomacentrus asyzron,* 113,838 for *Abudefduf vaigiensisi* and 96,583 for *Pomacentrus similis*. Among surgeon fish (Acanthuridae) used as aquarium species; *Acanthurus lineatus* and *A. triostegus* were common with an estimated TAC of 9,260 and 6,907 individuals respectively. The TAC for unidentified Acanthurids, mainly juveniles and sub adults amounted to 8,320 individuals.

The abundance of *Acanthurus leucosternon* and *Naso lituratus* was low with a TAC of 417 and 167 individuals respectively

Five species of angelfish (Pomacanthidae) were recorded. The abundance of *Centropyge flavipectoralis* was 3,333 whilst *Centropyge multispinis* was 9,998. The TAC for *Centropyge flavipectoralis* and *Centropyge multispinis* is 167 and 500 individuals respectively. The TAC for *Pomacanthus annularis* is 376 and the *P. semicirculatus* is 1,176 individuals.

Twelve species of butterflyfish (Chaetodontidae) were recorded and the species of highest abundance was *Chaetodon vagabundus* (127,380) whilst the lowest abundance was *C. trifascialis* (417). Accordingly the TAC for these two species is 6,369 and 21 individuals respectively. Only two species of butterflyfish listed in the Restricted Export category was recorded; both species had relatively low abundance and TAC. The TAC for *Chaetodon lunula* is 125, whilst the TAC for *C. meyeri* is 671 individuals. Due to the lower numbers recorded of *Forcipiger flavissimus* the TAC is only 126 individuals.

Fourteen species of wrasses (Labridae) were recorded. The TAC for *Labroides dimiditatus* (Cleaner wrasse) is 8,207. The TAC for *Gomphosus caeruleus* and *Macropharyngodon bipartitus* is 1,484 and 8,548 respectively. The abundance of *Halichoeres hortulanus* was low and the TAC was 213. *Hemigymnus fasciatus* was even lower and the TAC is only 21 individuals. The abundance of the scorpion fish *Pterois volitans* was very low and the TAC is 21 individuals.

Matara District

The abundance, maximum sustainable yield (MSY) and the total allowable catch (TAC) is given in appendix 5. The abundance of pomacentrids in the Matara District was also similar to Galle District. The estimated abundance of *Neopomacentrus asyzron, Abudefduf vaigiensis* and *Pomacentrus similis* was 3,804,168, 1,706,727 and 795,449 respectively. Consequently the TAC for these three species is 190,208; 85,336 and 39,772 respectively. The abundance of clown fishes was low with both *Amphiprion clarkii* and *A. sebae* having the same abundance level at 457 individuals each. As a result the TAC for these two species of clown fish is 23 individuals only. Among the Acanthurids the highest abundance was of *Acanthurus lineatus* (88,111) followed by *A. triostegus* (52,628). The TAC for these two species is 96 (*Acanthurus were low with 1,925 and 489 individuals respectively*. Therefore the TAC for these two species is 96 (*Acanthurus leucosternon*) and 24 (*Naso lituratus*) respectively. Unidentified Acanthurids amounted to 49,480 individuals and the TAC is 2,474. Very low abundance was also recorded for *Naso lituratus* (489); the TAC is only 24 individuals.

Six species of angelfish were recorded. Among the larger species the estimated abundance of *Pomacanthus* semicirculatus was 22,432 individuals and *P. annularis* and *P. imperator* were 7,381 and 489 respectively. The TAC for these three species is 1,122 for *Pomacanthus semicirculatus*, 369 for *P. annularis* and 24 for *P. imperator* respectively. The TAC for *Centropyge eibli* is 137 whilst *C. multispinis* is 397.

Thirteen species of butterfly fish (Chaetodontidae) were recorded. The highest abundance was *Chaetodon vagabundus* with 97,492 individuals. The TAC for this species is 4,875. The next highest TAC is for *Chaetodon lunula* at 923 individuals. *Chaetodon guttatisimus, C. kleini, C. xanthocephalus* and *C. lineolatus* 46, 69, 49 and 91 respectively. Two species listed in the Restricted Export category were recorded; the TAC for *Chaetodon xanthocephalus* and *Chaetodon meyeri* were 49 and 562 individuals respectively.

Thirteen species of wrasses (Labridae) were recorded of which *Labroides dimidiatus* had the highest abundance at 86,249 individuals. The TAC for *Labroides dimidiatus* is 4,312. The next highest TAC is for *Thallasoma lunare*, *Halichoeres marginatus* and *Gomphosus caeruleus* with 2,864, 2,304 and 2,155 respectively. The abundance of *Coris frerei* is relatively low and the TAC is 485 individuals.

Status of the habitats of the marine aquarium fishes in the study areas.

Coral rock was the main substrate type within the study area. Percentage of coral rock in the Galle District was 32.98 and 26.55 in the Matara District. The major categories of organisms on the substrate were hard corals, soft corals, sponges, coralline algae, fleshy and filamentous algae. There were small patches of sea grass among sandy areas in back reef spaces. Percentage cover of hard corals was relatively low in the Galle and Matara Districts with 23.47% and 21.36% respectively while the percentage of coral rubble was very high (Table 1 & 2; Fig. 4).

Categories	Percentage
Hard coral	23.47
Soft coral	06.11
Sponge	01.08
Coralline algae	00.72
Sea grass	02.31
Fleshy & filamentous algae	07.35
Sand	04.35
Coral rubble	21.59
Coral rock	32.98

Table 1. Percentage of benthic categories in the Galle District

Table 2. Percentage of benthic categories in the Matara District

Categories	Percentage
Hard coral	21.36
Soft coral	10.14
Dead coral	00.04
Sponge	00.34
Ascidian	00.43
Anemone	00.06
Zoanthid	00.19
Coralline algae	00.70
Sea grass	02.45
Fleshy & filamentous algae	08.07
Sand	07.28
Coral rubble	22.37





Figure 4. Percentage of substrate type and benthic organisms within the study area

The aquarium fishery in Galle and Matara Districts

The marine aquarium fishery in Sri Lanka has three distinct components, namely the fish collectors, dealers or suppliers and the exporters. Fish collectors and suppliers are located at the village level whilst the exporters are based in and around Colombo and suburbs. There are only fish collectors and suppliers in the Galle and Matara Districts; their operations are supported by many individuals that maintain holding facilities, operate scuba compressors, boats etc. Specimens are collected by scuba diving and snorkeling. A joint study conducted by NARA and the Marine Conservation Society of UK in 1997 with the support of the Darwin Initiative revealed that there were about 500 aquarium fish collectors within the Galle and Matara Districts. Approximately 60% were snorkelers whilst 15% were scuba divers. About 25% engaged in both snorkeling and scuba diving. Snorkelers swim out from the shore to collect fish among inshore reefs and scuba divers use boats to work the offshore areas. There were approximately 15 crafts (6m fiber glass boats) that operated both in Galle and Matara Districts during the study period.

The majority of fish collectors were located at Matara and Weligama followed by Mirissa and other locations (Fig. 5). Fish collectors and some suppliers migrate to the east coast during the southwest monsoon and thus they are able to engage in the fishery throughout the year. Almost all scuba divers are fulltime fish collectors whilst some

snorkelers are part time fish collectors. Most collectors are opportunistic and take advantage of the demand for other marine species such as sea cucumber and chanks (Wood, 1996). Collection of catch data proved to be a tremendous challenge. Due to past management initiatives by the Department of Wildlife Conservation to protected several species in 1993, the primary stakeholders are highly concerned about studies that provide information to management authorities. The difficulty in obtaining catch data was also reported by De Alwis (2007).



Figure 5. Distribution of 567 fish collectors in the coastal towns of Galle and Matara Districts.

Snorkelers operate within the back reef areas and on the seaward side of the fringing reefs to a depth of about 8m. Usually scuba divers operate from about 10m to a depth of about 40m. Collecting sites and the depth may vary depending on the availability of species. The main target species of the snorkelers are juvenile and sub-adult butterflyfish, wrasses, surgeonfish, gobies, blennies, scorpionfish and moray eels. The scuba divers collect all the species that the snorkelers target as well as reef shrimps, especially the painted shrimp (*Lysmata amboinensis*) and scarlet shrimp (*Lysmata debelius*) that are found on deeper reefs around 25 to 40m depth.

Collecting periods

Aquarium fish are collected in the southern coastal waters for a period of about 6 months; from mid October to end of March when the sea is calm and clear. Spring and neap tides are experienced during this period in conjunction with lunar cycles where the sea becomes rough for short periods and some of the inshore reef crests are exposed during the low tide. During such spells the visibility is reduced due to the swell action and the currents. Fish collecting is affected during such periods and only the protected back reef areas are accessible for snorkelers.

Collecting methods

The main collecting gears are the handnet, chaser net also called the tickler net or the night net, moxy net and the Barrier net. Barrier nets are used to capture medium to large individual fishes. Almost all the snorkelers use the moxy net although this is a banned fishing gear. The moxy net is used because it is difficult to catch small fish in the coral environment. Most snorkelers are also not skilled in the use of the hand nets, therefore they resort to the use of the moxy net even to collect species that can be easily collected with the use of the hand net. The scuba divers also use moxy nets, mainly to catch small angelfish, butterflyfish and other species that hide in crevices and holes in the reef structure. Greater damage to the reef structure is caused by the snorkelers working among the shallow coral patches. In Addition scuba divers use barrier nets. These are fairly large nets of about 8 to 10m in length and about 2 m in height. It is laid in a semicircle surrounding a patch of the reef where the target species are present and then the collector chases the fish into the net. Individual fish that get entangled in the net are collected with the night net and transferred to polythene bags held by the diver around his waist.

Holding facilities

At the village level, collected fish are given to the suppliers who maintain a temporary holding facility. Each supplier has a few tanks made of glass and some are large 100 liter plastic barrels cut in half (Fig. 6). These serve as temporary holding containers. The fish and invertebrates are put into these tanks/containers and aerated. Species that are aggressive towards conspecifics such as the *Acanthurus leucosternon* are put into individual polythene bags with sufficient water and oxygen (Fig. 7). Other species such as *Lyamata debelius* that cannibalize on conspecifics are kept in perforated small plastic cups or perforated plastic bottles that are floated inside the aquariums or are packed individually in polythene bags (Fig. 8).

Usually specimens are kept only for a day or two at these collecting centers before they are transported to the exporters in Colombo. The specimens are packed in polythene bags with sufficient water and oxygen for the journey to Colombo (Fig. 9). This journey usually takes about 4 to 5 hours from the collecting centers in the southern coast.



Figure 6. Temporary holding tanks at a collecting centre.



Figure 7. Species aggressive towards conspecifics held in individual bags with paper screens inserted between the bags.



Figure 8. Lysmata debelius shrimps held in separate bags.



Figure 9. Packing fish at a holding centre.

Management issues

During the study and subsequent meetings held with the primary stakeholders of the industry, several issues came to light with regard to management, species and habitat conservation.

- Increasing numbers of collectors.
- Lack of licensing of all collectors.
- Continued use of moxy nets.
- Lack of enforcement of regulations.
- Collection of small (small juveniles) of some species.
- Collection of large individuals of species (breeders).
- Uncontrolled harvesting.
- Habitat damage by fishing, pollution, sedimentation and development activities.
- Loss of corals, slow recovery of reefs that affect ornamental species.
- Habitat and species changes due to environmental shifts due to climate change.
- Improper handling of specimens by inexperienced collectors and packers, leading to mortality of collected specimens.
- Increasing expenses for collecting trips, maintenance of aquariums/holding facilities.

- The need to use several scuba cylinders and venture into deeper water resulting in decompression problems.
- Lack of knowledge on problems related to scuba diving.
- Low prices for many species. Prices have not been revised in the recent past.

Discussion

Three species of damselfish; *Neopomacentrus asyzron*, *Abudefduf vaigiensis* and *Pomacentrus similis* were the most abundant among the 66 species recorded in Galle and Matara Districts. All three species occur among coral, sandstone/limestone and rock reef habitats within the study area as well as in other locations in Sri Lanka and are not specifically dependent on corals. Among the surgeonfish the abundance of *Acanthurus leucosternon* and *Naso lituratus* was very low. Juveniles of these two species live mainly among branching coral until they reach a size of 6 cm to 8 cm and the loss of branching corals due to reef degradation and the pressure of collection seem to be the cause of the decline of the two species of surgeonfish.

Healthy populations of Labroides dimidiatus (cleaner wrasses) were found throughout the study area. This species is highly sought after by the aquarium industry, nevertheless the populations of Labroides dimidiatus seem to be stable. The population of Macropharyngodon bipartitus was also healthy as well as Gomphosus caeruleus. Halichoeres hortulanus had relatively low population density. Among the angelfish the populations of Centropyge flavipectoralis and C. eibli were low. Centropyge flavipectoralis which is also listed in the Restricted Export category was recorded only in the Galle District (TAC is 167 individuals). But the C. multispinis and both large species of angelfish Pomacanthus semicirculatus and P. annularis populations were not very low. The number and the distribution of large angelfish (Pomacanthus semicirculatus, P. annularis and P. imperator) in an area are limited because they are highly territorial and usually only mated pairs are found in a patch of reef. Pomacanthus imperator is also a species that has the largest territory and home range among the large angelfish in Sri Lanka and adults of this species is not found in large numbers. Furthermore their preferred habitat is among the shallow reefs; hence the numbers recorded were low. The pygmy angelfish (Centropyge spp.) are more gregarious and forms harems. The three species of Centropyge recorded in this study have preferred depth ranges, usually between 10 & 20m. They are not specifically found on coral reefs. They prefer sandstone/limestone habitats with low coral cover. also Therefore the low number recorded in this study is because much of their habitat was not within the sampled area since the study was limited to the shallow coral reef habitats.

Thirteen species of butterflyfish (Chaetodontidae) were recorded with the highest abundance recorded for *Chaetodon vagabundus*. Other species, however, recorded fairly low numbers with *Chaetodon xanthocephalus* which is a sought after species in low numbers. *Forcipiger longirostris* is uncommon in shallow coral reefs; hence the low TAC recorded is because its preferred habitat is outside the sampling area. *Pterois volitans* is a cryptic species and therefore the low abundance and TAC could be due to this reason. *Pomacanthus imperator* is a species that prefers deeper water below 15m along the southern coast, hence the estimated low TAC of 24 for this species. None of the Triggerfishes (Balistidae) listed under the Restricted Export category was sighted. Sea anemones and Clown fish (*Amphirpion* spp.) are uncommon to rare in the shallow coral areas in the southern coastal waters; hence their abundance was very low. Two species of clown fish were recorded in the Matara District.

From 12 species of butterflyfish (Chaetodontidae) listed under the Restricted Export category only two species were recorded in the Matara District *Chaetodon xanthocephalus* (TAC is 49 individuals) and *Chaetodon meyeri* (TAC 562). Only one species of butterflyfish (*Chaetodon meyeri*) was recorded in the Galle District (TAC 671).

The relatively low numbers recorded for many of the important aquarium species could be attributed to several factors. Habitat loss, habitat alteration, high levels of extraction and other unknown factors such as changes in breeding, larval survival, recruitment, availability of food and mortality due to predation could be causes for the low abundance recorded for many species. Habitat quality of nearshore reefs was very poor with large amounts of coral rubble (21.59% in Galle District and 22.37% in Matara District) which is almost equal to the percentage of live coral cover for the two districts (23.47% for Galle District and 21.36% for the Matara District). This is a the result of the 1998 coral bleaching event and the death of hard corals and the subsequent erosion of reef structures due to lack of reef recovery in terms of recruitment and growth of new hard corals. Furthermore, the tsunami in 2004, damaged reef structure and reduced much of the dead corals to coral of rubble and altered reef habitats drastically (Rajasuriya, 2005; Rajasuriya, 2005, 2008). Another factor that has contributed to reef degradation for several decades was severe coral mining for the production of lime for construction activities (De Silva, 1985; CCD, 1990; Perera, 2003). Although it is much less now, this activity is still present in some coastal stretches. Kumara et al. (2008) report on the damage caused to coral reef structure at Bandaramulla, Matara District, which is located within the survey area.

The study revealed that the ornamental fish collecting methods can be highly damaging to the reef structure especially where fragile live corals are present. The habitat damage caused by the inexperienced snorkelers has been reported previously by Wood (1985), However habitat damage cannot be attributed to aquarium fish collecting alone as there are many other forms of fishing that is highly detrimental to the marine environment. The use of bottom set nets to catch spiny lobsters causes much habitat degradation as well as blast fishing (Ohman et al. 1993, Dayaratne et al. 1997, Rajasuriya, 2005). Although all of these fishing methods are illegal they are rampant today due to lack of enforcement of the fisheries regulations (Rajasuriya, 2008). Therefore the marine aquarium fishery should be managed as part of overall fisheries management for the whole country, as all of the destructive fishing activities have a negative impact on the quality of the reef habitats and the ocean environment.

Habitat quality is a critical factor for the well being of reef organisms including reef fish (Pilliam and Danielson, 1991, Roberts 1996, Munday, 2002). Damage and alteration to habitats can have a serious impact on populations of reef fish (Sale 1991, Sadovy 1996). Reef fish depend heavily on the quality of their habitat for survival, reproduction and recruitment (Sale, 1978; 1991). They are particularly vulnerable at the recruitment stage where avoidance of predators and the availability of the right types of food are the most important factors that ensure survival. Habitat complexity (Roberts, 1996) and substrate quality (Luckhurst and Luckhurst, 1978; Roberts and Ormand, 1987) are also important and is linked to survival of juveniles, and mortality is very high among reef fish due to predation, particularly at the stage of settling from the plankton and immediately thereafter (Roberts, 1996). Roberts and Ormand, (1987) determined in a study conducted among the Red Sea coral reefs that 77% of the variance in fish abundances on reefs was due to the availability of refuge holes.

Marine refuges can play a key role in the protection of habitats and for populations of reef fish to recover (Roberts et al. 2001, TNC 2008). The types of habitats available in the southern coast are very specific and because of the seabed structure coral reefs are found only along the coast (Swan 1983, Ohman et al. 1998). Therefore, there are no similar coral reef habitats in the offshore areas and this leaves only the shallow fished areas to be protected. Most of the species used in the aquarium trade are species that recruit, spend their juvenile stages as well as adult stages in the same habitat. Ideally, protected areas should include the following; Representation and Replication, Critical areas, and Connectivity (TNC, 2008). However it is not always possible to find all of these components in small

inshore reefs. Most of the aquarium species are 'broadcast spawners' and their breeding patterns are linked to the monsoon seasons. The origin of these populations and the connectivity of these small reefs are not well understood. However, a basic understanding on the recruitment patterns can be derived for some species based on observations of the appearance of juvenile fishes in the reef system. Although the exact period of recruitment pulses is not known due to lack of studies on this aspect, the appearance of juveniles of some species of butterflyfish (Chaetodontidae), angelfish (Pomacentridae), wrasses (Labridae) and surgeon fish (Acanthuridae) is well known. For example the Bluering angelfish (*Pomacanthus annularis*) and the Koran angelfish (*P. semicirculatus*) are both species that prefer relatively silty environments where there is freshwater input. This fact is well established with regard to their distribution patterns both in Sri Lanka and also in the Indian Ocean Region. Both species are rare among oceanic islands and reef systems such as the Maldives and Chagos Archipelago where there is no river runoff. Along the coast of Sri Lanka both species occur in greater abundance where freshwater input is relatively high such as in the west coast. This is particularly noticeable when considering the recruitment pulses and subsequent appearance of juveniles on coastal reefs. In the study area juveniles of both species are found close to the Polwathumodera River in the Weligama Bay in the southern coast. Every season fish collectors catch the juveniles close to this area. This indicates that although both species are broadcast spawners their juveniles appear to recruit into nearby areas. However, this situation may not apply to many other species, where their larvae might be carried along greater distances before they finally recruit onto suitable habitats. Scientific literature related to breeding, larval dispersion and recruitment of most species used in the aquarium trade is lacking, hence it is prudent to use a 'precautionary approach' in the utilization of these species.

Fish refuges can be created by temporary closures during breeding and recruitment stages for highly migratory species (Roberts 2001). However, these refuges need to be sufficiently large for them to be effective, taking into consideration that larval dispersal and suitable areas for recruitment is extremely important to maintain viable breeding populations. Although the reef areas are quite small in the southern coast of Sri Lanka, a similar approach can be taken by setting up seasonal or periodical closures for fish collecting when the spawning and recruitment periods for target species are known. Reproductive patterns in reef fish are characterized by diversity and the reproductive output is highly variable within and among species (Sadovy, 1996). In some years juveniles of some species of butterflyfish and surgeonfish occur twice during the collecting period; the first time in the collecting season in December -January and then again in March -April. There may be several species that breed throughout the year and for such species closed seasons may not be necessary. Furthermore, spawning periods may vary between oceanic regions and even within the different coastal regions of a country that experience different oceanographic and climatic conditions. Therefore much more detailed information on the biology of individual species pertaining to this region is necessary. Many stakeholders in the aquarium fishery believe that a closed season is present naturally in the form of the southwest monsoon where conditions are not favourable for collecting. However, this reasoning appears to be incorrect due to the fact that juveniles of most species used in the trade is not seen among the inshore back reef areas during the southwest monsoon. Furthermore the absence of juveniles immediately after the monsoon also indicates that fish may not be breeding as expected during the southwest monsoon or their larvae are in offshore currents and have not reached the required level of maturity for settlement. Therefore the monsoon period cannot be considered as a closed season. In fact many juveniles of the desirable sizes are present only a month or two later after the end of the monsoon. Taking into consideration the planktonic life cycles and periods of several reef fishes (Benjamin 1991, Doherty 1991), it appears that some species used in the aquarium fishery spawn in the latter part of the monsoon and that larvae recruit immediately after the monsoon when the inshore shallow reefs are relatively calm and then appear as small juveniles among the reefs a few weeks

later. Settlement and survival until adulthood also depends much on the habitat, predators, food and on intra and inter-specific competition (Jones 1988; 1991).

In this study the total allowable (TAC) catch for species has been determined at 5% of the population, calculated for all species regardless of their abundance. Ochavillo & Hodgson (2006), recommend different TAC levels for species groups of aquarium fish, namely families of damselfish (20% to 25% of population depending on species), wrasses (10% of the population), angelfish (5% of population) and butterflyfish (10% to 15% of population depending on species). According to them their TAC limits for different species groups is very conservative because due to the high structural complexity of the coral reefs there are plenty of hiding spaces for reef fish and this could lead to underestimating their abundance. However, in relatively degraded habitats with low reef recovery and high levels of extraction such as in Sri Lanka, the TAC recommended by this study which is based on 5% of the population for all species is reasonable although it can be considered as highly conservative.

In the present study none of the currently protected species (appendix 7) were recorded indicating that those species are very rare. The scarcity of these species is mainly because they are naturally rare in Sri Lanka and therefore it is essential to protect them in the future. However, some of these species such as the *Pygoplites diacanthus* is a common angelfish in the Maldives and is currently imported to Sri Lanka for re-export. Only 3 species of fish were recorded from a total number of 17 species listed under the 'Restricted Export' category of the Fisheries and Aquatic Resources Act (appendix 8). This indicates that some of these species are relatively uncommon to rare in the shallow coral reef habitats in the southern coast.

Often very small size classes of some of the most sought after species are collected. These species are Cleaner wrasses (*Labroides dimidiatus*), Clown coris (*Coris freirei*), Checkerboard wrasse (*Halichores hortulanus*), Blue ring angelfish (*Pomacanthus annularis*), Koran angelfish (*Pomacanthus semicirculatus*), and some species of butterflyfish (Chaetodontidae). These small juvenile fish do not survive well in captivity. In the wild they feed constantly as they have to grow quickly to avoid being predated. Most aquarists that purchase these small fish in the importing countries may not have the correct type of feed to sustain the small juveniles at this critically important growth stage. As a result the small juveniles die soon after they are purchased by the aquarists. Therefore it is an utter waste to catch and export these small size classes. At the other end of the scale, it is harmful to the stocks when large individuals of species are collected and exported. The demand for large breeding size individuals comes from public aquaria. These special orders are catered to by some exporters and collectors use barrier nets to catch these fish. Species that are most vulnerable to this type of extraction are large Emperor angelfish (*Pomacanthus annularis*), Clown triggerfish (*Balistoides conspicillum*), Jigsaw triggerfish (*Pseudobalistes fuscus*) and Powder blue surgeonfish (*Acanthurus leucosternon*).

Management recommendations

Considering the degraded status of the coral reef habitats in the southern coastal waters it is important to adhere to the 'precautionary principal' in harvesting aquarium species. Recovery of the populations of aquarium species depends much on the improvement of the habitat and the survival of viable breeding populations. At present the reefs in the southern coastal waters are highly impacted by human activities and aquarium fish collecting is only one aspect of the threats to the populations of reef fish and many species of invertebrates. The following recommendations are made in view of the above.

Aquarium fish collectors catch the required species in all size classes due to the demand and management measures designed to control fish collecting through the divers is unlikely to succeed if the exporters purchase the catch. The most effective approach to control harvesting and to adopt responsible collecting methods is to implement management actions through the exporters. The results of this survey can be used as a guide to control harvesting of species. However, for the recommendation of species based quotas it is necessary to obtain the number of each species harvested. At present the collectors refuse to part with this information because they fear that the authorities would take management actions that are detrimental to their earning capability. Due to the patchy distribution of species it is necessary to obtain catch data by area or reef section or at larger spatial scales by district.

Although the marine aquarium trade utilizes a large number of species, it relies on several high value species to retain a hold in the highly competitive world market. Today the foreign buyers have the opportunity to browse the World Wide Web and select the required species from a vast array of suppliers. Many species with a high value have low abundances naturally. Others such as the powder blue surgeonfish (*Acanthurus leucosternon*) is a highly sought after species and is required for almost every consignment. Management recommendations for such species should take into consideration the possible impacts on the industry as well as the effect on the populations of these fishes.

Species

The results indicate that some of the most sought after species *Acanthurus leucosternon* and *Naso lituratus* have a very low abundance. Both species are highly important for the aquarium trade and exporters need these two species among several other species to maintain their orders in the international market. Although the TAC can be based on the standing stock or the upper or lower 90% CIs, in order to protect species with a low abundance the TAC should ideally be based on the number given under the TAC and not the upper 90% CI indicated for such species. However, due to prevailing market preferences species with very low abundance need to be harvested in order to maintain the trade. Therefore it is recommended that the 'precautionary principal' is applied in such situations and that these species are harvested at the level estimated by the TAC.

None of the species listed under 'Protected species' list of the Fisheries and Aquatic Resources Act and the Fauna and Flora Protection Ordinance were recorded during this study. Therefore these species should be retained in the list of protected species.

Only 3 species out of 17 species listed in the 'Restricted Export' category of the Fisheries and Aquatic Resources Act 1996 were recorded during the study. Therefore the status of the species in the Restricted Category requires reevaluation. The status of these species can be assessed further by examining results of the northwestern and eastern coastal waters under this project and recommendations can be made accordingly.

The export of small juveniles and large breeding stage adult fishes are harmful to the wild stocks and the exporters should be educated on the detrimental aspects of harvesting unsuitable size classes. However it is difficult to enforce restrictions on size classes as it is impractical to measure fish sizes at the time of exporting. Therefore it is suggested to establish a mechanism such as a monitoring team from the relevant management organizations to visit aquaria periodically to ensure that unsuitable size classes are not stocked. Furthermore, it is highly desirable for the exporters to voluntarily stop the export of unsuitable size classes.

Collecting methods

The use of the illegal moxy net should not be allowed. However, policing the coastal waters to prevent the use of moxy nets is extremely difficult if not impossible because of the small size of the moxy net and its use has to be checked underwater.

Fish collectors break coral branches to catch the *Gobiodon citrinus*. This activity causes much damage to branching corals and should be banned. It is recommended that this species be included in the protected list of species in order to prevent the habitat damage caused by their collection.

Although the barrier net does not cause habitat damage its use is harmful for some species as large breeding sized fishes can be caught with it. Therefore catching the breeders should be prevented. This is a matter that should be discussed with exporters as they can stop the export of large specimens.

Conduct awareness programmes and develop publications such as leaflets to educate the divers on the negative impacts of spear fishing, and the role of the groupers in maintaining the habitats of the scarlet shrimps (*Lysmata debelius*) and painted shrimps (*L. amboinensis*) and in proper collecting methods and post harvest care.

Catch data

It is recommended that a mechanism to obtain catch data be established through the network of fisheries inspectors and the Assistant Director of Fisheries for each District. Every fish collector and supplier maintains catch data in a personal record book. The exporter pays the collectors based on these lists. However, collecting the list from individual fish collectors is not practical and therefore it is recommended that the DFAR make it mandatory for the supplier to provide this list to the Assistant Director of Fisheries of the District. A logbook supplied by the DFAR to each Assistant Director of Fisheries would support this process.

Licensing

Issue licenses to all ornamental fish collectors and list the types of gear that can be used by the collectors. These should be listed in the permit itself.

Suppliers are not registered at present because they are not engaged in collecting the fish. But the registration of suppliers is important and a license issued, because they can control the size classes of fish when purchasing and they should be the primary source of catch data collection.

Holding facilities

The temporary holding facilities maintained by the suppliers should be improved as many have inadequate facilities with poorly maintained water quality. The suppliers are not concerned about the quality of these facilities because the fish are sent to the exporters daily or every few days. Therefore they do not think that it is necessary to improve the quality of the holding facilities. The DFAR should visit the holding facilities regularly and supervise these facilities.

Fish collectors should be educated in techniques of responsible harvesting, handling and care of the specimens. A series of regular lectures on a set of Best Practices together with diving safety should be conducted to educate them.

Protection of habitats

The marine aquarium fishery cannot be managed in isolation because the habitats of reef fish are being affected by various other human activities as well as natural impacts such as coral bleaching. The main causes of reef degradation due to human activities are; indiscriminate netting to catch spiny lobsters, pollution form land-based sources, blast fishing and coral mining. These should be controlled or eliminated by implementing the existing regulations. Assistance should be sought from the newly established Coast Guard Department to implement some of these regulations.

Declaration of protected areas

Although large areas cannot be declared as protected areas along the southern coastal waters, small reef sections or patches can be set aside as breeding areas. Because of planktonic larval dispersion of most reef fish species even small areas can serve as refuges. These sites should be identified with the participation and support of all stakeholders, particularly the fish collectors and suppliers in order to assure compliance. Ideally the responsibility of looking after such areas should be vested in the local fisheries management committees.

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Photo credits

All photographs: Arjan Rajasuriya - Survey team leader & lead researcher

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Appendix 1: Description & status of reef habitats

Three types of reef habitats have been described in Sri Lanka; coral reefs, rock and sandstone (Swan, 1983; Rajasuriya and De Silva, 1988). Sandstone reefs are a conglomerate of sandstone and coral rock or limestone (Rajasuriya et al. 1995). All three types of reefs are found in the southern coastal waters (Rajasuriya et al., 1998). All coral reefs in the southern area are fringing reefs that occur as a narrow band located adjacent to the coast (Fig. 10). They are characterised by having a narrow back-reef area that form small reef lagoons where patches of branching, foliose, massive and encrusting corals grow (Figs. 11 & 13). A narrow reef crest and a seaward reef slope extend to about 500m offshore. In addition there are rock reef patches and rock outcrops among the fringing reefs (Fig. 12). All of these fringing reefs are in shallow water and the maximum depth at the edge of the seaward reef slope is about 10m. Rock reefs and sandstone/limestone reefs extend further offshore to a distance of about 5km and a depth of about 80m.



Figure 10. Typical fringing reef in the southern coast.



Figure 11. Live coral patch in back-reef lagoon at Weligama.



Figure 12. Rock reef habitat.



Figure 13. Typical upper reef slope with adult aquarium fishes.

Reefs along the southern coast are subject to many human influences (De Silva, 1985; Rajasuriya et al. 1998) that continue to degrade them. Use of destructive fishing methods, uncontrolled harvesting, sedimentation, pollution and coral mining continue to damage nearshore reefs (Figs. 15 - 20). Studies on coral mining has been carried out

infrequently; Hale and Kumin (1992) reported that 2,282 tons of live corals were harvested from the sea in 1984 (Table 3). In 1998 coral reefs in Sri Lanka were severely bleached and most coral areas were destroyed. However, some locations in the southern coast were able to recover fairly rapidly (Rajasuriya, 2002) while in other locations recovery has been slow and variable. In 2004, the tsunami caused further devastation by breaking the degraded reef structures and distributing coral rubble and sand resulting in severe alteration of inshore reef habitats (Rajasuriya, 2005, 2008; Wilkinson, 2008). The declining trend of hard coral cover in a single location in the southern coast at Kapparatota, Weligama highlights the impacts of these events on the condition of the reef (Fig. 14).

Location of coral collected	Amount (Tons)	Total harvest (% of total)
Relic reefs on land		
Inland of the coastal zone	7,532	42
Within the coastal zone	2,868	16
Coral rubble on the beach	5 277	20
within the coastal zone	5,577	30
Live coral at sea from the reef		
Within the coastal zone	2,282	12
	10.070	100
Total	18,059	100

				1000
Table 3. Coral mined from	the southern coast o	of Sri Lanka in 198	84 (Hale & Kumin	, 1992).



Figure 14. Changes in the hard coral, algae & coral rubble Kapparatota, Weligama; before 1998 coral bleaching event up to 2008 (Rajasuriya et al., 1998; 2002, 2004, 2008)



Figure 15. Sediment accumulation on coral reefs.



Figure 16. Non-biodegradable material stuck on reef.



Figure 17. Discarded nets smother corals.



Figure 18. Proliferation of Didemnid tunicates on degraded reefs may indicate eutrophication.



Figure 19. Acanthurus leucosternon among coral rubble.



Figure 20. Anchor rope of fishing boats tied around coral head.

Appendix 2: Description of the Fishery

The marine aquarium fishery has three operational levels; fish collectors (divers), suppliers and exporters. The suppliers are the agents between the fish collectors and the exporter. A supplier can be a fish collector or a businessman. The supplier maintains a holding facility in the area where fish are collected. The exporters obtain the catch from the suppliers; however, some exporters prefer to buy the fish directly from the fish collectors. There are only collectors and suppliers in the study area. Organisms are collected by snorkeling or scuba diving. Snorkelers operate from the shore among the inshore fringing reef habitats while scuba divers operate on the offshore rock and sandstone/limestone reefs.

Small 6.5m fiberglass boats with out board motors are used in the fishery. The engine capacity varies from 9hp to 25hp. All engines use a mixture of kerosene and 2 stroke oil. Crafts are owned by fish collectors or suppliers. Exporters may also own some of crafts. Only scuba divers use boats and there are dedicated boat operators. Most fish collectors own their diving equipment. Sometimes exporters or suppliers provide equipment and boats; in such instances the fish are purchased at a lower price. Some collectors hire the equipment and the boats from the suppliers. The cost of hiring boats and the operator fee has to be borne by the fish collectors and may vary in different areas. Typically, a boat carries 2 divers and an operator. A collecting trip by boat may vary between Rs. 3000 to 5000 depending on the distance to sites. Due to increasing collecting pressure and the expanding numbers of fish collectors they are forced to travel further and dive deeper, particularly in search of the Lysmata spp, and fish that are on deep reefs. This has resulted in an increase in the incidences of decompression sickness. Many scuba divers have experienced the bends at varying levels and they often cure themselves by in-water recompression which is dangerous. However, they have no alternative as the only accessible decompression chamber is in the navy base at Trincomalee and requires several hours of travelling from distant collecting sites.

Four types of nets are used in the fishery. The species to be collected, the type of habitat determine the collecting method and the type of gear used. The four gear types are; 1. Hand net, 2. Night net/chaser net (tickler net), 3. Moxy net, 4. Barrier net. The moxy net is an illegal fishing gear but its use is widespread. There has not been any attempt to enforcement the regulations. Fish collectors are opportunistic hunters and may collect spiny lobsters, sea cucumber and chanks. Some also use hand spears or spear guns with scuba to shoot edible fish species such as groupers and snappers. Although it's a harmful practice and the use of spear guns and spears is illegal under the Fauna and Flora Protection Ordinance, the regulations are not enforced.



Figure 21. Fish collectors using moxy net.

Figure 22. A fish collector using hand nets.

Appendix 3: Regulations and management

The Department of Fisheries and Aquatic Resources (DFAR) is responsible for the management of this industry. Fisheries administration in each district is carried out by an Assistant Director of Fisheries. There are a number of fisheries inspectors in each district functioning under the Assistant Director of the district. Up to now the administration of the marine aquarium fishery has been limited to the issue of fishing licenses to divers and permits for crafts. Even then all fish collectors have not been registered. There is no mechanism for the DFAR to collect catch data. The only form of data available is from the exports which can be obtained from the customs department. This information is based on the packing lists that exporters have to provide with each shipment. The lists are not sorted and stored in a proper manner; as a result it is extremely difficult to access this data.

The Fauna and Flora Protection Ordinance (Chapter 469) and its amendment in 1993 and the Fisheries and Aquatic Resources Act of 1996 are the two main pieces of legislation for the protection and control of harvesting of marine organisms for the aquarium trade. The DFAR issues export permits for species listed under the 'Restricted Export' category (appendix 8). In addition, the Department of Wildlife Conservation (DWLC) together with DFAR ensures that protected species (appendix 7) under the Fauna and Flora Protection Ordinance are not exported. The Biodiversity Conservation Unit of the Sri Lanka Customs Department ensures that the exporters conform to the current regulations. However, some protected species have been exported illegally (De Alwis, 2007). Problems due to identification of some species at the Customs Department may contribute to illegal exports (De Alwis, 2007). Problems have arisen among different stakeholders (government agencies, non-governmental organisations and exporters) in the implementation of the regulations partly due to communication problems (Wood, 1996). Those in the industry feel that the regulations are affecting their livelihoods and that there has not been adequate participation in the process of framing regulations and the protection of some organisms such as soft corals (Sarcophyton and Dendronephthya spp), tube worms and fan worms (Sabellestarte spp). However, exporters and collectors do not have much disagreement about the species of fish, molluscs and crustaceans that have been protected (Wood, 1996). In order to resolve some of these problems it is necessary to have a forum between the management authorities and the primary stakeholders in the industry. It is only through a transparent participatory process that such issues can be resolved.

Appendix 4

The abundance, maximum sustainable yield and the Total Allowable Catch for the recorded fish species in the Galle District.

Species		Abundance	MSY	TAC
Abudefduf vaigiensis	Total	2,276,756	227,676	113,838
	Upper 90% CI	2,698,232	269,823	134,912
	Lower 90% CI	1,855,281	185,528	92,764
Acanthurus leucosternon	Total	8,345	835	417
	Upper 90% CI	11,619	1,162	581
	Lower 90% CI	5,072	507	254
Acanthurus lineatus	Total	185,196	18,520	9,260
	Upper 90% CI	214,710	21,471	10,735
	Lower 90% CI	155,682	15,568	7,784
Acanthurus spp.	Total	166,396	16,640	8,320
	Upper 90% CI	195,422	19,542	9,771
	Lower 90% CI	137,371	13,737	6,869
Acanthurus tennentii	Total	2,500	250	125
	Upper 90% CI	4,845	484	242
	Lower 90% CI	154	15	8
Acanthurus triostegus	Total	138,132	13,813	6,907
	Upper 90% CI	167,226	16,723	8,361
	Lower 90% CI	109,038	10,904	5,452
Acanthurus tristis	Total	3,333	333	167
	Upper 90% CI	7,594	759	380
	Lower 90% CI	-	-	-
Aethaloperca rogaa	Total	833	83	42
	Upper 90% CI	1,898	190	95
	Lower 90% CI	-	-	-
Apogon spp	Total	64,489	6,449	3,224
	Upper 90% CI	117,491	11,749	5,875
	Lower 90% CI	11,487	1,149	574
Apolemichthys xanthurus	Total	14,284	1,428	714
	Upper 90% CI	22,971	2,297	1,149
	Lower 90% CI	5,597	560	280
Arothron spp	Total	9,675	967	484
	Upper 90% CI	14,610	1,461	730
	Lower 90% CI	4,740	474	237
Carcharhinus melanopterus	Total	1,250	125	62
	Upper 90% CI	2,848	285	142
	Lower 90% CI	-	-	-
Centropyge eibli	Total	3,359	336	168
	Upper 90% CI	5,885	588	294
	Lower 90% CI	834	83	42

Centropyge flavipectoralis	Total	3,333	333	167
	Upper 90% CI	7,594	759	380
	Lower 90% CI	-	-	-
Centropyge multispinis	Total	9,998	1,000	500
	Upper 90% CI	15,708	1,571	785
	Lower 90% CI	4,288	429	214
Cephalopholis argus	Total	20,516	2,052	1,026
	Upper 90% CI	35,119	3,512	1,756
	Lower 90% CI	5,913	591	296
Cephalopholis formosa	Total	10,978	1,098	549
	Upper 90% CI	16,874	1,687	844
	Lower 90% CI	5,082	508	254
Chaetodon auriga	Total	26,415	2,642	1,321
0	Upper 90% CI	33.079	3.308	1.654
	Lower 90% CI	19.751	1.975	988
Chaetodon citrinellus	Total	47.888	4.789	2.394
	Upper 90% CI	59 897	5 990	2,995
	Lower 90% CI	35 879	3 588	1 794
Chaetodon decussatus	Total	21 403	2 140	1,77
Chuelouon uecussulus	Upper 90% CI	29,606	2,140	1,070
	Lower 90% CI	13 200	1 320	660
Chastodon auttatissimus	Total	8 332	833	417
Chaeloaon gallalissimus	Upper 00% CI	13 808	1 300	417 605
	Upper 90% CI	13,090	1,390	128
Charte low line eleter	Lower 90% CI	2,703	172	150
Chaetodon lineolatus	Total	1,720	172	80 151
	Upper 90% CI	3,027	505 41	151
	Lower 90% CI	412	41	21
Chaetodon lunula	I otal	2,500	250	125
	Upper 90% CI	5,695	570	285
	Lower 90% CI	-	-	-
Chaetodon meyeri	Total	13,411	1,341	671
	Upper 90% CI	17,486	1,749	874
	Lower 90% CI	9,335	934	467
Chaetodon plebeius	Total	847	85	42
	Upper 90% CI	1,556	156	78
	Lower 90% CI	137	14	7
Chaetodon trifascialis	Total	417	42	21
	Upper 90% CI	949	95	47
	Lower 90% CI	-	-	-
Chaetodon trifasciatus	Total	7,552	755	378
	Upper 90% CI	11,155	1,116	558
	Lower 90% CI	3,949	395	197

Chaetodon vagabundus	Total	127,380	12,738	6,369
	Upper 90% CI	145,519	14,552	7,276
	Lower 90% CI	109,241	10,924	5,462
Chromis spp	Total	502,535	50,253	25,127
	Upper 90% CI	758,882	75,888	37,944
	Lower 90% CI	246,187	24,619	12,309
Chrysiptera leucopoma	Total	46,448	4,645	2,322
	Upper 90% CI	59,099	5,910	2,955
	Lower 90% CI	33,798	3,380	1,690
Cirrhilabrus rubrisquamis	Total	1,290	129	64
	Upper 90% CI	2,695	269	135
	Lower 90% CI	-	-	-
Cirrhitichthys oxycephalus	Total	11,704	1,170	585
	Upper 90% CI	19,692	1,969	985
	Lower 90% CI	3,717	372	186
Coris frerei	Total	11,784	1,178	589
U U	Upper 90% CI	16,178	1,618	809
	Lower 90% CI	7,390	739	370
Ctenochaetus striatus	Total	14,148	1,415	707
	Upper 90% CI	21,837	2,184	1.092
	Lower 90% CI	6.458	646	323
Diodon hystrix	Total	2,150	215	107
3 1 1 1	Upper 90% CI	3.818	382	191
	Lower 90% CI	481	48	24
Forcipiger flavissimus	Total	2,526	253	126
	Upper 90% CI	4.275	428	214
	Lower 90% CI	777	78	39
Gomphosus caeruleus	Total	29.684	2.968	1.484
comproving care around	Upper 90% CI	39 171	3,917	1 959
	Lower 90% CI	20 198	2,020	1 010
Halichoeres argus	Total	6.275	628	314
Hunchoores argus	Upper 90% CI	11 530	1 153	576
	Lower 90% CI	1 021	102	51
Halichoeres hortulanus	Total	4 259	426	213
	Upper 90% CI	7 226	723	361
	Lower 90% CI	1 293	129	65
Halichoores marginatus	Total	1,293	11 215	5.607
nunchoeres marginatus	Upper 90% CI	140.479	14.048	7.024
	Lower 90% CI	83 820	2 4,040 8 3 8 7	7,02 4 7,101
Uglichogras ann	Lower 90% CI	05,020	0,302	4,191 502
nuuchoeres spp	I Unner 000/ CI	17,001	1,105	595 971
	Upper 90% CI	17,420	1,743	8/1
	Lower 90% CI	6,276	628	314

		100		
Hemigymnus fasciatus	Total	430	43	21
	Upper 90% CI	898	90	45
	Lower 90% CI	-	-	-
Labroides dimidiatus	Total	164,139	16,414	8,207
	Upper 90% CI	190,905	19,090	9,545
	Lower 90% CI	137,372	13,737	6,869
Macropharyngodon bipartitus	Total	170,952	17,095	8,548
	Upper 90% CI	209,783	20,978	10,489
	Lower 90% CI	132,121	13,212	6,606
Macropharyngodon ornatus	Total	4,729	473	236
	Upper 90% CI	9,881	988	494
	Lower 90% CI	-	-	-
Naso lituratus	Total	3,333	333	167
	Upper 90% CI	6,662	666	333
	Lower 90% CI	3	0	0
Nemateleotris magnifica	Total	4.166	417	208
i contacte ou is magnifica	Upper 90% CI	7 938	794	397
	Lower 90% CI	394	39	20
Neonomacentrus azysron	Total	4 202 918	420 292	210 146
reoponacenti as azyston	Upper 90% CI	5 105 567	510 557	210,140
	Lower 00% CI	2 210 270	221.027	160 512
Deres and the sinter	Lower 90% CI	3,210,270	321,027	100,515
Parupeneus bijasciaius	Total	430	45	21 45
	Upper 90% CI	898	90	45
	Lower 90% CI	-	-	-
Parupeneus indicus	I otal	2,150	215	107
	Upper 90% CI	4,491	449	225
	Lower 90% CI	-	-	-
Parupeneus macronema	Total	4,582	458	229
	Upper 90% CI	8,663	866	433
	Lower 90% CI	502	50	25
Parupeneus spp.	Total	42,486	4,249	2,124
	Upper 90% CI	56,397	5,640	2,820
	Lower 90% CI	28,574	2,857	1,429
Plectorhinchus vittatus	Total	5,846	585	292
	Upper 90% CI	9,506	951	475
	Lower 90% CI	2,185	218	109
Pomacanthus annularis	Total	7,512	751	376
	Upper 90% CI	10,725	1,072	536
	Lower 90% CI	4,299	430	215
Pomacanthus semicirculatus	Total	23,516	2,352	1,176
	Upper 90% CI	29,935	2,994	1,497
	Lower 90% CI	17,096	1,710	855

Pomacentrus similis	Total	1,931,662	193,166	96,583
	Upper 90% CI	2,497,759	249,776	124,888
	Lower 90% CI	1,365,564	136,556	68,278
Pomacentrus spp.	Total	54,156	5,416	2,708
	Upper 90% CI	123,397	12,340	6,170
	Lower 90% CI	-	-	-
Pterois volitans	Total	430	43	21
	Upper 90% CI	898	90	45
	Lower 90% CI	-	-	-
Rhinecanthus aculeatus	Total	2,150	215	107
	Upper 90% CI	4,069	407	203
	Lower 90% CI	230	23	12
Rhinecanthus rectangulus	Total	417	42	21
	Upper 90% CI	949	95	47
	Lower 90% CI	-	-	-
Thalassoma hardwicke	Total	61,918	6,192	3,096
	Upper 90% CI	79,797	7,980	3,990
	Lower 90% CI	44,040	4,404	2,202
Thalassoma jansenii	Total	17,157	1,716	858
	Upper 90% CI	26,257	2,626	1,313
	Lower 90% CI	8,057	806	403
Thalassoma lunare	Total	130,709	13,071	6,535
	Upper 90% CI	151,911	15,191	7,596
	Lower 90% CI	109,507	10,951	5,475
Valenciennea puellaris	Total	7,982	798	399
	Upper 90% CI	12,996	1,300	650
	Lower 90% CI	2,967	297	148
Zanclus cornutus	Total	6,812	681	341
	Upper 90% CI	9,804	980	490
	Lower 90% CI	3,820	382	191

Appendix 5

The abundance, maximum sustainable yield and the Total Allowable Catch for the recorded fish species in the Matara District.

Species		Abundance	MSY	TAC
Abudefduf vaigiensis	Total	1,706,727	170,673	85,336
	Upper 90%CI	2,082,322	208,232	104,116
	Lower 90%CI	1,331,132	133,113	66,557
Acanthurus leucosternon	Total	1,925	193	96
	Upper 90%CI	3,601	360	180
	Lower 90%CI	250	25	12
Acanthurus lineatus	Total	88,111	8,811	4,406
	Upper 90%CI	105,911	10,591	5,296
	Lower 90%CI	70,311	7,031	3,516
Acanthurus spp.	Total	49,480	4,948	2,474
	Upper 90%CI	64,119	6,412	3,206
	Lower 90%CI	34,841	3,484	1,742
Acanthurus triostegus	Total	52,628	5,263	2,631
	Upper 90%CI	67,659	6,766	3,383
	Lower 90%CI	37,598	3,760	1,880
Acanthurus tristis	Total	915	91	46
	Upper 90%CI	2,060	206	103
	Lower 90%CI	-	-	-
Amphiprion clarkii	Total	457	46	23
	Upper 90%CI	1,030	103	51
	Lower 90%CI	-	-	-
Amphiprion sebae	Total	457	46	23
	Upper 90%CI	1,030	103	51
	Lower 90%CI	-	-	-
Apogon spp	Total	172,713	17,271	8,636
	Upper 90%CI	331,179	33,118	16,559
	Lower 90%CI	14,246	1,425	712
Apolemichthys xanthurus	Total	1,372	137	69
	Upper 90%CI	3,089	309	154
	Lower 90%CI	-	-	-
Arothron spp	Total	979	98	49
	Upper 90%CI	2,028	203	101
	Lower 90%CI	-	-	-
Cantherhines pardalis	Total	979	98	49
	Upper 90%CI	2,028	203	101
	Lower 90%CI	-	-	-

Canthigaster solandri	Total	1,468	147	73
	Upper 90% CI	2,354	235	118
	Lower 90%CI	582	58	29
Centropyge eibli	Total	2,744	274	137
	Upper 90% CI	4,655	465	233
	Lower 90%CI	833	83	42
Centropyge multispinis	Total	7,935	793	397
	Upper 90%CI	12,571	1,257	629
	Lower 90%CI	3,298	330	165
Cephalopholis argus	Total	8,817	882	441
	Upper 90%CI	11,802	1,180	590
	Lower 90%CI	5,833	583	292
Chaetodon auriga	Total	14,295	1,430	715
	Upper 90% CI	20,981	2,098	1,049
	Lower 90%CI	7,609	761	380
Chaetodon citrinellus	Total	14,880	1,488	744
	Upper 90% CI	21,279	2,128	1,064
	Lower 90%CI	8,482	848	424
Chaetodon collare	Total	2,446	245	122
	Upper 90% CI	3,986	399	199
	Lower 90%CI	907	91	45
Chaetodon decussatus	Total	11,551	1,155	578
	Upper 90% CI	16,987	1,699	849
	Lower 90%CI	6,115	611	306
Chaetodon guttatissimus	Total	915	91	46
	Upper 90%CI	2,060	206	103
	Lower 90%CI	-	-	-
Chaetodon kleinii	Total	1,372	137	69
	Upper 90%CI	2,634	263	132
	Lower 90%CI	110	11	6
Chaetodon lineolatus	Total	1,829	183	91
	Upper 90% CI	3,189	319	159
	Lower 90%CI	470	47	23
Chaetodon lunula	Total	18,454	1,845	923
	Upper 90% CI	27,648	2,765	1,382
	Lower 90%CI	9,260	926	463
Chaetodon meyeri	Total	11,232	1,123	562
	Upper 90% CI	15,177	1,518	759
	Lower 90%CI	7,287	729	364
Chaetodon plebeius	Total	7,935	793	397
	Upper 90%CI	11,431	1,143	572
	Lower 90%CI	4,438	444	222

Chaetodon trifasciatus	Total	13,125	1,313	656
	Upper 90%CI	20,662	2,066	1,033
	Lower 90%CI	5,588	559	279
Chaetodon vagabundus	Total	97,492	9,749	4,875
	Upper 90%CI	109,711	10,971	5,486
	Lower 90%CI	85,273	8,527	4,264
Chaetodon xanthocephalus	Total	979	98	49
	Upper 90%CI	2,028	203	101
	Lower 90%CI	-	-	-
Cheilinus chlorourus	Total	1,829	183	91
	Upper 90%CI	4,119	412	206
	Lower 90%CI	-	-	-
Chromis spp	Total	871,301	87,130	43,565
	Upper 90%CI	1,267,852	126,785	63,393
	Lower 90%CI	474,749	47,475	23,737
Chrysiptera leucopoma	Total	54,032	5,403	2,702
	Upper 90%CI	66,913	6,691	3,346
	Lower 90%CI	41,152	4,115	2,058
Coris frerei	Total	9,700	970	485
	Upper 90%CI	14,104	1,410	705
	Lower 90%CI	5,296	530	265
Ctenochaetus striatus	Total	489	49	24
	Upper 90%CI	1,014	101	51
	Lower 90%CI	-	-	-
Ecsenius bicolor	Total	1,829	183	91
	Upper 90%CI	3,419	342	171
	Lower 90%CI	239	24	12
Gomphosus caeruleus	Total	43,098	4,310	2,155
	Upper 90%CI	53,293	5,329	2,665
	Lower 90%CI	32,902	3,290	1,645
Halichoeres hortulanus	Total	3,691	369	185
	Upper 90%CI	5,544	554	277
	Lower 90%CI	1,837	184	92
Halichoeres marginatus	Total	46,087	4,609	2,304
	Upper 90%CI	60,773	6,077	3,039
	Lower 90%CI	31,401	3,140	1,570
Halichoeres spp	Total	5,946	595	297
	Upper 90%CI	12,305	1,231	615
	Lower 90%CI	-	-	-
Hemigymnus fasciatus	Total	489	49	24
	Upper 90%CI	1,014	101	51
	Lower 90%CI	-	-	-

Labroides dimidiatus	Total	86,249	8,625	4,312
	Upper 90%CI	97,938	9,794	4,897
	Lower 90%CI	74,560	7,456	3,728
Lutjanus kasmira	Total	3,425	342	171
	Upper 90%CI	7,099	710	355
	Lower 90%CI	-	-	-
Macropharyngodon bipartitus	Total	14,189	1,419	709
	Upper 90%CI	26,220	2,622	1,311
	Lower 90%CI	2,158	216	108
Macropharyngodon ornatus	Total	43,311	4,331	2,166
	Upper 90%CI	63,333	6,333	3,167
	Lower 90%CI	23,289	2,329	1,164
Naso lituratus	Total	489	49	24
	Upper 90%CI	1,014	101	51
	Lower 90%CI	-	-	-
Nemateleotris magnifica	Total	6,860	686	343
	Upper 90%CI	12,949	1,295	647
	Lower 90%CI	771	77	39
Neopomacentrus azysron	Total	3,804,168	380,417	190,208
	Upper 90%CI	5,133,797	513,380	256,690
	Lower 90%CI	2,474,539	247,454	123,727
Parupeneus bifasciatus	Total	915	91	46
	Upper 90%CI	2,060	206	103
	Lower 90%CI	-	-	-
Parupeneus indicus	Total	979	98	49
	Upper 90%CI	1,712	171	86
	Lower 90%CI	246	25	12
Parupeneus spp.	Total	4,829	483	241
	Upper 90%CI	9,182	918	459
	Lower 90%CI	476	48	24
Platax teira	Total	1,829	183	91
	Upper 90%CI	3,620	362	181
	Lower 90%CI	39	4	2
Plectorhinchus vittatus	Total	489	49	24
	Upper 90%CI	1,014	101	51
	Lower 90%CI	-	-	-
Pomacanthus annularis	Total	7,381	738	369
	Upper 90%CI	11,682	1,168	584
D	Lower 90%CI	3,081	308	154
Pomacanthus imperator	I otal	489	49	24 51
	Upper 90%CI	1,014	101	51
	Lower 90%CI	-	-	-

Pomacanthus semicirculatus	Total	22,432	2,243	1,122
	Upper 90%CI	27,939	2,794	1,397
	Lower 90%CI	16,925	1,692	846
Pomacentrus similis	Total	795,449	79,545	39,772
	Upper 90%CI	1,105,374	110,537	55,269
	Lower 90%CI	485,524	48,552	24,276
Pomacentrus spp.	Total	3,659	366	183
	Upper 90%CI	8,238	824	412
	Lower 90%CI	-	-	-
Rhinecanthus aculeatus	Total	8,392	839	420
	Upper 90%CI	13,693	1,369	685
	Lower 90%CI	3,090	309	155
Scarus spp	Total	3,425	342	171
	Upper 90%CI	5,667	567	283
	Lower 90%CI	1,182	118	59
Scomberomorus spp	Total	979	98	49
	Upper 90%CI	2,028	203	101
	Lower 90%CI	-	-	-
Thalassoma hardwicke	Total	19,156	1,916	958
	Upper 90%CI	26,018	2,602	1,301
	Lower 90%CI	12,294	1,229	615
Thalassoma jansenii	Total	20,422	2,042	1,021
	Upper 90%CI	30,252	3,025	1,513
	Lower 90%CI	10,591	1,059	530
Thalassoma lunare	Total	57,276	5,728	2,864
	Upper 90%CI	75,015	7,502	3,751
	Lower 90%CI	39,537	3,954	1,977
Valenciennea puellaris	Total	1,893	189	95
	Upper 90%CI	3,447	345	172
	Lower 90%CI	340	34	17
Zanclus cornutus	Total	6,297	630	315
	Upper 90%CI	10,765	1,077	538
	Lower 90%CI	1,828	183	91
Zebrasoma scopas	Total	915	91	46
	Upper 90%CI	2,060	206	103
	Lower 90%CI	-	-	-

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Appendix 6

List of reef fish species used in sampling

Family	Species
Acanthuridae	Acanthurus leucosternon
	Acanthurus lineatus
	Acanthurus mata
	Acanthurus spp.
	Acanthurus tennentii
	Acanthurus triostegus
	Acanthurus tristis
	Ctenochaetus striatus
	Ctenochaetus strigosus
	Naso brachycentron
	Naso brevirostris
	Naso hexacanthus
	Naso lituratus
	Paracanthurus hepatus
	Zebrasoma desjardinii
	Zebrasoma scopas
Apogonidae	Apogon spp.
Balistidae	Balistapus undulatus
	Balistoides conspicillum
	Odonus niger
	Rhinecanthus aculeatus
	Rhinecanthus rectangulus
	Sufflamen bursa
	Sufflamen chrysopterus
	Sufflamen fraenatus
	Trigger fish
Blennidae	Ecsenius bicolor
	Plagiotremus phenax
Caesionidae	Caesio cuning
	Caesio spp
	Caesio xanthonota
	Pterocaesio chrysozona
	Pterocaesio spp.
	Pterocaesio tile
Callionymidae	Synchiropus stellatus
Carangidae	Caranx heberi
	Caranx ignobilis
	Caranx sexfasciatus
	Caranx spp.
	Gnathanodon speciosus
Carcharinidae	Carcharhinus melanopterus
Chaetodontidae	Chaetodon auriga

	Chaetodon bennetti
	Chaetodon citrinellus
	Chaetodon collare
	Chaetodon decussatus
	Chaetodon falcula
	Chaetodon gardineri
	Chaetodon guttatissimus
	Chaetodon interruntus
	Chaetodon kleinii
	Chaetodon lineolatus
	Chaetodon lunula
	Chaetodon melannotus
	Chaetodon mertansiji
	Chaetodon mertensit
	Chaeloaon meyeri
	Chaetoaon piebeius
	Chaetodon rafflesi
	Chaetodon semeion
	Chaetodon triangulum
	Chaetodon trifascialis
	Chaetodon trifasciatus
	Chaetodon unimaculatus
	Chaetodon vagabundus
	Chaetodon xanthocephalus
	Forcipiger flavissimus
	Hemitaurichthys zoster
	Heniochus acuminatus
	Heniochus pleurotaenia
	Heniochus singularius
Cirrhitidae	Cirrhitichthys oxycephalus
	Paracirrhites forsteri
Ephippidae	Platax orbicularis
	Platax teira
Fistularidae	Fistularia commersonii
Gohiidae	Valenciennea puellaris
	Valenciennea spn.
	Valenciennea strigata
Haemulidae	Diagramma pictum
	Plectorhinchus cevlonensis
	Plectorhinchus schotaf
	Plactorhinchus vittatus
Holocontridoo	A veriorintenas vitatas
	Sangaganthan diadama
	Sangocentron alaaema
Vanharidaa	Surgocentron spp.
Kypnosidae Labridae	Kypnosus cinerascens
	Anampses caeruleopunctatus
	Anampses lineatus
	Bodianus axillaris

	Bodianus diana
	Bodianus neilli
	Cheilinus chlorourus
	Cheilinus undulatus
	Cirrhilabrus rubrisquamis
	Coris frerei
	Gomphosus caeruleus
	Halichoeres argus
	Halichoeres hortulanus
	Halichoeres leucoxanthus
	Halichoeres marginatus
	Halichoeres spp.
	Hemigymnus fasciatus
	Hemigymnus melapterus
	Labroides bicolor
	Labroides dimidiatus
	Macropharyngodon bipartitus
	Macropharyngodon meleagris
	Macropharyngodon ornatus
	Novaculichthys taeniourus
	Stethojulis spp.
	Thalassoma hardwicke
	Thalassoma jansenii
	Thalassoma lunare
Lethrinidae	Lethrinus harak
	Lethrinus nebulosus
	Lethrinus spp.
Lutjanidae	Lutjanus argentimaculatus
	Lutjanus biguttatus
	Lutjanus bohar
	Lutjanus decussatus
	Lutjanus fulviflamma
	Lutjanus fulvus
	Lutjanus gibbus
	Lutjanus kasmira
	Lutjanus lunulatus
	Lutjanus malabaricus
	Lutjanus quinquelineatus
	Lutjanus rivulatus
	Lutjanus spp.
Microdesmidae	Nemateleotris magnifica
	Ptereleotris evides
	Ptereleotris heteroptera
	Ptereleotris spp.
Monacanthidaa	~
Wionacantinuae	Cantherhines pardalis
Mullidae	Cantherhines pardalis Mulloidichthys flavolineatus
Mullidae	Cantherhines pardalis Mulloidichthys flavolineatus Mulloidichthys vanicolensis

	Parupeneus indicus
	Parupeneus macronema
	Parupeneus spp.
Nemipteridae	Scolopsis spp.
Ostraciidae	Ostracion cubicus
	Ostracion meleagris
Pinguipedidae	Parapercis clathrata
Pomacanthidae	Apolemichthys xanthurus
	Centropyge eibli
	Centropyge flavipectoralis
	Centropyge multispinis
	Pomacanthus annularis
	Pomacanthus imperator
	Pomacanthus semicirculatus
Pomacentridae	Abudefduf vaigiensis
	Amphiprion clarkii
	Amphiprion nigripes
	Amphiprion sebae
	Chromis dimidiata
	Chromis spp.
	Chrysiptera kuiteri
	Chrysiptera leucopoma
	Dascyllus aruanus
	Dascyllus carneus
	Dascyllus spp.
	Dascyllus trimaculatus
	Neopomacentrus azysron
	Neopomacentrus cyanomos
	Pomacentrus similis
	Pomacentrus spp.
Pseudochromidae	Pseudochromis fuscus
Scaridae	Chlorurus rhakoura
	Parrot fish
	Scarus ghobban
	Scarus niger
	Scarus rubroviolaceus
	Scarus sordidus
	Scarus spp.
Scombridae	Scomberomorus spp
Scorpaenidae	Pterois antennata
	Pterois miles
	<i>Pterois volitans</i>
Serranidae	Aethaloperca rogaa
	Cephalopholis argus
	Cephalopholis formosa
	Cephalopholis miniata
	Cephalopholis sonnerati
	Cephalopholis spp.

	Epinephelus caeruleopunctatus
	Epinephelus fasciatus
	Epinephelus faveatus
	Epinephelus flavocaeruleus
	Epinephelus fuscoguttatus
	Epinephelus hexagonatus
	Epinephelus malabaricus
	Epinephelus merra
	Epinephelus polyphekadion
	Epinephelus quoyanus
	Epinephelus spp.
	Plectropomus areolatus
	Plectropomus laevis
	Plectropomus leopardus
	Plectropomus spp.
	Pseudanthias spp.
	Pseudanthias squamipinnis
	Variola louti
Siganidae	Siganus javus
	Siganus lineatus
	Siganus rivulatus
	Siganus spp.
Sphyraenidae	Sphyraena barracuda
	Sphyraena spp.
Tetraodontidae	Arothron hispidus
	Arothron spp.
	Canthigaster solandri
	Canthigaster valentini
	Diodon holocanthus
	Diodon hystrix
Zanclidae	Zanclus cornutus

Appendix 7

List of species of fish and invertebrates prohibited from export in live form (Part 1) under the Fisheries and Aquatic Resources Act No. 2 of 1996

Family	Species
Chaetodontidae	Chaetodon semeion
Pomacanthidae	Centropyge bispinosus
	Pygoplites diacanthus
Labridae	Coris aygula
	Labroides bicolor
Scorpaenidae	Pterois radiata
Ephippidae	Platax pinnatus
Serranidae	Epinephelus lanceolatus
	Epinephelus flavocaeruleus
Haemulidae	Plectorhinchus obscurum
	Plectorhinchus albovittatus
Pomacentridae	Chrysiptera kuiteri

Appendix 8

List of species of marine fish (Restricted Export) that require a permit for export in live form (Part II) under the Fisheries and Aquatic Resources Act No. 2 of 1996

Family	Species
Chaetodontidae	Chaetodon octofasciatus
	Chaetodon ornatissimus
	Chaetodon falcula
	Chaetodon xanthocephalus
	Chaetodon ephippium
	Chaetodon unimaculatus
	Chaetodon madagascariensis
	Chaetodon bennetti
	Chaetodon meyeri
	Chaetodon triangulum
	Heniochus monoceros
	Heniochus pleurotaenia
Pomacanthidae	Centropyge flavipectoralis
Balistidae	Balistoides conspicillum
	Pseudobalistes fuscus
Serranidae	Variola louti
	Variola albimarginata