SUSTAINABILITIY OF THE MARINE ORNAMENTAL FISHERY IN PUERTO RICO: ECOLOGICAL ASPECTS

Final Report

Antares Ramos Álvarez
Award number: NA09NMF4630126

Submitted: 27/December/11

INTRODUCTION

The trade of ornamental fisheries has existed in Puerto Rico (PR) since the 1960's (Sadovi 1991, Ojeda 2002, Mote 2002, Matos-Caraballo & Mercado-Porrata 2006). Ornamental fisheries were originally started by foreign surfers looking for a way to gain an income during the surfing off-season, giving them a means to stay on the island. It is a trade that remained unregulated until the 1998 Fisheries Law of Puerto Rico (Law 278) and its Fisheries Regulation 6768 of 2004 were passed. The new fishing law requests that ornamental fishermen acquire a fishing permit so that they can both capture and export ornamental species, in addition to the commercial fisherman license. Regulation 6768 establishes the commercial fishermen license fee to $40 with duration of four years, the capture permit fee to $100, and the export permit fee to $400 both with duration of one year. Appendix 4 of Regulation 6768 limits the list of permitted exported species to 20 fish species and 8 invertebrate species (see Appendix 1 for list), compared to over 100 species that were previously exported (Sadovy 1991, Ojeda 2002). The limitation of permitted species took place due to a perceived fear of resource abuse (Mote 2002).

These changes in legislation intensified the already existing friction between fishermen and regulation authorities in PR. Fishermen were not properly consulted during any part of the process (LeGore & Hardin 2005); they were informed about the new changes once the law was passed. An official explanation on the selection of these 28 species has not been found. By looking at the statistics of ornamental exports we were able to infer that the list in Regulation 6768 was established by using the "top 20" fish species on the export list (and we imagine the same happened for the invertebrates). Scientific environmental assessments were not carried out to measure the state of the resource or its habitat. The result was a law that barely took into consideration the needs and uses of fishermen and did not accurately reflect the reality of the resources.

Fishermen have made themselves be heard and some have even taken cases to court to appeal to new sanctions. The regulatory agency, Department of Natural and Environmental Resources (DNER), has found itself in the obligation to review the legislation and open channels of communication with the users. As part of this effort independent and unbiased researchers have been hired with the purpose of studying and understanding the current situation and the possibilities of amending the law. The result of one of these studies has brought light onto the fact that ornamental fisheries in Puerto Rico are not being abused as it was thought (LeGore 2006).

The ornamental fish trade in the Caribbean currently supplies a small percentage of the global trade (Bruckner 2005, FAO 2005), but represents an important emerging industry. Ornamental fisheries typically target non-edible species that are economically valuable. Marine aquariums, private or public, can help educate about these fish and their environments as well as increase awareness on the need to conserve these ecosystems (Wood 2001). It would be naïve not to mention that an increase in the participation of the fishery could potentially lead to over-exploitation and harm reef communities. This is why we seek to further understand the ornamental trade in Puerto Rico and explore the possibility of further expanding the trade.

This study investigated the reality of the ornamental fish industry with an effort to

understand user needs and resource use impact, with the goals of providing suggestions to legislation modification that favors both the users and the resources, and establishing base-line ecological data to support the sustainability and profitability of the trade. For effects of this report, we will focus on the ecological aspects of the study.

METHODOLOGY

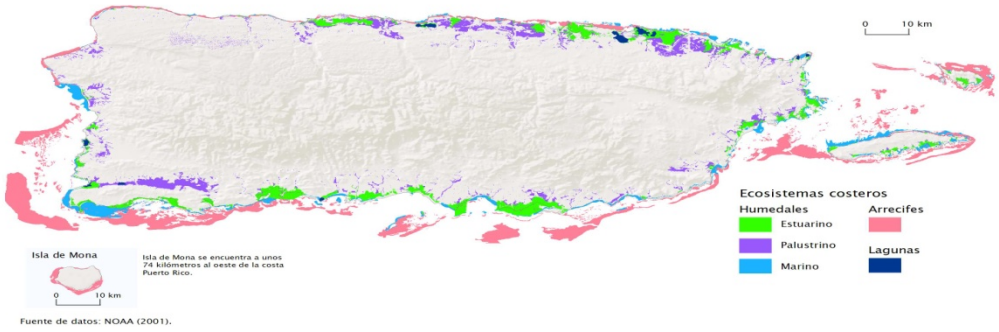
The study covers five main activities: Managers' Views, Users' Perspectives, Market Forces Analysis, Ecological Assessment, and Public Policy Implications. For the purpose of this report, we will focus on the Ecological Assessment.

Ecological Assessment

The goal of the ecological assessment was to ground truth the quotas established by the fishing law, analyze accuracy of those species that were chosen to be on the list, and assess abundance of other ornamental species not on the list.

The ecological surveys were carried out from January to October 2010. The study sites for the ecological assessments were identified through ornamental fishermen interviews, literature reviews, and past studies. Past studies identified the west side of the island (Arecibo to Lajas) as the geographical area of the trade (Sadovy 1991, Ojeda 2002). Ornamental fishing has, however, been observed in the eastern coast (Sadovy 1991, LeGore 2006). This goes in agreement with the geographical distribution of reefs in Puerto Rico, which are found in all its periphery (Goenaga & Cintrón 1979) but with more intensity in the western peninsular shelf and in the south and east of the island (Figure 1). Through the ornamental fishermen interviews, we found out that the area where the trade (for export purposes) currently takes place is the west coast of Puerto Rico.

Figure 1. Location of coral reefs (in pink) in Puerto Rico. (From López-Marrero, & Villanueva-Colón 2006).



Five Regions were chosen (see Figure 2):

Region 1: Southwest - Guánica, La Parguera, Cabo Rojo (Figure 3)
It was reported that fishing takes place in La Parguera and Cabo Rojo, and sometimes in Guánica.

Region 2: West - Añasco, Rincón, Aguada (Figure 4)
The heaviest load for ornamental fishing takes place in this area.

Region 3: West - Tres Palmas Natural Reserve (non-fished), in Rincón (Figure 5)
As a no-take natural reserve, it was chosen to study if there is any difference with adjacent reefs outside the reserve where fishing takes place.

Region 4: East - Culebra, adjacent keys to Luis Peña (Figure 6)
An area that is not fished for ornamental species but is fished for commercial species.

Region 5: Luis Peña Natural Reserve (non-fished), in Culebra (Figure 7)
As a no-take natural reserve in an area where ornamental fisheries was reported not to take place (mainly due to the logistics of transporting and shipping the fish), this was chosen as the control.

We considered sampling in the southeast of Puerto Rico as well as the island of Vieques (also on the east of PR), but decided not to include them in the study. The southeast coast is of high energy impact and the window of possible days in the field was found to be very narrow. Also, ornamental fishing was not reported in this area. Vieques was until recently under the jurisdiction of the US Navy. There are still unidentified unexploded ordinances in the coastal waters, which presented a possible hazard to the researchers. For safety precautions and also due to the fact that ornamental fishing was not reported in the area (for the same reasons as in Culebra) this area was not chosen. Recreational ornamental fishing (for personal/home aquariums) was reported in the north coast of the island as well as the east coast. These areas were not chosen since the focus of the study is the export trade.

Figure 2: All Regions

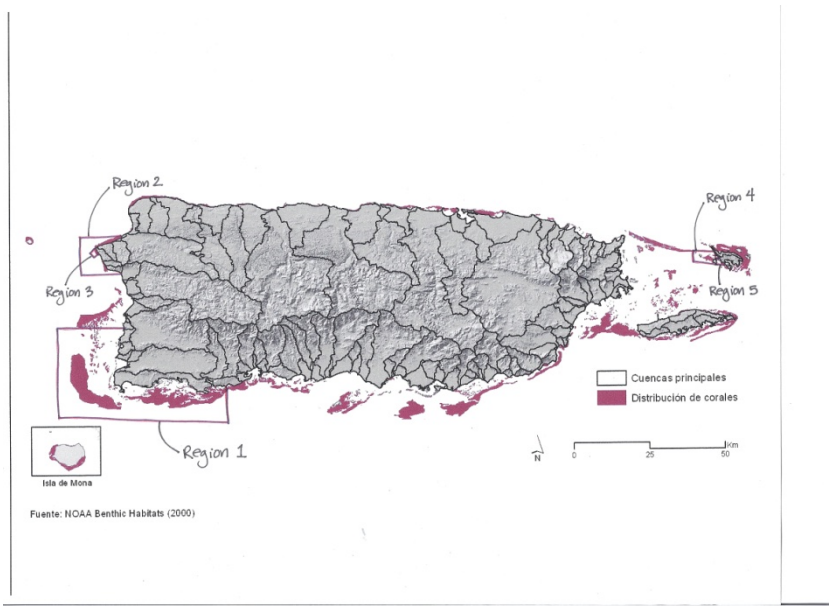


Figure 3: Region 1 – Guánica, La Parguera and Cabo Rojo

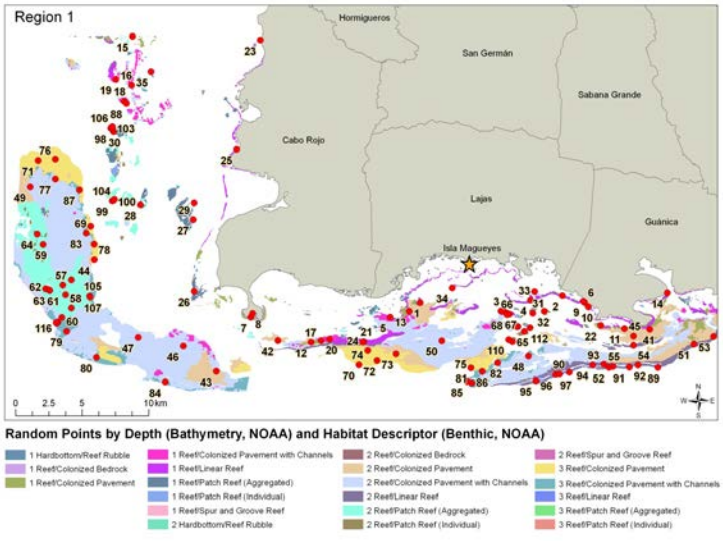


Figure 4: Region 2 – Añasco, Rincón and Aguada

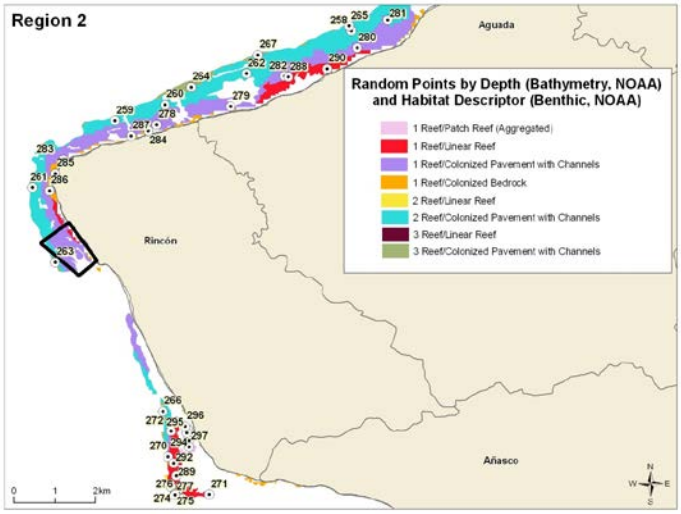


Figure 5: Region 3 – Tres Palmas Natural Reserve

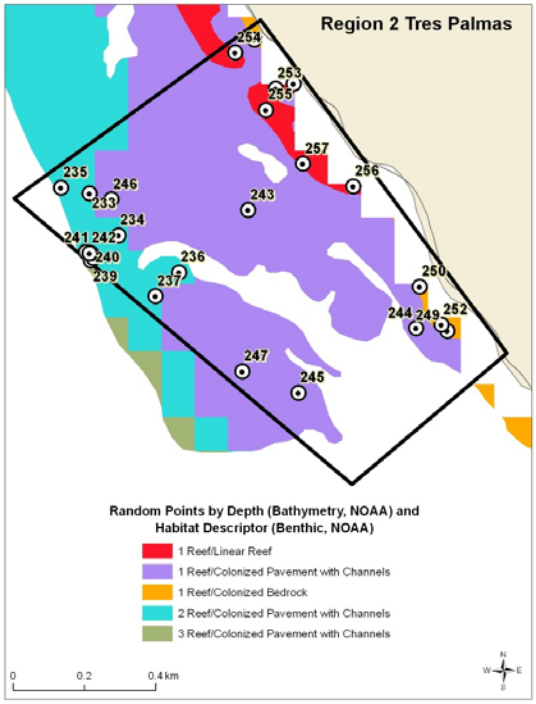


Figure 6: Region 4 – Culebra, adjacent to Luis Peña Natural Reserve

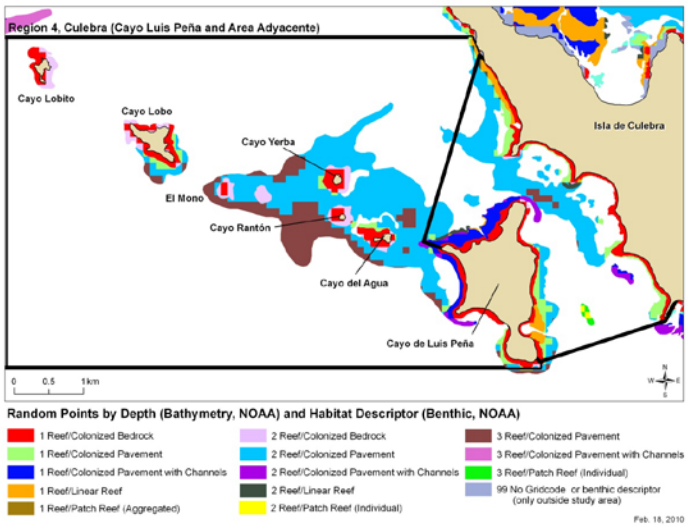
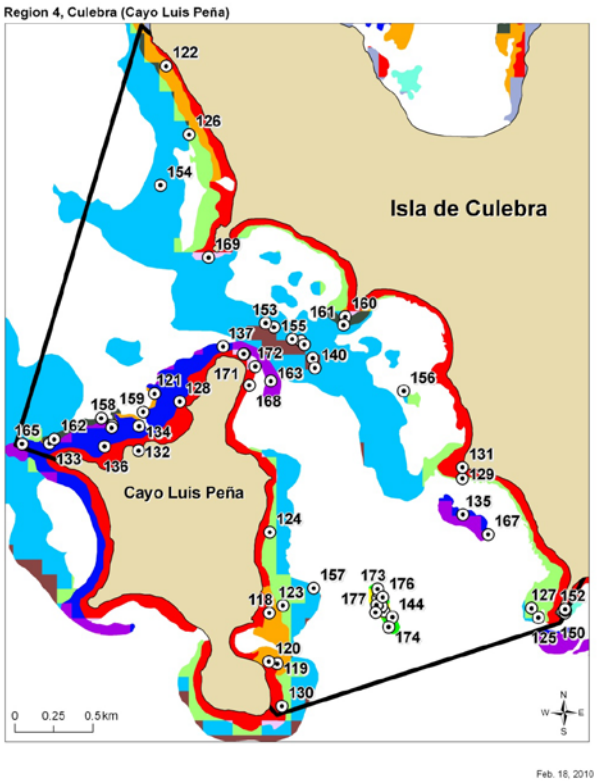


Figure 7: Region 5 – Luis Peña Natural Reserve



Sites were randomly chosen using Arc GIS within each of the five Regions. A total of 107 sites were surveyed island-wide: 50 in Region 1, 16 in Region 2, 5 in Region 3, 11 in Region 4, 25 in Region 5. Benthic habitats were taken into consideration when sites were chosen, to assure that there was ample representation of each sea floor type. NOAA's (2002) Benthic Habitat Maps of Puerto Rico were used as a cross reference when choosing the sites with Arc GIS. The benthic habitats that were surveyed were coral reefs and coral rubble. Habitat type for each sampled species was identified through NOAA's (2005) Coral Reef

Ecosystem Assessment and Monitoring Database. The habitat types sampled were: Reef/Colonized Bedrock, Reef/Colonized Pavement, Reef/Colonized Pavement with Channels, Reef/Linear Reef, Reef/Patch Reef (Aggregated), Reef/Patch Reef (Individual), Reef/Spur and Groove Reef, and Hardbottom/Reef Rubble. In addition, three depth categories were used, as per NOAA's nautical charts: 0-10 meters, 10-20 meters and 20-30 meters, since many of the species live in same habitat types but at different depths.

The sites were surveyed using underwater visual census (UVC) techniques, using SCUBA. The methodology established by LeGore Environmental Associates, Inc. (2004) was used. Swimming Belt Transects (SBT) were the UVC technique used for the species and habitat assessments, 10m long x 3m wide. Cryptic species were searched for under rocks and inside crevices, with minimal habitat perturbation, through an active search census (LeGore Environmental Associates, Inc. 2004), where species that are hard to find by just swimming over their habitats were targeted.

The swimming belt transect surveys occurred in three phases: 1) Initial transit to survey species sensitive to diver presence, 2) Active search for cryptic species, and 3) Recording of habitat parameters. For each transect, the following information was recorded underwater:

- Number of fish individuals (not commercially fished for consumption demand) with life stage specification (for some species)
- The five habitat parameters (discussed below)
- Habitat type
- Depth (average taken from recordings at the 1m and 10m marks)
- Start- and end-time of survey

In addition to the species assessment, habitat complexity data was measured. The goal of this assessment was to further expand knowledge on benthic structure throughout Puerto Rico, measure their state, and to further classify habitat types for each species. Habitat complexity, as a strong correlate to abundance, can also be used for post stratification of densities to improve confidence limits. Each habitat complexity parameter was recorded on each meter mark, for a total of 10 marks per transect. Two of the parameters were measured using the HAS score illustrated on Table 2 (Gratwicke & Speight 2005), but modified to be measured on every meter mark. The parameters measured are below. Appendix 2 has an excerpt taken from the Gratwicke & Speight (2005) publication, further explaining some of the parameters.

- Rugosity: visual topographic estimate will be taken of the substratum (see Table 2).
- Benthos: organisms found under the meter mark will be recorded (hard coral, soft coral, algae, sponge)
- Live cover: identification if benthos is dead or alive
- Sea floor structure: identification of substratum (sand, rubble, mud, reef)
- Height: visual estimate of height of architecture will be recorded (see Table 2).

Table 2. HAS Score (Gratwicke & Speight 2005).

	HAS SCORE				
	1	2	3	4	5
Rugosity (visual topographic estimate of the substratum in each quadrat)					
Variety of growth forms (stalked/lobed/filamentous/ ribbon-like/massive/branching/ cylindrical/tube/fan/plate/ pinnate/encrusting/other)	<2	3 & 4	5 & 6	7 & 8	9–10
Height (visual estimate of average height of habitat architecture) (cm)	0–9	10–19	20–39	40–79	>80
Refuge size categories (holes or gaps in habitat architecture or substratum in the following size categories: 1–5, 6–15, 16–30, 31–50 and >50cm)	0–1	2	3	4	5
Live cover (total per cent cover of *e.g.* living corals, mangrove roots, seagrass, macroalgae and sponges)	0–19	20–39	40–59	60–79	80–100
Hard substratum (%)	0–19	20–39	40–59	60–79	80–100

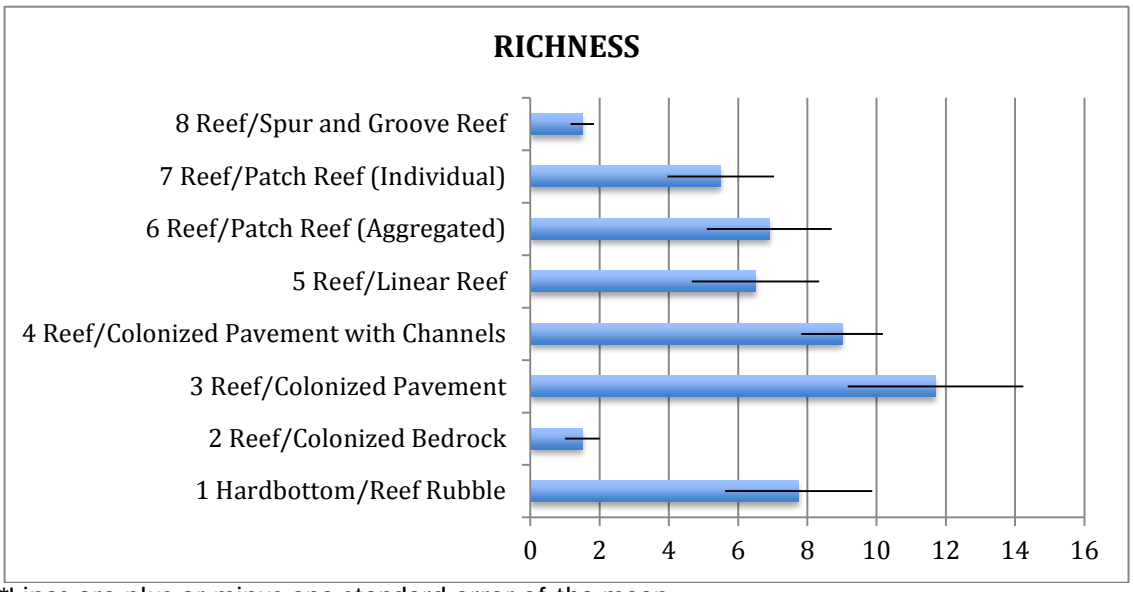
RESULTS

Data analysis was carried out using SPSS 18.0 and the Community Analysis Package (by Pisces Conservation: www.pisces-conservation.com)

Ranking order comparison of species occurrence and species abundance (see Appendix 3) show a discrepancy with the permitted species list. Many of the highest occurring or most abundant species are not on the permitted species list, which might lead to think that the list is not in accordance with the ecological reality of the aquarium trade. There were four species on the permitted species list that were not sighted at all on any of the sites visited: *Centropyge argi*/Cherubfish, *Gobiosoma multifasciatum*/Greenbanded Goby, *Opistognathus whitehursti*/Dusky Jawfish, and *Xanthichthys ringens*/Sargassum Triggerfish. When looking at the top 25 ranking fish abundance (Appendix 3), it is of interest to note juvenile vs. adult stages in some of the species. Focusing on those species on the permitted species list, there are two which juveniles where found in higher abundance than adults: *Thalassoma bifasciatum*/Bluehead wrasse ranking 2nd as juvenile and 11th as adults; and *Halichoeres garnoti*/Yellowhead wrasse ranking 10th as juvenile, 25th as intermediate, and 93rd as adults. *Acanthurus coeruleus*/Blue tang and *Chromis cyanea*/Blue chromis had the opposite results, with higher ranking adult numbers than juveniles: 6th for adults and 15th for juveniles for the Blue Tang, and 7th for adults and 21st for juveniles for the Blue Chromis.

When looking at habitat type and species richness (Graph 1) it was found that Reef/Colonized Pavement (as identified by NOAA's Benthic categories) sites had higher species richness, whereas Reef/Spur and Groove and Reef/Colonized Bedrock had the lowest scores.

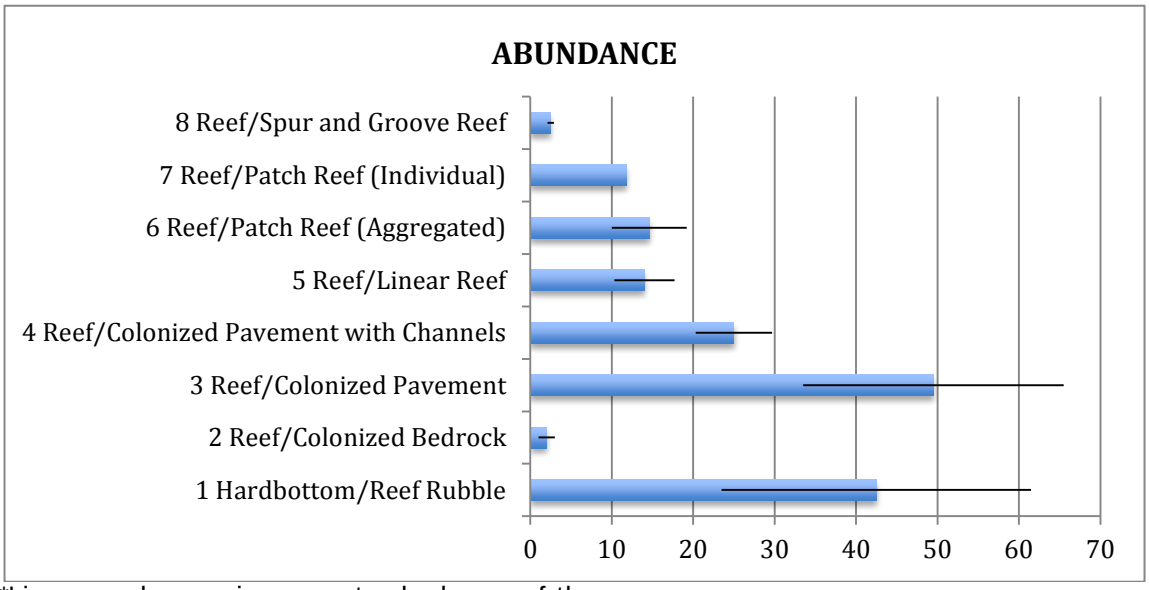
Graph 1: Habitat Type and Species Richness in Region 1



*Lines are plus or minus one standard error of the mean.

Similarly, habitat type and species abundance comparison (Graph 2) also resulted in Reef/Colonized Pavement sites having higher species richness, whereas Reef/Spur and Groove and Reef/Colonized Bedrock had the lowest scores.

Graph 2: Habitat Type and Species Abundance in Region 1

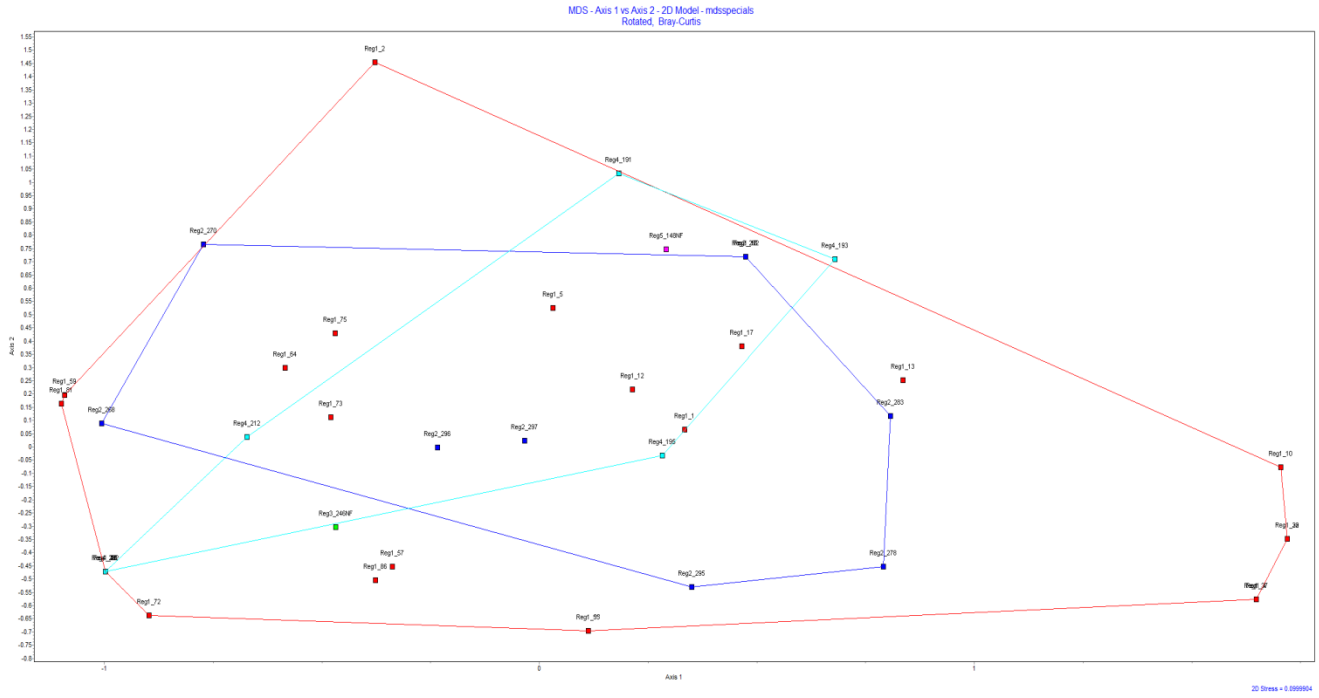


*Lines are plus or minus one standard error of the mean.

Multi-dimensional scaling tests looking at the permitted fish species in all regions resulted in significant differences (Graph 3). Very significant difference (p-value of 0.001) was found between Regions 1 and 5, Regions 2 and 5 and regions 4 and 5. Significant difference (p-value of 0.02) was found between Regions 1 and 3. There was no significant difference (p-value >0.05) found, however, between Regions 2 and 3 and Regions 3 and 5.

Graph 3: Permitted fish species MDS by region: Square root transformed, outliers removed

Red=Region1; blue=Region2; green-Region3NF; pale blue=Region4; purple=Region5NF



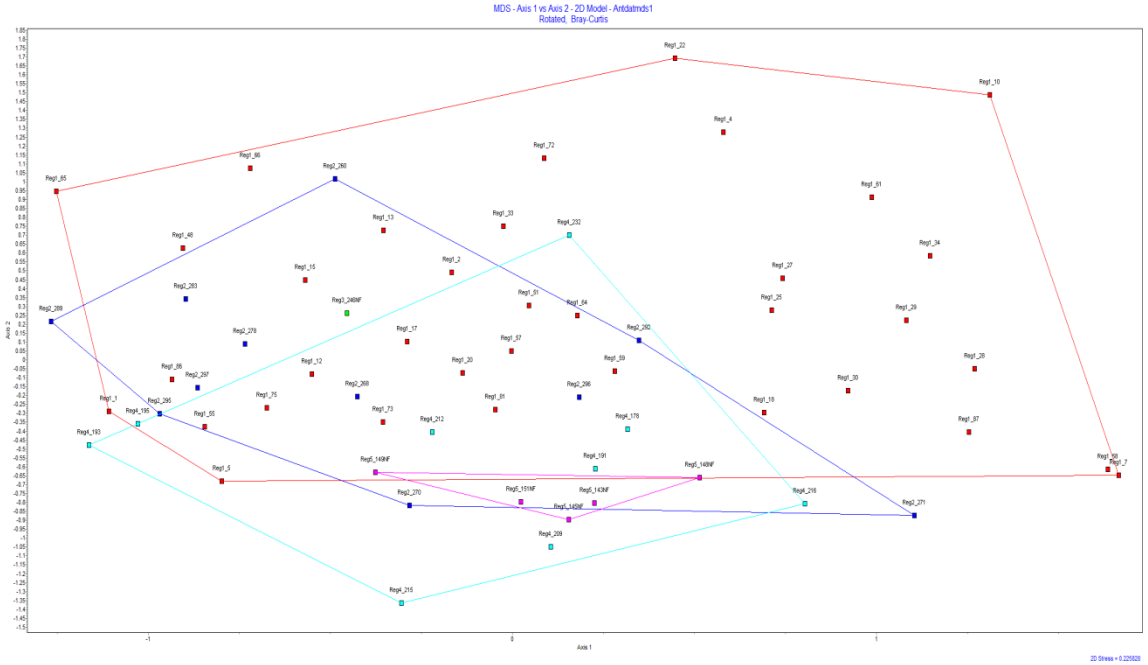
Region1 (41)	Region2 (11)	> 1000000	1000	0.001
Region1 (41)	Region3NF (1)	42	42	0.0238095
Region1 (41)	Region4 (9)	> 1000000	1000	0.001
Region1 (41)	Region5NF (5)	> 1000000	1000	0.001
Region2 (11)	Region3NF (1)	12	12	0.0833333
Region2 (11)	Region4 (9)	167960	1000	0.001
Region2 (11)	Region5NF (5)	4368	1000	0.001
Region3NF (1)	Region4 (9)	10	10	0.1
Region3NF (1)	Region5NF (5)	6	6	1
Region4 (9)	Region5NF (5)	2002	1000	0.001

Note: Furthest column to the right holds the p-values

Multi-dimensional scaling tests looking at depth and fish diversity in all regions resulted in significant differences (Graph 4). Very significant difference (p-value of 0.005 and 0.004 respectively) was found between Regions 1 and 2 and between Regions 1 and 4. Significant difference (p-value of 0.01) was found between Regions 1 and 5.

Graph 4: Fish Diversity MDS in all regions and depths: Square root transform, outliers removed

Red=Region 1; blue=Region 2; green=Region 3NF; pale blue=Region 4; purple=Region 5NF



Region1 (41)	Region2 (11)	> 1000000	1000	0.005
Region1 (41)	Region3NF (1)	42	42	0.142857
Region1 (41)	Region4 (9)	> 1000000	1000	0.004
Region1 (41)	Region5NF (5)	> 1000000	1000	0.013
Region2 (11)	Region3NF (1)	12	12	0.833333
Region2 (11)	Region4 (9)	167960	1000	0.275
Region2 (11)	Region5NF (5)	4368	1000	0.183
Region3NF (1)	Region4 (9)	10	10	0.4
Region3NF (1)	Region5NF (5)	6	6	0.166667
Region4 (9)	Region5NF (5)	2002	1000	0.818

Note: Furthest column to the right holds the p-values

DISSEMINATION OF INFORMATION

The dissemination of information is a vital aspect of the project, since one of the main goals is provide information to managers and policy makers with information that can be used to amend current policy. Educating other stakeholders, such as academics, fishermen and exporters is another important aspect of the study, especially when the communication between the DNER and fishermen is hindered by past conflict.

A report will be written for both the DNER and CFMC where the findings of the study will be presented (Users' Perspectives, Market Forces, and Ecological Assessment), in addition to the Policy Implications developed based on the results of the entire study. Feedback will be sought from managers to ensure it is written in a way useful to them. A copy of the report will be facilitated to all the management stakeholders where communication and collaboration has occurred. In addition, a copy of the report will be facilitated to Daniel Galán, the Secretary of the DNER, and to Miguel Rolón, Director of CFMC. If any other stakeholders that should receive the report are identified, a copy will also be facilitated. In

a letter accompanying the report, willingness to meet with the stakeholders to discuss the findings and policy implications will be expressed.

Those academics involved in the study will receive copy of the above mentioned report. Peer reviewed articles will be submitted to scientific journals with the hope of sharing the results of the study with a global scientific community. Participation in scientific conferences will also be sought, with this same purpose.

Collaboration with Sea Grant and DNER has been attained to create a leaflet which explains the trade, the regulation and identifies the species. The target audience are resource users (fishermen) and enforcement forces (rangers).

DISCUSSION

Species abundance ranking showed a discrepancy between the permitted species list and the ecological reality. This leads us to think that the permitted species list should indeed be amended. As per the four species that were not found, it is possible that the more habitat and depth specific searches ought to take place to find them. Temporal absence might also be a reason for not sighting them. Further research should be conducted on these four species before deciding removing or keeping them on the list.

For both *Thalassoma bifasciatum*/Bluehead wrasse and *Halichoeres garnoti*/Yellowhead wrasse, which juveniles were found higher in ranking than adult individuals. These two species are fished as adults for the ornamental fish trade, which could mean sustainability in the extraction of the species. In the case of the Bluehead wrasse this is especially promising, since once the adult (male) is removed, another individual transforms into a male, thus replenishing the balance. In the case of the *Acanthurus coeruleus*/Blue tang, it is a species which is fished as a juvenile (when it's smaller in size and yellow, making it more attractive to have in an aquarium). The fact that more adults were found than juveniles may not be of vast concern, since their ranking were not that far apart. The *Chromis cyanea*/Blue chromis is fished both as an adult or juvenile. We find that the difference in raking between adult and juvenile is of no great concern, especially when in sampling they could have been mislabeled as adult or juvenile due to its size.

The difference between Species richness and abundance to habitat type might be due to species preference and possibly location of sites visited in relation to habitat. Further analysis is needed to further understand these findings. In general, the more complex habitats were found to have higher abundance and richness, which is what is expected to be found.

There were differences found between regions and the species on the permitted list. It is extremely interesting the find that there was very significant difference found between Luis Peña (Region 5), the non-fished control region, and all other regions EXCEPT the other non-fished site. This finding could support the premise that non-fished sites yield higher number of species presence than fished sites. However, it is also interesting to note that there was no significant difference found between Rincón (Region2) and Tres Palmas (Region 3), fished and non-fished sites. The reason for this lack of difference might be the fact that they are adjacent to each other and there is some sort of spill-over effect raking

place.

The difference found in depth and fish diversity across regions could be due to the fact that most deep dives took place in Parguera. This was due to diving logistics and safety. Dives 20-30 meters deep took place in all Regions except Region 3 and Region 5 (both of the non-fished Regions) since the were no sites found in that depth category. Another variable might be distance of sites from shore, where access by fishermen or even landbased sources of pollution might play a role. Further analysis is necessary to take these variables into consideration.

It was found that the ornamental trade might play a minimal impact on the species fished. Further analysis is needed in order to recommend a change in the permitted species list. Comparison of these findings with the market forces should yield clearer results of what species are of high value to the trade, and thus of importance for management. The socio-economic aspects of the study will be submitted as part of a PhD dissertation. An executive summary will be prepared and facilitated to DNER and NOAA, as a supplement to this report.

REFERENCES

Bruckner, A.W. (2005). The importance of the marine ornamental reef fish trade in the wider Caribbean. *Revista de Biología Tropical* (53), 127- 137.

FAO (2005). World fisheries production by capture and aquaculture. Food and Agriculture Organization of the United Nations. ftp://ftp.fao.org/fi/STAT/summary/a-0a.pdf (accessed 5/5/08)

Goenaga, C. & G. Cintrón (1979). Inventory of the Puerto Rico Coral Reefs. Report submitted to the Coastal Zone Management of the Department of Natural Resources, San Juan, 190pp.

Gratwicke, B. & Speight, M.R. (2005). The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. *Journal of Fish Biology* (66), 650-667.

López-Marrero, T.M. & Villanueva-Colón, N. (2006). Atlas ambiental de Puerto Rico**.** San Juan, Puerto Rico: Editorial de la Universidad dePuerto Rico, 160pp.

LeGore Environmental Associates, Inc. (2004). Protocol development for marine ornamental stock assessment in Puerto Rico. Rep. to National Oceanographic and Atmospheric Admin., National Marine Fisheries Service, Office of Habitat Conservation, under Delivery Order DG133F- 03-SE-0950. LeGore Environmental Associates, Inc. Tech. Rep. No. 03- 105A. 51 pp. + app.

LeGore, R.S. & Hardin, M.P. (2005). Development of management policy for the marine ornamental fish and invertebrate fishery in Puerto Rico: A case study. *Revista de Biología Tropical* (53), 139-144.

LeGore, R.S., Hardin, M.P., & Ter-Ghazaryan, D. (2005). Organization and operation of the marine ornamental fish and invertebrate export fishery in Puerto Rico. *Revista de Biología Tropical* (53), 145-153.

LeGore Environmental Associates, Inc. (2006). Puerto Rico ornamental fishery evaluation: Wild population Assessment (Phase II). Report submitted to the Caribbean Coral Reef Institute, Mayagüez, 63pp.

Matos-Caraballo,D. & Mercado-Porrata, A. (2006). Description of the ornamental fishery in Puerto Rico: 1997-2005. Presented at the 59th Gulf and Caribbean Fisheries Institute Meeting, November 6-11, 2006, Belize.

Mote Environmental Services, Inc. (2002). A description of the export fishery for marine ornamental fish and invertebrates in Puerto Rico. Report submitted to The Puerto Rico Coral Reef Advisory Comité, San Juan, 41pp.

NOAA. (2002). Benthic Habitats of Puerto Rico and the U.S. Virgin Islands.\National Oceanic and Atmospheric Administration. NCCOS Biogeography Program, Silver Spring, MD, USA. http://ccma.nos.noaa.gov/products/biogeography/benthic/startup.htm

NOAA. (2005). Coral Reef Ecosystem Assessment and Monitoring Database. National Oceanic and Atmospheric Administration. NCCOS Center forCoastal Monitoring and Assessment, Silver Spring, MD, USA. http://www.ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish.html

Ojeda, E. (2002). Los peces ornamentales marinos en Puerto Rico y la piscicultura. *Boletín Marino* (7-9), 3-8.

Sadovy, I. (1991). A preliminary assessment of the export trade in marine aquarium organisms in Puerto Rico. Report submitted to the Caribbean Fisheries Management Council, San Juan, 43pp.

Wood, E. (2001). Collection of coral reef fish for aquaria: Global trade, conservation issues and management strategies. Marine Conservation Society, UK. 80pp.

Appendix 1. List of species permitted for export, as presented in the Fisheries Regulation 6768

Scientific Name	Common Name	Common Name (Sp.)
Acanthurus coeruleus	Blue Tang	Barbero, médico, navajón
Amblycirrhitus pinos**	Red spotted hawkfish	Halconcito
Apgon maculatus * *	Flame cardinal	Cardenal candela
Bodianus rufus*	Spanish hogfish	Loro capitán*
Centropyge argi	Pygmy angelfish	Querubin azul
Chromis cyanea	Blue chromis	Burrito, jaqueta azul, cromis
Gobiosoma multifasciatum	Greenbanded goby	Gobio verde, guaseta
Gramma loreto	Royal Gramma	Gramma, chernita bicolor
Halichoeres garnoti	Neon wrasse	Doncella cabeciamarilla
Holacanthus tricolor	Rock beauty	Isabelita medioluto,
Hypsoblennius exstochilus	Long horned blenny	Dardo ojón, miron, mirador
Microspathodon chrysurus**	Yellowtail, jewel damselfish	Damisela coliamarilla
Myripristis jacobus*	Blackbar soldierfish	Toro, torito, cundeamor
Ophioblennius macclurei	Redlip blenny	Dardo puya, miron, mirador
Opistognathus aurifrons	Yellowhead Jawfish	Quijada colirrubia
Opistognathus whitehurstii	Dusky jawfish	Quijada prieta
Pomacanthus paru	French angelfish	Isabelita negra, palometa
Serranus tigrinus**	Harlequin bass	Guaseta arlequín
Thalassoma bifasciatum	Bluehead wrasse	Doncella cabeciazul, runone
Xanthichthys ringens	Sargassum triggerfish	Puerquito, cayuco

Scientific Name	Common Name	Common Name (Sp.)
Alpheus armatus * * *	Red snapping shrimp	Camarón tirador colorao
Mithrax sculptus * * *	Green/emerald crab	Juey colgante verde
Oliva reticularis	Measle cowrie/olive snail	Oliva
Oreaster reticulatus***	Red Bahama west indies starfish	Estrella de mar
Stenopus hispidus***	Red banded coral shrimp	Camarón arlequín
Stenopus scutellatus * * *	Golden coral shrimp	Camarón dorado
Stenorhynchus seticornis	Arrow crab	Cangrejo de flecha
Thor ambionensis***	Squat anemone shrimp	Camarón de anémonas

Appendix 2: Explanation of HAS Score: excerpt from scientific article

From: Gratwicke, B. & Speight, M.R. (2005). The relationship between fish species richness, abundance and habitat complexity in a range of shallow tropical marine habitats. *Journal of Fish Biology* (66),p.654. *underlined effect was added to give emphasis to the parameters.

HAS SHEET

The substratum profile across the 25m quadrat was examined to assess the rugosity score (in this study substratum refers to mud, sand, rubble, boulders, rock, hard coral skeletons, concrete pillars and other artificial structures). This means that two flat sandy areas would score 1 regardless of any seagrass, mangroves or soft corals growing on it. If the substratum was generally flat with few bumps it was rated 1 or 2 while the very complex substratum-profile of a quadrat filled with hard, branching corals would score 5.

The term 'growth forms' was applied very generally to living organisms such as coral algae and seagrass. The algae Penicillus spp. are examples of a 'stalked' growth form, the coral Montastrea annularis is usually lobed, manatee grass Syringodium filiforme is filamentous, turtle grass Thalassia testudinum is ribbon-like, brain corals Diploria spp. are massive, staghorn coral Acropora cervicornis is branched, mangrove roots are usually cylindrical or branched, tube sponges (e.g. Agelas conifera) are tubular, the seafan Paramuricea placomus is fan-like, some firecorals Millepora spp. have a plate-like growth forms while others may be encrusting or branched, and an example of a pinnate growth form is the alga Caluerpa taxifolia. The aim of this score is to assess the diversity of structural attributes of the habitat that might provide resources for different fish species.

The average height of the habitat architecture was a subjective visual estimate to distinguish between taller and shorter habitats. For example in areas with mangrove roots this would usually be equivalent to the water depth, while seagrass beds were generally 10–19 cm, but in sparse or closely cropped areas would be 0–9 cm. The average height of reefs was usually assessed in relation to the lowest point in the quadrat.

The refuge-size categories of Roberts & Ormond (1987) were used in this study. Holes in reefs were easily measured, and gaps between structures that would provide an avenue for a fish to escape a predator were estimated visually. For example small gaps of 1–5 cm between seagrass blades were abundant in seagrass beds but larger gaps were uncommon. The gaps between mangrove prop roots, however, ranged from small to quite large providing hiding places for fishes of many different sizes.

Live cover was estimated by looking at the substratum with a 'bird's-eye view' and judging the percentage area covered by live coral, mangrove roots, seagrass, macroalgae or any other living substratum (excluding epiphytic algal films). Hard substratum referred to the percentage of substratum that was not mud, sand or rubble. A total HAS score was calculated by adding the scores of each of the six complexity variables to give an approximate impression of the overall habitat complexity for rapid assessment purposes.

Appendix 3:

FISH SPECIES	OCCURRENCE SITES (out of a possible 75 sites)	SPECIES ABUNDANCE	RANK (1=most common)	Green= on the list
Coryphoterus personatus/hyalinus (Masked/Glass Goby)	13	700	1	SPECIES ON PERMITTED LIST
Thalassoma bifasciatum –**Juv**i (Bluehead wrasse)	34	341	2	NOT FOUND AT ALL
Stegastes partitus (Bicolor damsel)	27	94	3	*Centropyge argi* (Cherubfish)
Scarus taeniopterus – **Juvi** (Princess Parrot)		15	77	4 *Gobiosoma multifasciatum* (Greenbanded Goby)
Scarus iserti-**Juvi** (Striped Parrot)	14	67	5	*Opistognathus whitehursti* (Dusky Jawfish)
Acanthurus coeruleus (Blue tang)	16	61	6	*Xanthichthys ringens* (Sargassum Triggerfish)
Chromis cyanea (Blue Chromis)	10	53	7	
Coryphopterus glaucofraenum (Bridled Goby)	12	53	8	
Acanthurus bahianus (Ocean Surgeonfish)	15	48	9	
Halichoeres garnoti - **Juvi** (Yellowhead wrasse)	16	45	10	
Thalassoma bifasciatum (Bluehead wrasse)	19	37	11	
Pomacanthus arcuatus (Grey Angel fish)	6	36	12	
Acanthurus chirurgus (Doctorfish)	7	34	13	
Stegastes partitus **- Juvi** (Bicolor Damsel)	8	34	14	
Acanthurus coeruleus- **Juvi**	3	30	15	

(Blue Tang)			
Clepticus parrae (Creole wrasse)	2	30	16
Chaetodon capistratus (Four eyed butterflyfish)	16	29	17
Gnatholepis thompsoni (Goldspot Goby)	14	27	18
Gramma loreto (Fairy Basslet)	5	27	19
Canthigaster rostrata (Sharpnose puffer)	21	26	20
Chronis cyanea-**Juvi** (Blue Chromis)	4	25	21
Gobiosoma genie (Cleaning Goby)	14	25	22
Holocentrus adscensionis (Squirrelfish)	19	25	23
Halichoeres bivittatus-**Juvi** (Slippery Dick)	6	24	24
Halichoeres garnoti-**Inter** (Yellowhead Wrasse)	11	24	25
Serranus tigrinus (Harlequin Bass)	19	23	26
Ophioblennius atlanticus (Redlip Blenny)	9	20	27
Scarus taeniopterus (Striped Parrot)	7	19	28
Halichoeres maculipinna - ***Juvi*** (Clown wrasse)	8	18	29
Microspathodon chrysurus (Yellowtail Damsel)	9	18	30
Sparisoma aurofrenatum - **Initial** (Redband Parrotfish)	8	15	31
Stegastes dorsopunicans (Dusky Damsel)	6	15	32
Stegastes leucostictus (Beaugregory)	12	15	33
Melichthys niger	2	14	34

(Black Triggerfish)			
Gobiosoma evelynae (Sharknose Goby)	8	14	35
Coryphopterus dicrus (Colon Goby)	3	13	36
Apogon binotatus (Barred Cardinal)	3	12	37
Chromis multilineata - **Juvi** (Brown Chromis)	2	12	38
Scarus taeniopterus **- Inter** (Princess Parrot)	3	12	39
Bodianus rufus (Spanish Hogfish)	5	11	40
Pseudupenus maculatus (Spotted Goatfish)	2	11	41
Gobiosoma oceanops (Neon Goby)	2	10	42
Chaetodon striatus (Banded butterflyfish)	5	9	43
Stegastes dorsopunicans **-Juvi** (Dusky Damsel)	2	9	44
Halichoeres bivittatus (Slippery Dick)	7	9	45
Myripristes jacobus (Blackbar soldierfish)	4	9	46
Malacoctenus boehlkei (Diamond Blenny)	4	8	47
Acanthemblemaria maria (Secretary Blenny)	5	7	48
Stegastes variabilis (Cocoa damselfish)	5	7	49
Hypoplectrus gummigutta	5	7	50
Malacoctenus triangulatus	7	7	51
Pomacanthus paru	2	7	52
Halichoeres radiatus- **Juvi (**Puddingwife)	7	7	53
Stegastes planifrons	7	7	54
Hypoplectrus unicolor	6	6	55
Synodus intermedius	4	6	56
Sparisoma rubripinne (Yellowtail parrotfish)	2	6	57

Aulostomus chinensis	5	5	58
Sparisoma radians (Bucktooth Parrot)	2	5	59
Garra rufa – **Juvi (**Doctorfish)	1	5	60
Coryphopterus lipernes (Peppermint Goby)	1	5	61
Stegastes leucostictus **– Juvi (**Beaugregory)	2	4	62
Neoglyphidodon oxyodon (Black Damsel)	1	4	63
Hypoplectrus puella	4	4	64
Anisotremus virginicus	3	3	65
Chromis multilineata	2	3	66
Coryphopterus eidolon	1	3	67
Holacanthus ciliaris	3	3	68
Holacanthus tricolor	3	3	69
Holocentrus sp.	1	3	70
Abudefduf saxatilis	2	2	71
Apogon maculatus	1	2	72
Thalassoma bifasciatum - **Inter** (Bluehead wrasse)	1	2	73
Cantherhines pullus	2	2	74
Coris aygula - **Inter** Clown wrasse	2	2	75
Labrisomus nuchipinnis (Hairy Blenny)	2	2	76
Halichoeres maculipinna	2	2	77
Hypoplectrus nigricans	1	2	78
Opistognathus aurifrons	1	2	79
Sparisoma aurofrenatum (Redband Parrotfish)	2	2	80
Chaetodon sedentarius (Reef Butterfly)	1	2	81
Scarus iserti	2	2	82
Scorpaenidae spp.	2	2	83
Serranus tortugarum	1	2	84
Halichoeres bivittatus (Slippery Dick)	2	2	85
Bodianus pulchellus	1	1	86
Canthifaster	1	1	87

jamestyleri			
Chaetodon aculeatus	1	1	88
Stegastes variabilis - **Juvi** (Cocoa damselfish)	1	1	89
Emblemariopsis spp.	1	1	90
Hyphessobrycon Flammeus (Flamefish)	1	1	91
Gymnothorax miliris (Golden spotted eel)	1	1	92
Halichoeres garnoti (Yellowhead wrasse)	1	1	93
Hypoplectrus sp (Hamlet Hybrid)	1	1	94
Holocentrus rufus	1	1	95
Lactophrys	1	1	96
Longtail damsel	1	1	97
Cheilodipterus parazonatus (Mimic Cardinal)	1	1	98
Neoniphon marianus	1	1	99
Paraclinus fasciatus	1	1	100
Priacanthus arenatus	1	1	101
Ptereleotris calliurus	1	1	102
Acanthemblemaria aspera (Rough head blenny)	1	1	103
Rypticus saponaceus	1	1	104
Aulostomus chinensis- **Juvi** (Trumpet)	1	1	105
Chrysiptera parasema **- Juvi** (Yellowtail Damsel)	1	1	106