LEGORE
ENVIRONMENTAL ASSOCIATES, INC.

PUERTO RICO
MARINE ORNAMENTAL FISHERY EVALUATION
Phase II: Wild Population Assessments

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PROLOGUE

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The authors are grateful for the assistance and participation of several individuals, each making valuable contributions to the efforts described in this document. Dr. Craig Lilyestrom of the Puerto Rico Department of Environmental and Natural Resources initiated the three-phased program to develop rational management policy for the marine ornamental fishery, of which this study represents the second phase. He also reviewed a draft of this report prior to its finalization. Mr. Jason Gregory of Greystone Consultants conducted all GIS analyses, while Ms. Jackie Headrick, also of Greystone, tabulated and integrated the extensive finfish database. Representatives of the marine ornamental fisher community, Mr. Gary Rogers and Mr. William McMillan, provided invaluable background information concerning fishery practices and behavior of target species. Dr. Richard Appeldoorn of UPR's Caribbean Coral Reef Institute managed the contracting process, while Ms. Lillian Ramírez Cesaní served as the CCRI Program Manager and Ms. Nereida Santiago Morales of the UPR Contracts Office managed contract provisions. All of these contributions were essential to the successful conduct of this effort, and all are appreciated.

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1.0 INTRODUCTION

1.1 RECENT HISTORY OF MARINE ORNAMENTAL FISHERIES IN PUERTO RICO

In recent years the collection of tropical marine organisms for the aquarium trade has been perceived as an activity with an unsustainable history as well as obvious potential for rehabilitation through resource-based fisheries management and consumer-oriented product certification. In the case of Puerto Rico, collection of ornamentals has occurred for decades, though unregulated due to a weak fisheries law dating from the 1930s. The more recent Fisheries Law 278 of 1998 and the recent Coral Conservation Law of 1999 enabled new regulatory approaches for marine ornamentals, but initial resource management agency attempts toward regulation encountered serious challenges rooted in (1) an information gap concerning the fishery, extending even to the numbers of collectors, their collection methods and export volumes, and (2) the absence of prior communication between agency regulators and fishers. The information gap led to worst-case assumptions of impact by regulators, and a closure of the fishery, setting the stage for threatening personal confrontations and lawsuits, the latter leading to *de facto* resource management by judicial order. To redress these issues and return fishery management to the arena of science and public policy, regulators initiated a three-phase program to (1) characterize fisher numbers, methods, and exports; (2) assess populations of exploited species; and (3) develop and propose appropriate fishery management approaches for subsequent application. This history is reviewed in greater detail by LeGore and Hardin (2002*a*) and Hardin and LeGore (2005).

1.2 SUMMARY OF THE PHASE I FISHERY CHARACTERIZATION

Figure 1-1. Fish in Protective Cups

The marine ornamental fisheries in Puerto Rico harvest finfish, invertebrates, and several species of macroalgae. These fisheries were examined utilizing public records, stakeholder interviews, and operational site visits to develop descriptions for the Puerto Rico Coral Reef Advisory Committee in order to achieve objectives of the Phase I fishery characterization described above. The fishery is currently not large, including fewer than 20 licensed fishers operating primarily on the west end of the island, presenting a very favorable opportunity for development of rational fishery management policy in advance of inevitable pressure for growth to satisfy increasing worldwide product demand (Wood

2001). Only three operators currently export product, with the remaining fishers providing specimens to the exporters based on customer order requirements.

Most collection of coral reef species occurs over hard rubble zones mixed with relic reef structures and rock, or on the sides and frontal areas of active reefs. Other species are collected from among mangrove prop root zones, tidal flats, and seagrass beds. Collections are made using simple barrier and dip nets for fish and motile invertebrates such as shrimp. Many invertebrates, including crabs, starfish and sea cucumbers are commonly collected by overturning small rocks, gathering the specimens, and then replacing the rocks in their original positions. Specimens are then carried to the boat and transferred to individual cup holders to maximize survival.

Although statements concerning former use of chemicals to assist capture were noted, no evidence of current chemical use was observed. Specimens are held in re-circulating seawater systems onshore until collections are aggregated and shipped. The fishery strives to operate with mortality of <1%, as mortalities of >3% are reported as unacceptable to customers.

More than 100 fish species are collected in this fishery, but the top ten species account for >70% of the total numbers and >60% of the total value of the fishery. A single species, *Gramma loreto* (Royal Gramma), comprises >40% of the numbers. More than 100 species of invertebrates are collected, but this fishery is also dominated by a handful of species, including anemones, hermit crabs, turbo snails, brittle starfish, and feather duster polychaetes.

These fisheries are described in greater detail by LeGore and Hardin (2002*a*) and LeGore *et al.* (2005).

1.3 PURPOSE OF THIS PHASE II POPULATION ASSESSMENT STUDY

The Phase II population assessments reported in this document enable a first-order estimate of fishery impacts on wild populations of exploited species, as an important component of developing rational marine ornamental fishery management policy in Puerto Rico.

Figure 1-2. Brittle Starfish

Assessing impacts of this fishery using classical environmental impact methods comparing impacted areas to "control" areas is not readily feasible. Identification of "impacted" areas is very difficult, because ornamental fishing areas are widespread and occur in a variety of habitats. Furthermore, reefs and other coastal areas have been subjected to a broad variety of anthropogenic and natural stressors, including sedimentation associated with deforestation and dredging; turbidity and nutrient enrichment effects from domestic and industrial discharge of sewage and other organic materials; over fishing; regional mass mortalities of uncertain etiology; coral bleaching effects; and mechanical destruction caused by boat anchors, hurricanes, and ship groundings (García-Sais *et al.* 2003). Isolating impacts caused by the marine ornamental fishery from this variety of stressors is not possible given realistic consideration of funding and research resource availability.

This fishery involves more than 100 fish species and more than 100 invertebrate species collected from seagrass meadows, tidal flats, mangrove prop root zones, hard bottom rubble zones mixed with relic reef structures and rock, and on the sides and frontal areas of growing reefs. The majority of marine ornamental collection in Puerto Rico does not occur over growing reefs, chiefly because of the difficulties posed to the deployment and use of fragile barrier nets over structurally complex surfaces. In addition, most collectors have made a collaborative decision to not collect on growing reefs to avoid potential conflict with recreational dive tour operators. Nevertheless, the variety of habitat and the geographic areas involved are daunting, and do not lend themselves readily to quantitative definitive estimation of impacts caused by this fishery. A different approach is required to make a first order estimate of this fishery's impacts.

While all areas used by ornamental collectors are not known, the numbers of each species being exported from Puerto Rico are known (Matos-Caraballo 2000; Ojeda-Serrano *et al.* 2001; LeGore and Hardin 2002*a;* LeGore *et al*. 2005). A first-order estimate of the total populations of each species will make it possible to understand what portion of each population is being harvested, thereby clarifying the overall impact of this extractive fishery.

This approach requires the quantitative assessment of numerous habitat types to yield estimates of the average density of each species in each major habitat type, estimating the amount of each habitat type in relevant regions of Puerto Rican waters, and calculating the total possible population from these data. Habitat data provided by NOAA (2002) were accessed using GIS to calculate population estimates from data gathered by the surveys described in this report.

2.0 MATERIALS AND METHODS

2.1 OVERVIEW OF FIELD EFFORT

Original recommendations for this Phase II study included sampling areas around the entire island of Puerto Rico, and sampling twice per year to account for seasonal or other temporal changes in populations or target species behavior (LeGore and Hardin 2002*b*). Funding limitations dictated reduction of the effort, however, to a one-time survey limited to particular west- and south-island areas (Figure 2-1). Nevertheless, the regions sampled include >90% of the area used by the island's extant marine ornamental export fishery, with finfish being collected primarily in the Rincón and La Parguera Regions, and invertebrates being collected primarily in the La Parguera and Boquerón Regions. This scope does not account, however, for additional areas being exploited as and if the fishery grows in the future.

Figure 2-1. Map of Study Regions

The domestic and recreational marine ornamental fisheries are not as well documented as the export fishery, but they are believed to occur throughout the island. Potential impacts of these domestic components are therefore outside the scope of this present effort.

Field surveys were conducted over the two week period of May 10-24, 2005. Separate teams sampled finfish and invertebrates, with the Finfish Survey Team consisting of Mr. Mark Hardin of Greystone Consultants, and Dr. Jorge R. García-Sais and Mr. Milton Carlo of the University of Puerto Rico. The Invertebrate Survey Team consisted of Dr. Steve LeGore of LeGore Environmental Associates, Inc. and Mr. James Brice of Wetlands by Design, Inc. These teams operated independently each day, comparing notes and findings each evening. Sampling areas of each are presented in Figure 2-2, with red markers denoting Invertebrate Survey GPS stations, and blue markers indicating Finfish Survey GPS stations.

Figure 2-2. Survey Locations
Blue Markers indicate Finfish Survey GPS Stations.
Red Markers indicate Invertebrate Survey GPS Stations.

2.2 FINFISH SURVEYS

2.2.1 Census Protocols and Procedures

Sampling approaches appropriate for marine ornamental finfish were described and evaluated under a separate study effort funded by NOAA (LeGore *et al.* 2004). This Phase II report is based on results of using one of these techniques, namely the 10m x 3m Swimming Belt Transect (SBT), which is used to provide quantitative estimates of density for target species. In effect, a 10m long line is placed on the bottom, and a diver-scientist then slowly swims the length of the line counting all fish of interest within 1.5m on either side of the line. Additional procedural details are provided in LeGore *et al.* (2004).

Figure 2-3. Siting a Transect Line

Water depth can be an important determinant of species abundance within habitat types, but the resources available for the Phase II assessment precluded stratified sampling replicated by depth in a meaningful manner. These variations were important to recognize, however, as species counts would ultimately be related to two-dimensional habitat area surveys provided by NOAA (2002). To account for depth-related variation in species abundance within habitats, therefore, the SBT transects were sited across ranges of depths wherever possible. Total counts for a given species were then aggregated across all depths in a given habitat type.

The target proxy list for use in the Phase II assessment was identified in LeGore *et al.* (2004), which included the rationale for each species' inclusion and the type of habitat where it could be expected. This information is reproduced here as Table 2-1. Also noted was that "this list is considered preliminary, at least until the initial round of full survey effort is underway, during which the addition or deletion of some species may emerge as a means of strengthening the overall effectiveness of the monitoring program." Such modification indeed occurred during the 2005 Phase II Surveys, as described here.

Table 2-1.
Preliminary Target Fish Species List

Common Name	**Taxonomic Name**	**Rationale**	**Anticipated Habitat** [1]
Royal Grama	*Grama loreto*	Among Top 12 Exported Species	Hardbottom
Blue Chromis	*Chromis cyanea*	As Above	As Above
Bluehead Wrasse	*Thalassoma bifasciatum*	As Above	As Above
Blackbar Soldier	*Myripristis jacobus*	As Above	As Above
Blue Tang	*Acanthurus coeruleus*	As Above	As Above
Neon Wrasse	*Halichoeres garnoti juv.*	As Above	As Above
Rock Beauty	*Holacanthus tricolor*	As Above	As Above
Pygmy Angelfish	*Centropyge argi*	As Above	As Above
Yellowhead Jawfish	*Opistognathus aurifrons*	As Above	Reef rubble
Greenbanded Goby	*Gobiosoma Multifasciatum*	As Above	Colonized Pavement and Colonized Bedrock
Redlip Blenny	*Ophioblennius atlanticus*	As Above	Colonized Bedrock, and Colonized Pavement with and without Sand Channels
Longhorn Blenny	Hypsoblennius exstochilus	As Above	As Above
French Angelfish	*Pomacanthus paru*	High Value, Easy ID, Vulnerable	Coral Reef and Colonized Hardbottom
Gray Angelfish	*Pomacanthus acuatus*	As Above	As Above
Spanish Hogfish	*Bodianus rufus*	Common Export [2]	As Above
Yellowtail Hamlet	*Hypoplectrus chlorurus*	Common Export	As Above
Beaugregory	*Stegastes leucostictus*	As Above	Sand, Coral Reef, Submerged Vegetation, Colonized & Uncolonized Hardbottom, Reef Rubble
Sharpnose Puffer	*Canthigaster rostrata*	As Above	Coral reef

[1] NOAA Habitat Classification (NOAA, 2002)
[2] Gary Rogers (fisher), personal communication (2004)

<u>Pygmy Angelfish</u> (*Centropyge argi*) are usually observed at sufficiently great depths to prevent collection using normal SCUBA techniques, at least in western Puerto Rico (Jorge R. García-Sais, personal communication). The exception to this generality is a population of this

species found in nearshore waters of Desecheo Island, which accounted for virtually all previous export record data as reported by LeGore and Hardin (2002*a*) and LeGore *et al.* (2005) (G. Rogers, fisher, personal communication). Desecheo Island and its resident pygmy angelfish population are now within a marine protected area closed to fishing. No replacement stock has taken its place as a source for the marine ornamental fishery, and the species was no longer considered relevant to the Phase II stock assessment effort.

Greenbanded Gobies (*Gobiosoma multifasciatum*) are found in shallow tidal pools along rocky shorelines, and enter the export stream only by virtue of a single specialist fisherman in the Rincón area. This individual was not available during the Phase II assessment effort to guide the survey team to his harvest locations. Other members of the survey team and their industry contacts were not familiar with the species, and thus could not propose alternate populations to target during the Phase II surveys.

The "Longhorn Blenny" was a species identified as having commercial interest in the Phase I final report (LeGore and Hardin 2002*a*), which cited exports of 2,109 specimens, or 2% of total exports, over the 1998-2000 period of record. However, "Horned Blenny" proved to be more of a commercial than useful common name, and the taxonomic identification of this taxon was alternately identified as *Ophioblennius* sp. and *Hypsoblennius exstochilus*. No definitive determination was possible by the time the Phase II effort was initiated, so the species was dropped from the target list.

The Yellowtail Damsel (*Microspathodon chrysurus*) was added to the target list on the basis of discussion among the Phase II Team and commercial fishers as to whether there was confusion in the 1998-2000 export records between this species and the Yellowtail Hamlet (*Hypoplectrus chlorurus*).

As a result of these three deletions and the single addition, data were collected on a total of 16 finfish species (Table 2-2) during the Phase II surveys.

2.2.2 Regions, Habitats and Stations Sampled

Finfish surveys were conducted in two broad areas of Puerto Rico, identified as the "Rincón" and "La Parguera" Regions, which correspond to the areas of primary importance for finfish collectors active in the current export fishery. Locations of these surveys stations, and the dates they were surveyed are provided in Table 2-3, and their GPS locations are depicted in Figures 2-4, 2-5, and 2-6.

Some instances of variance between published habitat types (NOAA 2002) and habitats observed during survey site visits were found, and certain other distinctions useful to the surveys were noted. General habitat descriptions are therefore provided in Table 2-4.

Table 2-2. Final Target Fish Species List For the Phase II Assessment		
Common Name	**Taxonomic Name**	**Anticipated Habitat [1]**
Royal Grama	*Grama loreto*	Hardbottom
Blue Chromis	*Chromis cyanea*	As Above
Bluehead Wrasse	*Thalassoma bifasciatum*	As Above
Blackbar Soldier	*Myripristis jacobus*	As Above
Blue Tang	*Acanthurus coeruleus*	As Above
Neon Wrasse	*Halichoeres garnoti* Juv.	As Above
Rock Beauty	*Holacanthus tricolor*	As Above
Yellowhead Jawfish	*Opistognathus aurifrons*	Reef rubble
Redlip Blenny	*Ophioblennius atlanticus*	Colonized Bedrock Colonized Pavement with & without Sand Channels
French Angelfish	*Pomacanthus paru*	Coral Reef and Colonized Hardbottom
Gray Angelfish	*Pomacanthus acuatus*	Coral Reef &Reef Rubble, Colonized Bedrock & Hardbottom, Colonized Pavement with & without Sand Channels
Spanish Hogfish	*Bodianus rufus*	As Above
Yellowtail Hamlet	*Hypoplectrus chlorurus*	As Above
Yellowtail Damsel	*Microspathodon chrysurus*	As Above
Beaugregory	*Stegastes leucostictus*	Sand, Submerged Vegetation, Coral Reef & Reef Rubble, Colonized and Uncolonized Hardbottom
Sharpnose Puffer	*Canthigaster rostrata*	Coral reef

[1] NOAA Habitat Classification (NOAA, 2002)

Table 2-3. Fish Survey Station Locations					
ID	**Name**	**Latitude**	**Longitude**	**Survey Date**	**# SBTs**
	La Parguera Region	//////////////////	//////////////////	////////////////	///////
FP-1	Shelf-Edge (Guanica)	N17º53.715’	W66º58.459’	5/10/2005	6
FP-2	Turrumote Fore-Reef	N17º56.044’	W67º01.029’	5/10/2005	9
FP-3	Media Luna Back-Reef	N17º46.463’	W67º03.078’	5/11/2005	12
FP-4	Turrumote Back-Reef	N17º56.440’	W67º01.294’	5/11/2005	9
FP-5	Shelf-Edge (Boya Vieja)	N17º53.413’	W66º59.908’	5/12/2005	9
FP-6	Media Luna Fore-Reef	N17º56.195’	W67º02.896’	5/12/2005	9
FP-7	South Turrumote Patch Reef	N17º55.359’	W67º00.300’	5/14/2005	12
FP-8	La Gata Patch Reef	N17º57.568’	W67º02.128’	5/14/2005	9
FP-9	El Palo	N17º55.996	W67º05.263’	5/20/2005	9
FP-10	Margarita	N17º55.187’	W67º06.020’	5/20/2005	12
	Rincón Region	//////////////////	//////////////////	////////////////	///////
FM-1	Tourmaline Reef 30m	N18º10.115’	W67º16.601	5/21/2005	9
FM-2	Tourmaline Reef 10m	N18º09.800’	W67º16.439’	5/21/2005	9
FR-1	Tres Palmas	N18º20.906’	W67º16.292’	5/16/2005	9
FR-2	Lighthouse-Domes	N18º21.926’	W67º16.502’	5/16/2005	9
FR-3	Tambu	N18º22.767	W67º15.662	5/18/2005	12
FR-4	Porkfish Cave	N18º22.556’	W67º15.753’	5/18/2005	12
FR-5	Aguada	N18º23.335’	W67º13.804’	5/19/2005	12
FR-6	Second River Mouth	N18º22.936’	W67º14.216	5/19/2005	9

SBT= 10m x 3m Swimming Belt Transect

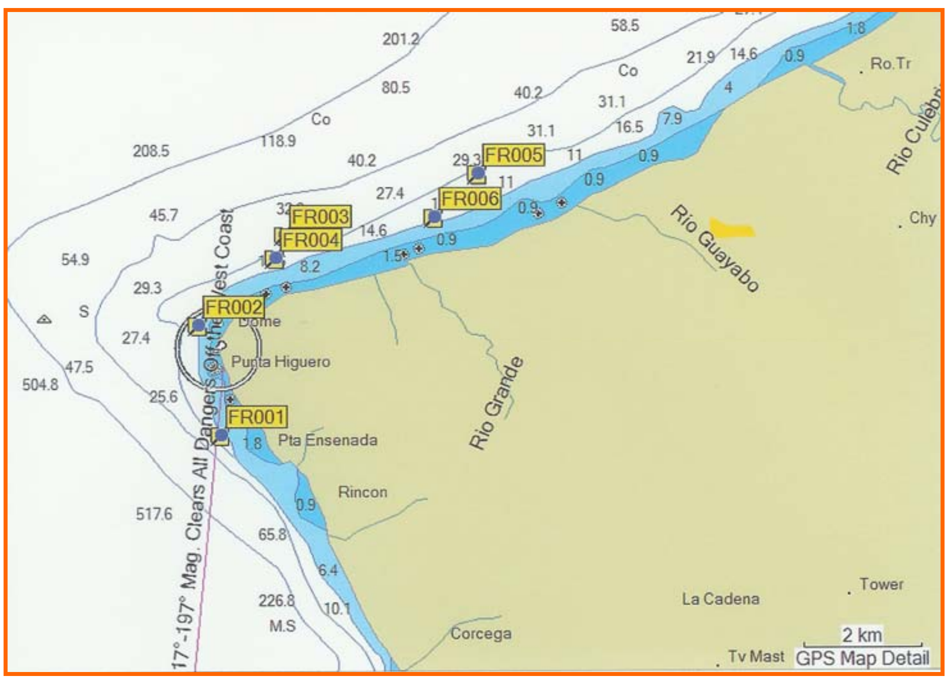

Figure 2-4. Finfish Survey Stations in the Rincón Area

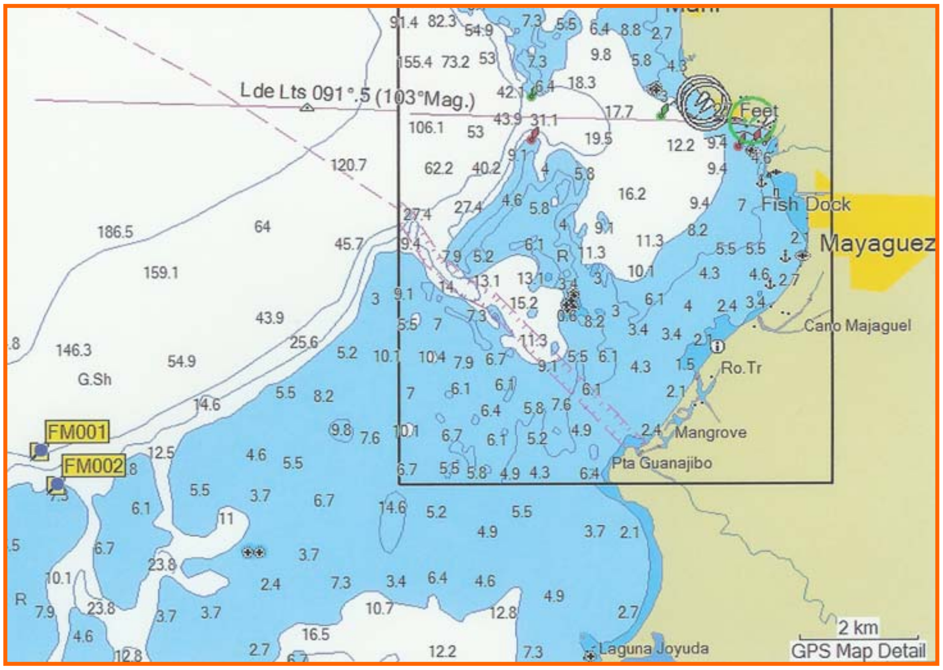

Figure 2-5. Finfish Survey Stations in the Mayagüez Area (Rincón "Region")

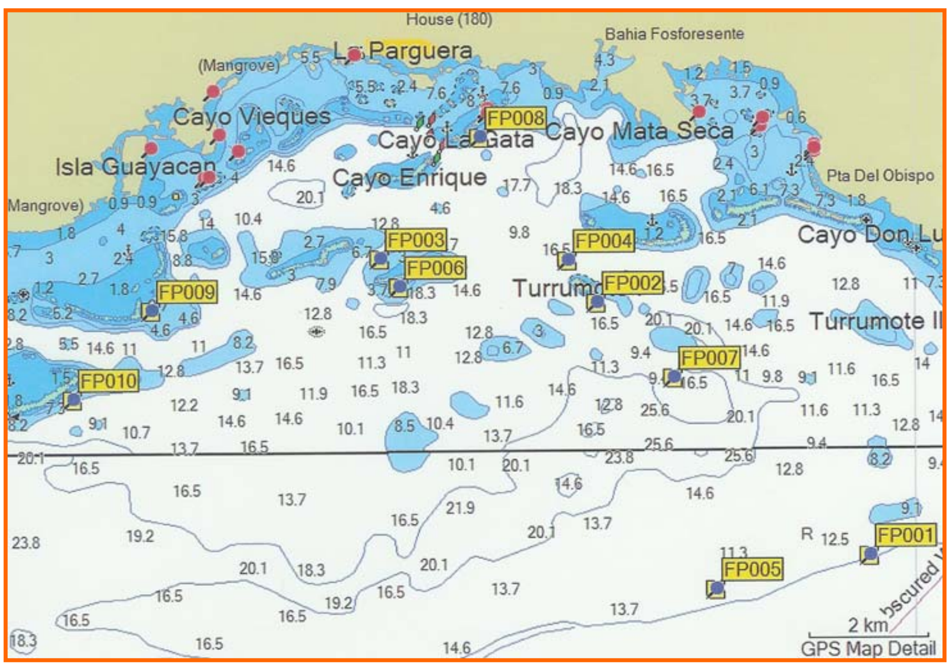

Figure 2-6. Finfish Survey Stations in the La Parguera Area

Table 2-4. Habitat Types at Fish Survey Stations			
ID	**Name**	**NOAA Habitat**	**Observed Habitat**
La Parguera Region		//	//
FP-1	Shelf-Edge (Guanica)	Linear Reef	Spur & Groove
FP-2	Turrumote Fore-Reef	Linear Reef	Linear Reef/Fore-Reef
FP-3	Media Luna Back-Reef	Linear Reef	Linear Reef/Back-Reef
FP-4	Turrumote Back-Reef	Linear Reef	Linear Reef/Back-Reef
FP-5	Shelf-Edge (Boya Vieja)	Linear Reef	Spur & Groove
FP-6	Media Luna Fore-Reef	Linear Reef	Linear Reef/Fore-Reef
FP-7	South Turrumote Patch Reef	Patch Reef (Individual)	Patch Reef (Individual)
FP-8	La Gata Patch Reef	Patch Reef (Individual)	Patch Reef (Individual)
FP-9	El Palo	Colonized Pavement With Sand Channels	Colonized Pavement With Sand Pools
FP-10	Margarita	Colonized Pavement	Colonized Pavement
Rincón Region		//	//
FM-1	Tourmaline Reef 30m	Linear Reef/Spur & Groove	Linear Reef/Spur & Groove
FM-2	Tourmaline Reef 10m	Linear Reef/Spur & Groove	Linear Reef/Spur & Groove
FR-1	Tres Palmas	Colonized Pavement With Sand Channels	Linear Reef
FR-2	Lighthouse-Domes	Colonized Pavement With Sand Channels	Colonized Pavement With Sand Pools
FR-3	Tambu	Colonized Pavement With Sand Channels	Colonized Pavement With Rubble Pools
FR-4	Porkfish Cave	Scattered Coral Rock/ Unconsolidated Sediments	Scattered Coral Rock/ Unconsolidated Sediments
FR-5	Aguada	Colonized Pavement With Sand Channels	Colonized Pavement With Sand Channels
FR-6	Second River Mouth	Scattered Coral Rock/ Unconsolidated Sediments	Scattered Coral Rock/ Unconsolidated Sediments

2.3 INVERTEBRATE SURVEYS

2.3.1 Census Protocols and Procedures

Target Species

Protocols and procedures for the Phase II Invertebrate surveys were adapted from LeGore *et al.* (2004). The invertebrate ornamental fishery in Puerto Rico is diverse, with >100 species being captured and exported. Comprehensive study of these species was beyond resources

Table 2-5.
Preliminary Invertebrate Target Species List [1]

Common Name	Taxonomic Name	Anticipated Habitat
Blue Legged Hermit Crab	*Clibanarius tricolor*	Rock Rubble
Pink Tip Anemone	*Condylactis gigantean*	Grass Flats
Turbo snail	*Trochus spp.*	Rock Rubble
Serpent Star	*Ophiocoma echinata (?)*	Under Rocks
Feather Duster	*Bispira variegate*	Grass Flats
Rock Anemone	*Phymanthus* sp.	Rocks, Sand
Curly Cue Anemone	*Bartholomea annulata*	Grass Flats
Flame Scallop	*Ctenoides scabra*	Under Rocks
Sea Mat	*Zoanthus pulchellus*	Grass, Mangrove Fringe
Sea Cucumber	*Astichopus* sp.	All
Fiddler Crab	*Uca* sp.	Sand and Mud Intertidal
Emerald Crab	*Mithraculus sculptus*	Under Rocks
Red Thorn Starfish	*Echinaster echinophorus*	Mangrove edge, low light
Sunray Anemone	*Actinostella flosculifera*	Grass, near mangroves
Pincushion Urchin	*Lytechinus variegatus*	Grass, Under Rocks
Carpet Anemone	*Stichodactyle* sp.	Grass Flats
Stinging Anemone	*Bartholomea annulata*	Grass Flats, Sand
Star Snail	*Astraetuber* sp.	Rock and Rubble
Blue Filter Starfish	*Astropecten* spp.	Sand, Grass Flats
Red Frilly Sponge	*Agelas* sp.	Grass Flats
Bahamas Starfish	*Oreaster reticulatus*	Grass Flats
Sally Lite Foot Crab	*Percnon gibbesi*	Rock Rubble, Rocks
Mushroom Polyps	*Tealia coriacea*	Grass Flats
Shaving Brush	*Penicillus capitatus*	Grass Flats
Brittle Starfish	*Ophiocoma* spp. (?)	Under Rocks
Harlequin Serpent Star	*Ophioderma appressum*	Under Rocks
Challis Halimeda	*Udotea cyathiformis*	Grass Flats
Long Spine Urchin	*Diadema antillarum*	Sand, Coral Heads, Rocks
Corky Sea Fingers	*Briareum asbestinum*	Grass Flats
Pine Tree	*Rhipocephalus phoenix*	Grass Flats
Red Serpent Starfish	*Opdioderma rubicundum*	Under Rocks, Sandy Areas
Fan Halimeda	*Udotea flabellum*	Grass Flats
Red Rock Urchin	*Echinometra* sp.	Under Rocks, Mangrove
Short Spine Urchin	*Lytechinus* sp.	Under Rocks & Debris

[1] from LeGore *et al.* (2004)

available, so a preliminary list of representative or surrogate target species was developed (LeGore *et al.* 2004), which is reproduced here as Table 2-5.

This list was developed beginning with the 50 species most frequently exported on the basis of numbers shipped (LeGore and Hardin 2002*a*, 2005), and subsequently deleting the species presenting significant survey issues. Candidate species were eliminated on the basis that they are highly cryptic such that they are difficult to discern in their habitat, they are typically nocturnal which renders daylight surveys ineffective, or they typically inhabit waters deeper than were to be surveyed in Phase II. Other species were eliminated on the basis that their taxonomy is unclear.

Among the species listed in Table 2-5 are four plant species traded as marine ornamentals as part of the "invertebrate" fishery. They are macro algae, and are included here because some of them are found in the habitats scheduled for study during Phase II. These plants include the Shaving Brush, Challis Halimeda, Pine Tree and Fan Halimeda.

The invertebrate fishery in Puerto Rico is somewhat unstructured in that the marketing names used for several species are taxonomically unclear, and in some cases overlapping. That is, the same common or marketing name may be used for more than one species, or conversely, a single species may be marketed under more than one name, depending on the vagaries of the marketplace. In particularly difficult cases of taxonomic uncertainty, some taxa were eliminated from the surrogate target list.

Prior to and during the Phase II surveys, additional deletions were made for similar reasons or based upon specific field experience. Six were removed because of uncertain and, at the time, irreconcilable taxonomic issues, including the Rock Anemone, "Stinging Anemone" (includes eight species, four of which occur at depths of 10-30m), Mushroom Polyps, Red Frilly Sponge, Serpent and Red Serpent Starfish (combined with Brittle Starfish because of difficulty in rapid field identification, especially among smaller specimens), and Short Spine Urchin, which was confused in field practice with some specimens of young Red Rock Urchins.

The Blue Filter Starfish (*Astropecten* sp.) was deleted because it tends to be nocturnal, generally visible only in very early morning or late evening, which did not coincide with survey schedules. The "Turbo" snail was removed because it typically inhabits fringing reef faces at depth of 2-3m, which was not scheduled as part of the invertebrate survey. The fiddler crab is an intertidal organism, and would require a specific and targeted survey for this single species, which was beyond available resources for this effort. Similarly, the Sally Lite Foot Crab was deleted because it is highly elusive and therefore difficult to efficiently characterize.

Two species were deleted based upon survey experience. The Star Snail's camouflage renders it very difficult to see, particularly during a rapid survey in which speed and efficiency are paramount. Finally, the Challis Halimeda and Pine Tree Halimeda were eliminated because none were seen during the surveys, indicating that the wrong habitats were being surveyed to account for this species or there was an unrecognized seasonal aspect to their occurrence.

These alterations resulted in a target list of 20 species that could be effectively surveyed with the rapid assessment methods scheduled for this study effort. The final list is presented in Table 2-6.

Survey Methods

Several methods were used in these surveys including Swimming Belt Transects, Swimming Area Searches, and Quadrat procedures involving surface counts and digging quadrats.

Table 2-6.
Final Invertebrate Target Species List
for the Phase II Assessment

Common Name	Taxonomic Name	Anticipated Habitat [1]
Blue Legged Hermit Crab	*Clibanarius tricolor*	Rock Rubble
Pink Tip Anemone	*Condylactis gigantean*	Seagrass
Feather Duster	*Bispira variegata*	Seagrass
Curly Cue Anemone	*Bartholomea annulata*	Seagrass
Flame Scallop	*Ctenoides scabra*	Under Rocks
Sea Mat	*Zoanthus pulchellus*	Seagrass, Mangrove Fringe
Sea Cucumber	*Astichopus* sp.	Ubiquitous
Emerald Crab	*Mithraculus sculptus*	Under Rocks
Red Thorn Starfish	*Echinaster echinophorus*	Mangrove edge, low light
Sunray Anemone	*Actinostella flosculifera*	Grass, near mangroves
Pincushion Urchin	*Lytechinus variegatus*	Seagrass & Under Rocks
Carpet Anemone	*Stichodactyle* sp.	Seagrass
Bahamas Starfish	*Oreaster reticulatus*	Seagrass
Shaving Brush	*Penicillus capitatus*	Seagrass
Brittle Starfish	*Ophiocoma* spp. (?)	Under Rocks
Harlequin Serpent Star	*Ophioderma appressum*	Under Rocks
Long Spine Urchin	*Diadema antillarum*	Sand, Coral Heads, Rocks
Corky Sea Fingers	*Briareum asbestinum*	Seagrass
Fan Halimeda	*Udotea flabellum*	Seagrass
Red Rock Urchin	*Echinometra* sp.	Under Rocks & Mangrove Fringe

[1] William McMillan (fisher), personal communication

Swimming Belt Transects involved two divers swimming side by side following a line-marked transect, each counting all visible target organisms within 0.75m of their respective sides of the line. This narrow area was required to facilitate careful inspection in search of small target species. A wider area required the diver to swim side to side to enable searching straight down among seagrass and other sight line obstructions, which was both inefficient and led to double counting when the diver occasionally lost his bearings relative to the transect line, particularly in areas with significant water currents.

When the survey station configuration allowed, a structured transect pattern was used, in which a square 50m on a side was plotted, yielding four 50m transects. The midpoints of opposing sides of the square were then connected, yielding two additional 50m transects. This

Figure 2-7. Research Vessel "El Corcho"

formal pattern was used when possible to avoid prejudicial siting and to encourage randomness across depths and microhabitat types. Both considerations were deemed critical, as survey counts would ultimately be related to two-dimensional habitat maps without differentiation of depth or microhabitats. The transects, therefore, were required to be positioned in such manner as to integrate across these variables, yielding a usable "average" count per unit of habitat type.

When survey stations were not amenable to this pattern, transects of variable length were established in near-random directions, but with the non-random intent of crossing depth contours to account for this variable to the degree possible. Transect length varied depending upon configuration limitations of the site being surveyed, and subsequent species density calculations, as discussed elsewhere, accounted for this variable.

Swimming Area Searches were utilized when time availability was an issue or when site microhabitats appeared unusually variable to the extent that doubt existed concerning whether representative transects could be established within reasonable time. These surveys were conducted by a diver swimming a back and forth pattern to thoroughly cover a measured area while counting all target species encountered. While not as accurate as Belt Transects, these surveys were nevertheless deemed adequate for providing conservative population information suitable for developing management policy based upon minimum – or "at least as many as" – population estimates.

Quadrat samples were collected at numerous shallow sites. They varied from 0.25m^2 to 1.0m^2 in size, depending upon local conditions. Also, several were limited to surface counts of organisms visible with minimal disturbance of the habitat surface, generally limited to lifting and subsequent careful replacement of small rocks and debris. In other cases, the surface within the quadrat was dug to a depth possible by hand, generally to a depth of <10cm, with all captured organisms being placed into a bucket for later identification and counting. Some species were more effectively counted using surface counts, most notably Blue Legged Hermit C Emerald Crabs, and Red Rock Urchins. Other species were better collected by digging in the quadrat, such as small Sea Cucumbers, Pincushion Urchins, Brittle Starfish, and Harlequin Serpent Starfish.

Figure 2-8. Typical "Dug" Quadrat Haul.

2.3.2 Regions, Habitats and Stations Sampled

Invertebrate surveys were conducted in two broad areas of Puerto Rico, identified as the "Boquerón" and "La Parguera" Regions, which correspond to the areas of primary historical importance for invertebrate collectors active in the current export fishery. Samples were also collected in other regions, including outside the mouth of Guanica Bay, and around mangrove islands offshore of Salinas. Samples from the latter two areas proved of little value, however, and are not discussed in depth here. Locations of these survey stations and the dates they were surveyed are provided in Table 2-7. Their GPS locations are depicted in Figures 2-9 through 2-14.

Table 2-7.
Invertebrate Survey Station Locations

ID	Name	Latitude	Longitude	Survey Date
La Parguera Region		//////////////////////////	//////////////////////////	//////////////////
IM-1	Bahia Montalva-1	N17º57.793'	W66º59.492'	5/13/2005
IM-2	Bahia Montalva-2	N17º57.767'	W66º59.495'	5/13/2005
IM-3	Bahia Montalva-3	N17º57.850'	W66º59.471'	5/16/2005
IM-4	Bahia Montalva-4	N17º57.539'	W66º58.985'	5/16/2005
IM-5	Bahia Montalva-5	N17º57.565'	W66º58.987'	5/16/2005
IM-6	Bahia Montalva-6	N17º57.600'	W66º58.984'	5/16/2005
IM-7	Bahia Montalva-7	N17º57.897'	W67º00.073'	5/16/2005
IM-8	Bahia Montalva-8	N17º57.563'	W66º58.988'	5/16/2005
IP-1	Punta Cueva de Ayala-1	N17º57.321'	W67º04.772'	5/10/2005
IP-2	Punta Cueva de Ayala-2	N17º57.331'	W67º04.724'	5/10/2005
IP-3	N/A	N17º57.567'	W67º04.447	5/11/2005
IP-4	Parguera East	N17º57.945'	W67º02.082'	5/14/2005
IP-5	Parguera East Island	N17º57.904'	W67º02.082'	5/14/2005
IP-6	Isla Guayacan	N17º57.595'	W67º05.280'	5/22/2005
IP-7	Isla Cueva	N17º57.719'	W67º04.631'	5/22/2005
IP-8	Fat Albert	N17º58.112'	W67º04.684'	5/22/2005
IP-9	Punta Parguera	N17º58.445'	W67º03.337'	5/22/2005
Boquerón Region		//////////////////////////	//////////////////////////	//////////////////
IB-1	Boquerón Bay North Shore	N18º02.296'	W67º12.414'	5/19/2005
IB-2	Boquerón Bay South Shore-2	N18º00.309'	W67º11.685'	5/20/2005
IB-3	Boquerón Bay South Shore-3	N18º00.254'	W67º11.913'	5/20/2005
IB-4	Punta Moja Casabe	N17º59.145'	W67º12.986'	5/20/2005
IB-5	Boquerón Bay South Shore-5	N18º00.420'	W67º11.457'	5/20/2005
IC-1	Puerto Real	N18º04.688'	W67º12.013'	5/29/2005
IC-2	Punta la Mela	N18º04.116'	W67º11.807'	5/19/2005
IC-3	Punta Boca Prieta	N18º02.784	W67º12.154'	5/19/2005
Other Regions		//////////////////////////	//////////////////////////	//////////////////
IG-1	Guanica Bay Entrance	N17º56.526	W66º52.472'	5/21/2005
IS-1	Cayo Mata	N17º57.445'	W66º17.866'	5/23/2005
IS-2	Cayos de Ratones East	N17º56.309'	W66º17.866'	5/24/2005
IS-3	Cayos de Ratones West	N17º56.278'	W66º18.068'	5/24/2005
IS-4	N/A	N17º56.264'	W66º17.590'	5/24/2005

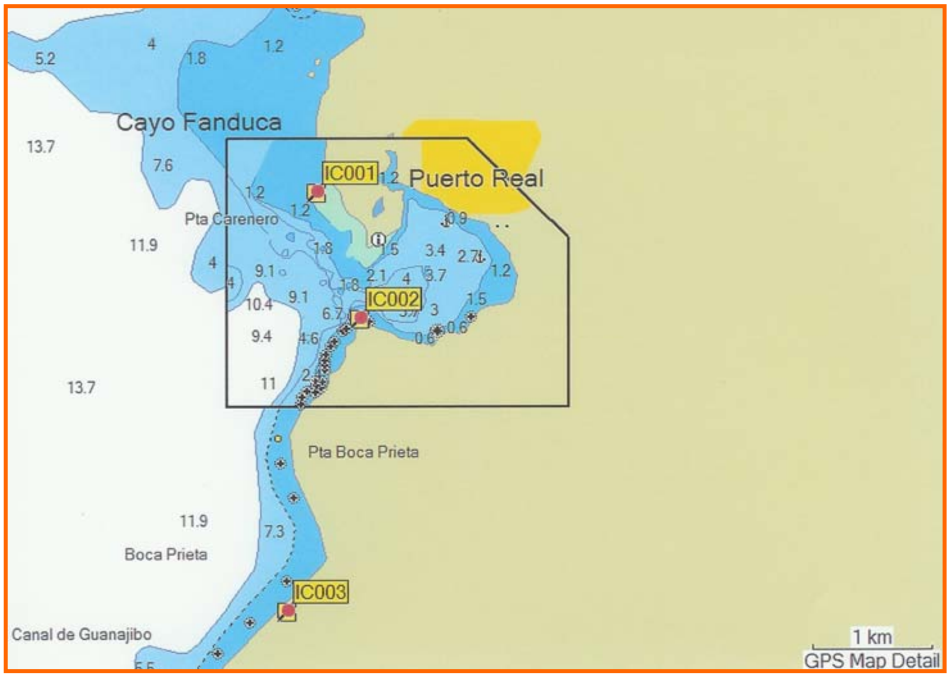

Figure 2-9. Invertebrate Survey Stations in the Puerto Real Area. (Boquerón Region)

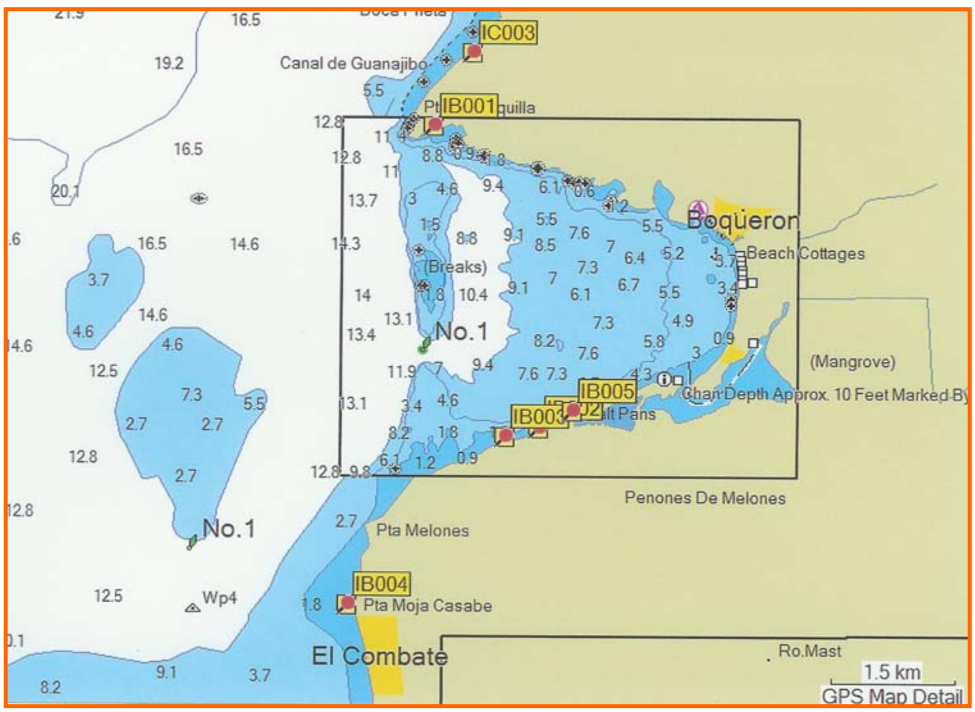

Figure 2-10. Invertebrate Survey Stations in the Bahía Boquerón Area. The flag for IB-002 is obscured by the IB-003 flag.

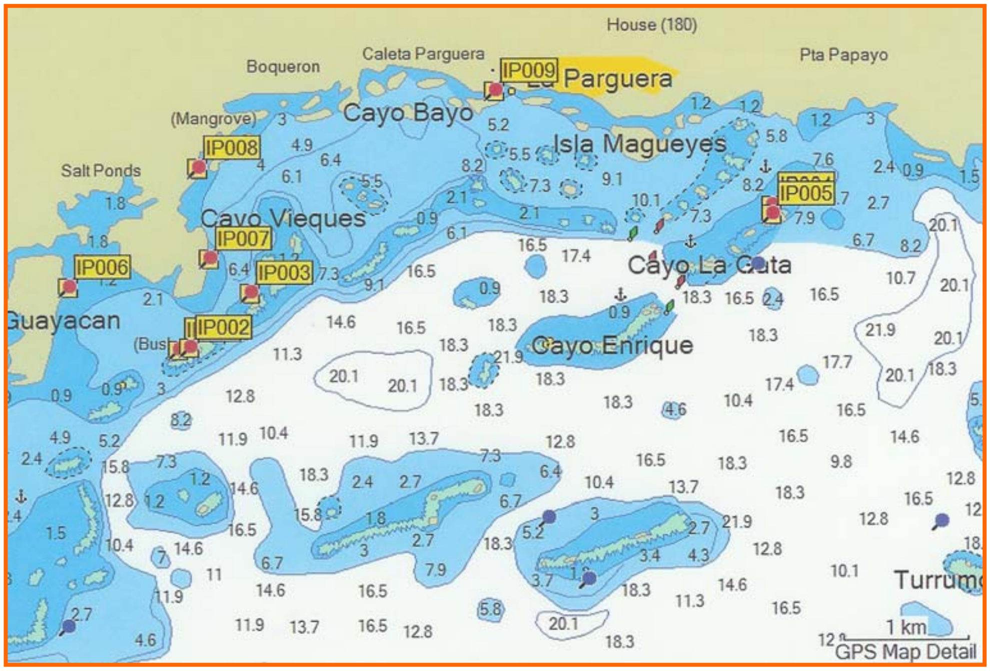

Figure 2-11. Invertebrate Survey Stations in the La Parguera Area. The flag for IP-001 is obscured by IP-002, and the flag for IP-004 is obscured by IP-005.

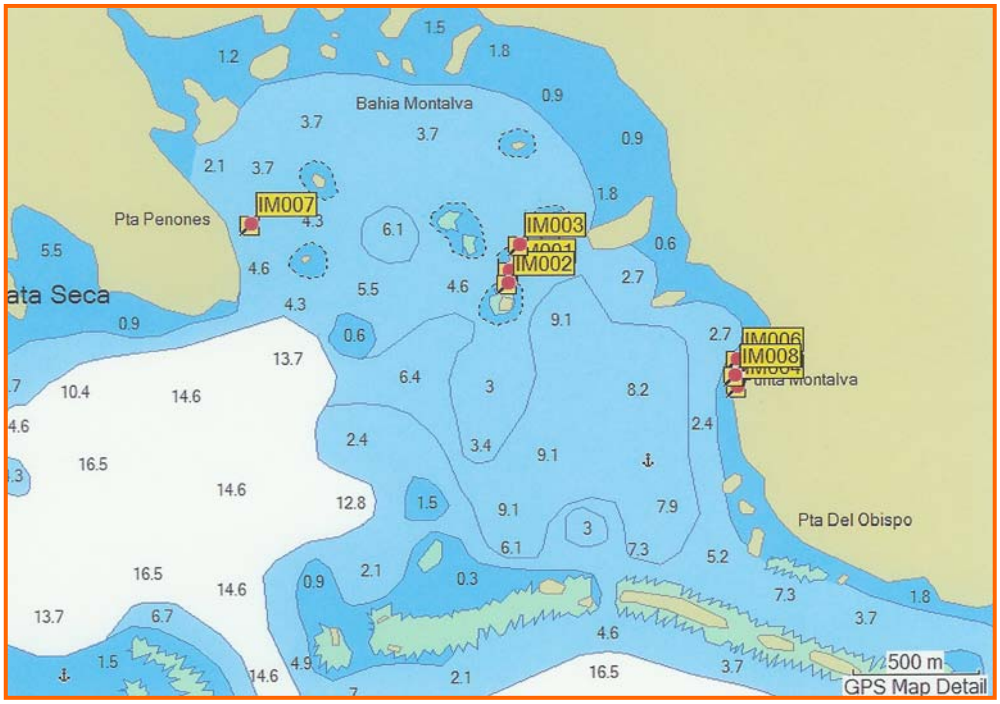

Figure 2-12. Invertebrate Survey Stations in Bahía Montalva. The flag for IM-001 is obscured by IM-002, and the flags for IM-004, 005, and 006 are obscured by IM-008.

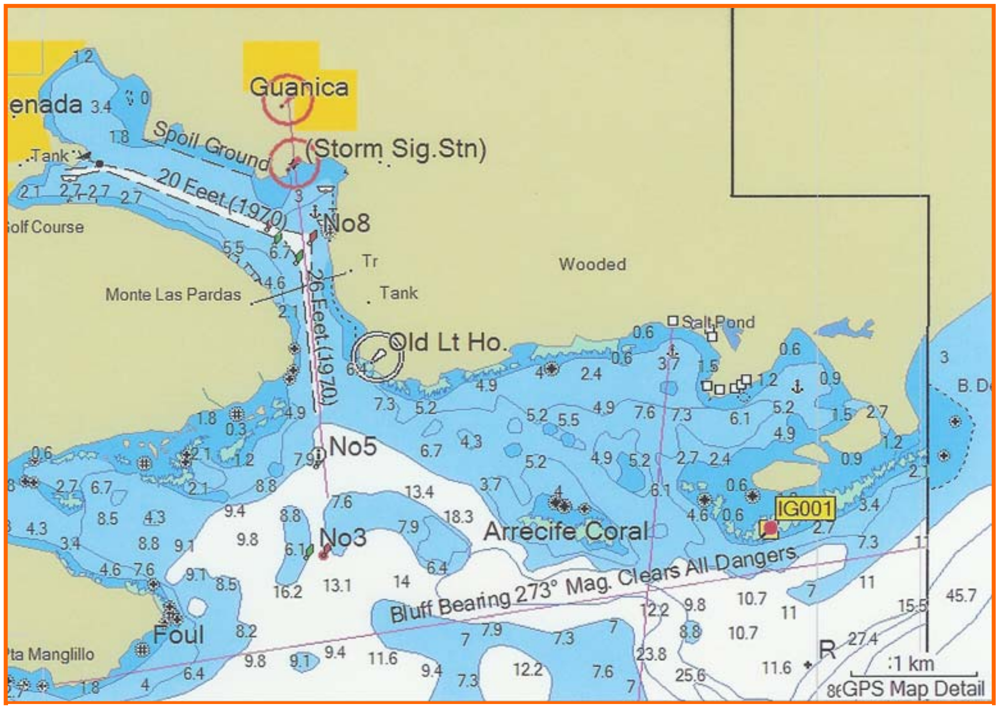

Figure 2-13. Invertebrate Survey Station outside Bahía Guanica.

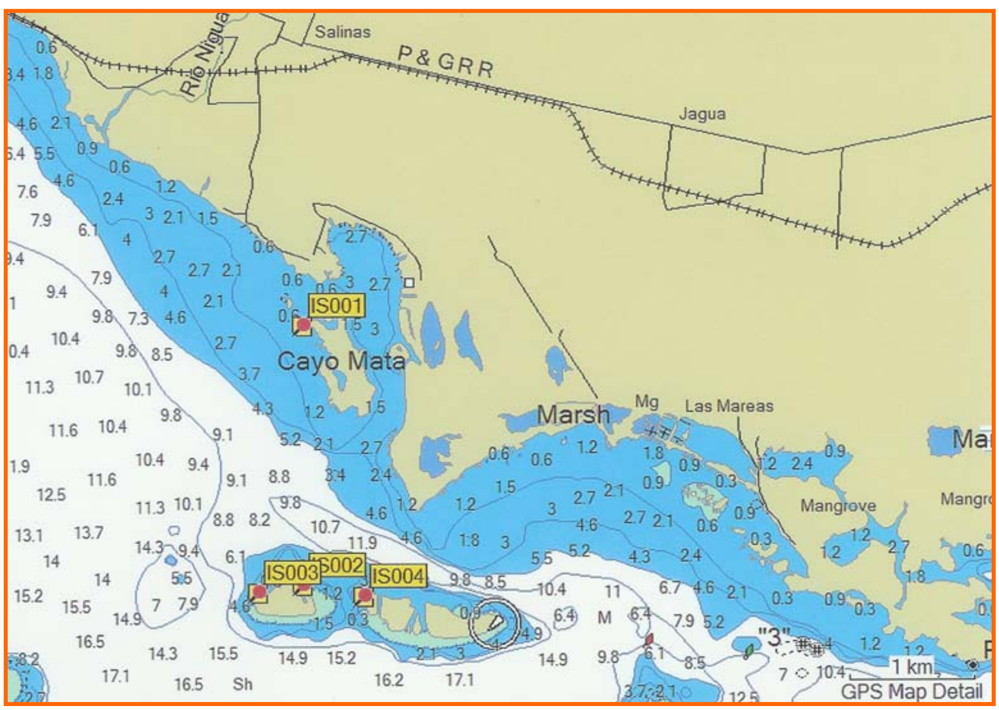

Figure 2-14. Invertebrate Survey Stations in the Salinas Area.

3.0 RESULTS

3.1 FISH ASSESSMENT RESULTS

As presented in Table 2-4,, there was some difference between the habitat types observed by the Phase II Finfish Survey Team and the indicated habitat types provided by the NOAA database. These differences were considered relevant to the study objectives only in the case of the reef types "spur & groove" and "linear." Specifically, the habitat associated with sites FP-1 and FP-5 was indicated as "linear" in the NOAA database, but was observed to be spur & groove formation when visited during this survey. The Phase II Team concluded that "spur & groove" is significantly under-represented in the NOAA database, with only 63 hectares identified as "spur & groove" island wide, even though it is the characteristic structure of the shelf-edge along the southwestern coastline (Jorge R. García-Sais, personal communication). To compensate for this observation, the "spur & groove" and "linear" reef habitat categories and associated fish count data were aggregated for purposes of this evaluation.

3.1.1 Presentation of Survey Data

Raw fish counts for the La Parguera and Rincón Regions are provided in Tables 3-1 and 3-2, respectively. Also provided in these tables are the numbers of Swimming Belt Transects

Table 3-1.
Fish Counts by Habitat Type
in the La Parguera Region

Common Name	Linear Reef + Spur & Groove	Patch Reef	Colonized Pavement	Col. Pavement + Sand Channels	Scattered Rock & Coral
Number of SBTs	54	21	12	12	0
Royal Gramma	183	20	0	0	NS
Blue Chromis	647	93	0	0	NS
Bluehead Wrasse	993	171	37	133	NS
Red Lip Blenny	3	1	0	0	NS
Blackbar Soldier	47	15	0	9	NS
Blue Tang	56	10	3	0	NS
Neon Wrasse	41	4	7	1	NS
Rock Beauty	1	1	0	0	NS
Yellowhead Jawfish	0	0	2	0	NS
French Angel	1	1	0	0	NS
Gray Angel	5	3	0	0	NS
Spanish Hogfish	5	1	0	0	NS
Beaugregory	48	10	1	4	NS
Sharpnose Puffer	22	7	6	0	NS
Yellowtail Hamlet	13	7	0	0	NS
Yellowtail Damsel	38	16	0	25	NS

SBT = 10m x 3m Swimming Belt Transect NS = Not Sampled

sampled in each habitat. It is important to note that not all habitat types were sampled in both Regions. Specifically, "Scattered Rock & Coral" habitat was sampled in the Rincón Region, but not in the La Parguera Region. Conversely, "Patch Reef" and "Colonized Pavement" habitats were sampled in the La Parguera Region but not in the Rincón Region. This becomes a significant consideration relative to population estimates discussed elsewhere in this document.

Table 3-2.
Fish Counts by Habitat Type
in the Rincón Region

Common Name	Linear Reef + Spur & Groove	Patch Reef	Colonized Pavement	Col. Pavement + Sand Channels	Scattered Rock & Coral
Number of SBTs	18	0	0	42	22
Royal Gramma	79	NS	NS	33	41
Blue Chromis	192	NS	NS	334	10
Bluehead Wrasse	125	NS	NS	375	501
Red Lip Blenny	0	NS	NS	0	23
Blackbar Soldier	38	NS	NS	26	13
Blue Tang	6	NS	NS	6	6
Neon Wrasse	41	NS	NS	61	11
Rock Beauty	1	NS	NS	4	5
Yellowhead Jawfish	0	NS	NS	94	0
French Angel	0	NS	NS	1	2
Gray Angel	0	NS	NS	0	0
Spanish Hogfish	4	NS	NS	4	3
Beaugregory	48	NS	NS	29	4
Sharpnose Puffer	12	NS	NS	11	8
Yellowtail Hamlet	2	NS	NS	1	0
Yellowtail Damsel	0	NS	NS	1	0

SBT = 10m x 3m Swimming Belt Transect NS= Not Sampled

It may be noted from these counts that the most abundant species in the Phase II assessment was the Bluehead Wrasse, numbering 2,335 individuals in 181 transects, and which was found in every habitat type sampled. The Blue Tang (87 count), Beaugregory (144 count) and Sharpnose Puffer (66 count) were also found in each of the five habitat types sampled, though less abundantly than several other species found in four or fewer habitat types. The latter include the Royal Gramma with 356 counted in four of five habitat types, and the Blue Chromis with 1,276 counted in four habitat types.

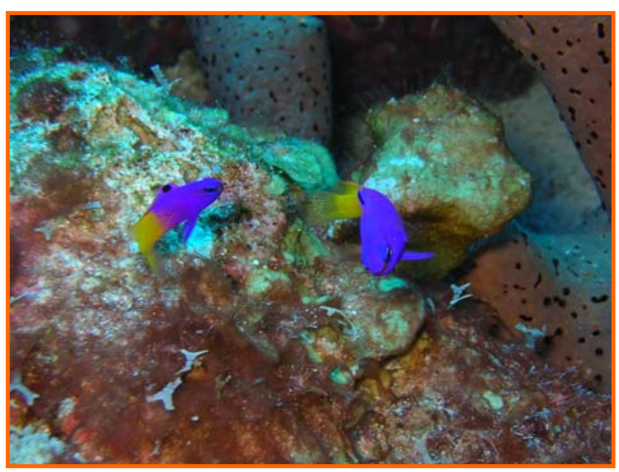

Figure 3-1. Royal Grammas

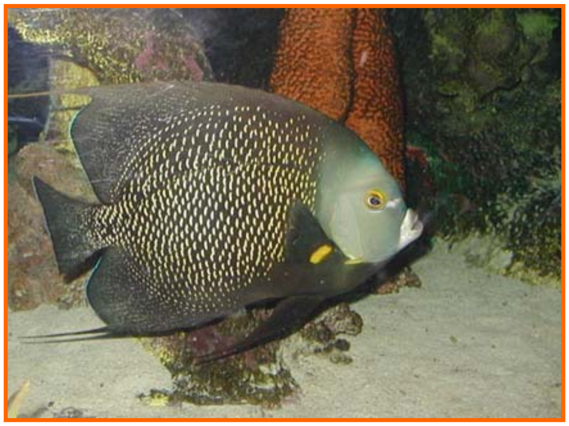

Figure 3-2. French Angelfish

The least abundant species was the French Angel, though it should be noted that the five individuals recorded were observed in four of the five habitat types surveyed. The Yellowhead Jawfish had the most habitat-restricted distribution, with 94 of the 96 individuals recorded being found in a single habitat type, i.e. colonized pavement with sand channels.

A core objective of the Phase II Assessment is to develop density estimates for the species of interest in primary habitat types, and to subsequently use these density estimates to calculate population estimates as a benchmark against which to compare harvest rates. To facilitate these inferences, mean species densities per hectare for each habitat type for the La Parguera and Rincón Regions are presented in Tables 3-3 and 3-4, respectively. More detailed information including Minimum, Maximum and Mean Counts, Count Ranges and Standard Deviations, and calculated Coefficients of Variation is provided in Tables A-1 and A-2 in Appendix A to this document.

Table 3-3.
Mean Fish Densities per Hectare (/ha) by Habitat Type in the La Parguera Region

Common Name	Linear Reef + Spur & Groove	Patch Reef	Colonized Pavement	Col. Pavement + Sand Channels	Scattered Rock & Coral
Royal Gramma	1,171	278	0	0	NS
Blue Chromis	4,860	1,292	0	0	NS
Bluehead Wrasse	6,190	2,713	1,028	3,694	NS
Red Lip Blenny	17	19	0	0	NS
Blackbar Soldier	352	236	0	250	NS
Blue Tang	341	171	83	0	NS
Neon Wrasse	302	56	194	28	NS
Rock Beauty	6	14	0	0	NS
Yellowhead Jawfish	0	0	56	0	NS
French Angel	9	19	0	0	NS
Gray Angel	32	51	0	0	NS
Spanish Hogfish	31	14	0	0	NS
Beaugregory	295	144	28	111	NS
Sharpnose Puffer	147	106	167	0	NS
Yellowtail Hamlet	73	111	0	0	NS
Yellowtail Damsel	225	292	0	694	NS

NS = Not Sampled

As may be seen by reference to the detailed tables A-1 and A-2 presented in Appendix A, there is considerable variability around the mean density of most species in given habitats. Indeed, calculation of coefficients of variation (= 100 x Standard Deviation/Mean Value of Set) are >200% for the less common species such as the French Angel, but are still >100% even for most of the more common fish such as the Royal Gramma and Blue Chromis (Tables A-1 and

A-2 in Appendix A). This high degree of variability among transects reflects the patchy distribution characteristic of hardbottom finfish species in general, and the target species of this assessment in particular.

Figure 3-3. Yellowhead Jawfish Examining Surroundings

This patchiness was compensated for by placing individual and multiple sequential transects along representative habitat profiles, including:

- Depth profiles ranging from 1.5 to 28m
- Reef structure along fore-, back- and crest-reef sections of linear reef, as well as along reef and sand channels for spur & groove formations
- Habitat heterogeneity, to include isolated coral colonies, sand pools, uncolonized rock surface and scattered coral/rock along transects within areas of colonized pavement with sand channels and areas of scattered coral & rock.

Figure 3-4. Spanish Hogfish

The study team relied on Dr. García-Sais' *in-situ* professional judgment, based on more than three decades of underwater research in Puerto Rico, to establish transects in such manner as to maximize their integrated representation of the habitat types being evaluated. The mean population densities presented in Tables 3-3 and 3-4 are by extension considered sufficiently reliable to be used in the fishery management applications for which they are intended.

3.1.2 Population Estimates

Total area for each habitat type of interest within the La Parguera and Rincón Regions as depicted in Figure 2-1 was estimated by querying the NOAA Benthic Habitat Survey database (NOAA 2002). Results of these GIS computations in hectares are presented in Table 3-5.

Using these figures, the fish mean density statistics provided in Tables 3-3 and 3-4 were then used to prepare first-order estimates of species populations in each of the surveyed habitat types in each of the two study regions. All extrapolations were internal to each Region, in that only species density estimates from the La Parguera Region were used to extrapolate that Region's estimated populations, and only species density estimates from the Rincón Region were used to extrapolate the Rincón Region's estimated populations.

Table 3-4. Mean Fish Densities per Hectare (/ha) by Habitat Type in the Rincón Region					
Common Name	**Linear Reef + Spur & Groove**	**Patch Reef**	**Colonized Pavement**	**Col. Pavement + Sand Channels**	**Scattered Rock & Coral**
Royal Gramma	1,463	NS	NS	294	736
Blue Chromis	3,556	NS	NS	2,905	128
Bluehead Wrasse	2,315	NS	NS	3,127	8,001
Red Lip Blenny	0	NS	NS	0	426
Blackbar Soldier	704	NS	NS	206	218
Blue Tang	111	NS	NS	51	94
Neon Wrasse	759	NS	NS	502	141
Rock Beauty	19	NS	NS	30	81
Yellowhead Jawfish	0	NS	NS	653	0
French Angel	0	NS	NS	9	37
Gray Angel	0	NS	NS	0	0
Spanish Hogfish	74	NS	NS	32	56
Beaugregory	889	NS	NS	257	74
Sharpnose Puffer	222	NS	NS	100	114
Yellowtail Hamlet	37	NS	NS	9	0
Yellowtail Damsel	0	NS	NS	9	0

NS = Not Sampled

Table 3-5. Estimated Extent (Hectares) of Habitat Types of Interest in the Fish Sampling Regions					
Region	**Linear Reef + Spur & Groove**	**Patch Reef**	**Colonized Pavement**	**Col. Pavement + Sand Channels**	**Scattered Rock & Coral**
La Parguera	1,603	334	3,488	4,490	1,238
Rincón	135	38	89	1,234	335

Results of these calculations are presented for the La Parguera and Rincón Regions in Tables 3-6 and 3-7, respectively.

Some differences between the two regions are apparent. No Gray Angelfish were counted, for example, in the Rincón Region, despite the inclusion of 18 SBTs in Linear Reef + Spur & Groove habitat, which was noted as Grey Angelfish habitat in the La Parguera Region. A second habitat for Gray Angels in La Parguera, however, was patch reef habitat, which was not sampled in the Rincón Region.

Conversely, the estimated population of Rock Beauty was relatively low in La Parguera, at 14,294 compared to 66,720 in the Rincón Region, despite Rincón's smaller size. Interestingly, a primary Rock Beauty habitat in the Rincón Region was Colonized Pavement with Sand Channels, but similar habitat in the La Parguera Region yielded no counts of this species.

Table 3-6. Fish Population Estimates by Habitat Type in the La Parguera Region						
Common Name	**Linear Reef + Spur & Groove**	**Patch Reef**	**Colonized Pavement**	**Col. Pavement + Sand Channels**	**Scattered Rock & Coral**	**Total Est.**
Area of Habitat (ha.)	1,603	334	3,488	4,490	1,238	
Royal Gramma	1,877,113	92,852	0	0	NS	1,969,965
Blue Chromis	7,790,580	431,528	0	0	NS	8,222,108
Bluehead Wrasse	9,922,570	906,142	3,585,664	16,586,060	NS	31,000,436
Red Lip Blenny	27,251	6,346	0	0	NS	33,597
Blackbar Soldier	564,256	78,824	0	1,122,500	NS	1,765,580
Blue Tang	546,623	57,114	289,504	0	NS	893,241
Neon Wrasse	484,106	18,704	676,672	125,720	NS	1,305,202
Rock Beauty	9,618	4,676	0	0	NS	14,294
Yellowhead Jawfish	0	0	195,328	0	NS	195,328
French Angel	14,427	6,346	0	0	NS	20,773
Gray Angel	51,296	17,034	0	0	NS	68,330
Spanish Hogfish	49,693	4,676	0	0	NS	54,369
Beaugregory	472,885	48,096	97,664	498,390	NS	1,117,035
Sharpnose Puffer	235,641	35,404	582,496	0	NS	853,541
Yellowtail Hamlet	117,019	37,074	0	0	NS	154,093
Yellowtail Damsel	360,675	97,528	0	3,116,060	NS	3,574,263

ha. = Hectares NS = Not Sampled

In La Parguera, the primary habitat in which Red Lip Blennies were found was in Linear Reef + Spur & Groove, but this species was not found in similar habitat in the Rincón Region. In this region, however, the primary habitat for Red Lip Blennies was Scattered Rock & Coral, in which zero counts were found in the La Parguera Region.

Similarly, a primary habitat for French Angels in the Rincón Region was Colonized Pavement with Sand Channels, but no French Angels were found in similar habitat in the La Parguera Region.

These clear differences emphasize the need to use internally-generated species density estimates for extrapolating each region's population estimates.

3.1.3 Discussion

Comparisons of aggregated population estimates from both Regions against annualized harvest data derived from export records from the 1998-2000 year period are provided in Table 3-8. These comparisons illustrate that the average annual export figures prior to regulation of this finfish fishery represent very small percentages of the estimated populations found in this Phase II survey. Export of only two species represented more than 1% of the estimated species populations, namely the Rock Beauty (1.56%) and the French Angel (1.16%).

Table 3-7. Fish Population Estimates by Habitat Type in the Rincón Region						
Common Name	**Linear Reef + Spur & Groove**	**Patch Reef**	**Colonized Pavement**	**Col. Pavement + Sand Channels**	**Scattered Rock & Coral**	**Total Est.**
Area of Habitat (ha.)	135	38	89	1,234	335	
Royal Gramma	197,505	NS	NS	362,796	246,560	806,861
Blue Chromis	480,060	NS	NS	3,584,770	42,880	4,107,710
Bluehead Wrasse	312,525	NS	NS	3,858,718	2,680,335	6,851,578
Red Lip Blenny	0	NS	NS	0	142,710	142,710
Blackbar Soldier	95,040	NS	NS	254,204	73,030	422,274
Blue Tang	14,985	NS	NS	62,934	31,490	109,409
Neon Wrasse	102,465	NS	NS	619,468	47,235	769,168
Rock Beauty	2,565	NS	NS	37,020	27,135	66,720
Yellowhead Jawfish	0	NS	NS	805,802	0	805,802
French Angel	0	NS	NS	11,106	12,395	23,501
Gray Angel	0	NS	NS	0	0	0
Spanish Hogfish	9,990	NS	NS	39,488	18,760	68,238
Beaugregory	120,015	NS	NS	317,138	24,790	461,943
Sharpnose Puffer	29,970	NS	NS	123,400	38,190	191,560
Yellowtail Hamlet	4,995	NS	NS	11,106	0	16,101
Yellowtail Damsel	0	NS	NS	11,106	0	11,106

ha. = Hectare NS = Not Sampled

It should be noted that these statistics represent very conservative estimates in that the total species population estimates are considered low. Rather than representing total populations, they may be more accurately considered as minimum population estimates, i.e. there are at least as many as the population estimates indicate. Only 5 of 13 hardbottom habitat types recorded in the La Parguera and Rincón study areas were included in the survey, although the remaining habitat types likely host some undetermined numbers of the same species. In addition, the 12,387 hectares of the five surveyed habitat types recorded by NOAA (2002) in the two study areas only account for 6.5% the island-wide total (189,512 hectares) for these same habitat types.

Another area of conservatism lies within this survey itself. For several species, significant numbers were found on Scattered Rock & Coral Habitat in the Rincón Region, but this habitat was not surveyed in the La Parguera Region, resulting in estimates of zero population in this habitat within the La Parguera Region. Conversely, these same species were commonly found in Patch Reef habitat of the La Parguera Region, but Patch Reef was not surveyed in the Rincón Region, resulting in estimates of zero population in Patch Reef habitat in the Rincón Region. These factors combined may have resulted in significant underestimates of population numbers for these species, which include Royal Gramma, Red Lip Blenny, Rock Beauty, French Angel, and Spanish Hogfish.

Table 3-8. Aggregated Population Estimates *vs.* Fish Harvest Numbers across the La Parguera - Rincón Regions					
Common Name	**La Parguera Population Est.**	**Rincón Population Est.**	**Aggregate Pop. Est.**	**Harvest per annum[1]**	**Per cent Harvested**
Royal Gramma	1,969,965	806,861	2,776,826	15,024	0.54% [2]
Blue Chromis	8,222,108	4,107,710	12,329,818	1,419	0.01%
Bluehead Wrasse	31,000,436	6,851,578	37,852,014	844	<0.01%
Red Lip Blenny	33,597	142,710	176,307	1,366	0.78% [2]
Blackbar Soldier	1,765,580	422,274	2,187,854	344	0.02%
Blue Tang	893,241	109,409	1,002,650	868	0.09%
Neon Wrasse	1,305,202	769,168	2,074,370	500	0.02%
Rock Beauty	14,294	66,720	81,014	1,263	1.56% [2]
Yellowhead Jawfish	195,328	805,802	1,001,130	3,388	0.34%
French Angel	20,773	23,501	44,274	513	1.16% [2]
Gray Angel	68,330	0	68,330	87	0.13%
Spanish Hogfish	54,369	68,238	122,607	716	0.58% [2]
Beaugregory	1,117,035	461,943	1,578,978	56	<0.01%
Sharpnose Puffer	853,541	191,560	1,045,101	160	0.02%
Yellowtail Hamlet	154,093	16,101	170,194	4	<0.01%
Yellowtail Damsel	3,574,263	11,106	3,585,369	454	0.01%

[1] = Annualized over 30-month period 1998-2000 as described in LeGore and Hardin 2002a, 2005
[2] = Potentially overstated % Harvest; see discussion in text

Using the Royal Gramma as an example, if the Rincón density estimates for this species in Scattered Rock & Coral are applied to the area of this same habitat in La Parguera, and if the La Parguera density estimates for this same species in Patch Reef habitat are applied to Patch Reef habitat in Rincón, the total aggregate population estimate would be increased by 921,732 fish. If this higher population estimate is compared to Harvest, the percent of the population harvested as in Table 3-8 is reduced from 0.54% to 0.41%. If only 50% of this population increase is allowed, then the harvest rate becomes 0.46%. If this same procedure is applied to the other four species, harvest rates would be altered as follows:

- Red Lip Blenny at 100% allowance → 0.19% and at 50% allowance → 0.31% as compared to 0.78% in Table 3-8
- Rock Beauty at 100% allowance → 0.70% and at 50% allowance → 0.96% as compared to 1.56% in Table 3-8
- French Angel at 100% allowance → 0.57% and at 50% allowance → 0.76% as compared to 1.16% in Table 3-8
- Spanish Hogfish at 100% allowance → 0.37% and at 50% allowance → 0.45% as compared to 0.58% in Table 3-8

It is also important to recognize that this survey represents only a "snapshot" in time. Annual reproduction and recruitment dynamics, other species behavior, and environmental considerations may place more or fewer fish in these areas at other times of the year or over multi-year periods than may be indicated by a one-time survey. Because these variables introduce uncertainties, the conservative population estimates provided by this survey are considered a useful and valuable foundation for developing fishery management principles within “Precautionary Approach” tenets.

Finally, it is recognized that the Phase II survey provided data on only 16 species from a total of 101 recorded in the 1998-2000 period in which export records were kept. As noted in Section 2.0 and by LeGore *et al*. (2004), however, the species selected for the Phase II survey represent the most frequently exported fish such as the Royal Gramma and Yellowhead Jawfish, as well as the species less frequently exported by virtue of their smaller populations, such as the French and Gray Angelfish. It is believed, therefore, that the relative numbers harvested as a portion of total population would be of proportionate magnitude for most, if not all, species currently and historically exported from Puerto Rico.

3.2 INVERTEBRATE ASSESSMENT RESULTS

Central to purposes of this Phase II assessment is the assignment of species densities to habitat types consistent with habitat categories presented in the habitat database produced by NOAA (2002). A category determined during surveys to be exceedingly important to the invertebrate component of this fishery, however, is the shallow tidal flat, which is not explicitly identified as a habitat type in the database. These flats consist of the shallow subtidal areas less than about 1-2ft (0.3-0.6m) deep at low tide. Many are associated with offshore mangrove islands, but others exist as shoals in their own right.

Figure 3-5. A typical Shallow Flat associated with a Mangrove Island in Bahía Montalva

Many shallow areas occur adjacent to mainland shorelines, but most of these are low-energy soft-sediment areas relatively unimportant to the fishery. An exception occurs, however, in the area lying between Station IB-5 in Bahía Boquerón and the more southerly Station IB-4, located on Punta Moja Casabe (Figure 2-9). This is a higher energy shore with sand, rock, and coral substrates supporting some of the organisms used in the invertebrate ornamental fishery. This area is therefore included in the computation of "shallow flats" area elsewhere in this document.

Quadrat sampling was the primary survey method on these shallow flats.

3.2.1 Presentation of Survey Data

Presentation of raw species counts as in the finfish section would be meaningless for invertebrate data, because the variability in survey methods, including variable transect lengths and quadrat sizes, renders direct comparisons difficult. Computation of species densities provides more meaningful information, and density data for each species in each habitat type are presented for the La Parguera and Boquerón Regions in Tables 3-9 and 3-10, respectively. More detailed information, including Minimum, Maximum and Mean Densities; Density Ranges; Standard Deviations; and calculated Coefficients of Variation, is provided in Tables B-1 through B-4 in Appendix B to this document.

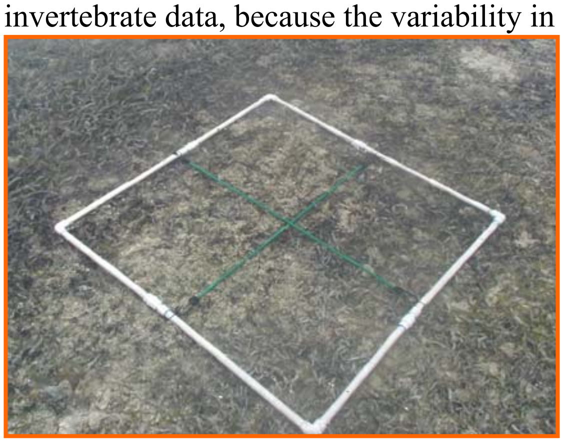

Figure 3-6. The 1m^2 Quadrat Frame

Examination of Tables B-1 through B-4 in Appendix B clearly reveals that substantial variability exists around the mean density of most species in the several habitats, as is also true of the finfish surveys. The Coefficients of Variation (= 100 x Standard Deviation/Mean Value of Set) are almost all >100%, and are commonly >200%, reflecting the patchy distribution commonly characteristic of benthic species. In order to compensate for this patchiness, it was important that as many samples as possible be collected from a variety of microhabitats within the major habitat types, which was accomplished within constraints of project resources.

Figure 3-7. A Shallow Flat Seaward of Mangrove Island In La Parguera Region

Quadrats were randomly placed by throwing the quadrat frame over the shoulder and behind, to prevent prejudicial selection of specific habitats. Swimming transects were selected to include all depths sampled and as complete coverage of visible microhabitats as possible.

Table 3-9.
Mean Invertebrate Densities by Habitat Type
in the La Parguera Region

Common Name	Number of Organisms/ha		Number of Organisms/Linear Km	
	Seagrass	Shallow Flats	Offshore Island Mangrove Fringe	Mainland Mangrove Fringe
Blue Legged Hermit Crab	0	716,571	136	0
Pink Tip Anemone	172	0	4	8
Feather Duster	870	0	11	64
Curly Cue Anemone	856	0	151	60
Flame Scallop	2	0	0	5
Sea Mat	N/A	N/A	N/A	N/A
Sea Cucumber	723	53,333	33	137
Emerald Crab	41	34,667	0	0
Red Thorn Starfish	29	0	0	0
Sunray Anemone	0	0	127	27
Pincushion Urchin	1,379	4,444	69	4
Carpet Anemone	322	0	278	7
Bahamas Starfish	28	0	0	0
Shaving Brush	25,139	0	1	521
Brittle Starfish	35	93,333	0	0
Harlequin Serpent Star	0	148,889	0	0
Long Spine Urchin	3	0	14	0
Corky Sea Fingers	518	0	0	0
Fan Halimeda	1,158	0	152	178
Red Rock Urchin	98	212,571	242	0

N/A = Not Applicable

Table 3-10. Mean Invertebrate Densities by Habitat Type in the Boquerón Region				
Common Name	**Number of Organisms/ha**		**Number of Organisms/Linear Km**	
	Seagrass	**Shallow Flats**	**Offshore Island Mangrove Fringe**	**Mainland Mangrove Fringe**
Blue Legged Hermit Crab	255	666,667	0	0
Pink Tip Anemone	6	NS	0	0
Feather Duster	47	NS	0	20
Curly Cue Anemone	6	NS	0	0
Flame Scallop	0	NS	0	0
Sea Mat	N/A	N/A	0	0
Sea Cucumber	11	NS	20	0
Emerald Crab	2	NS	0	0
Red Thorn Starfish	0	NS	0	0
Sunray Anemone	0	NS	0	0
Pincushion Urchin	4	NS	0	0
Carpet Anemone	0	NS	0	0
Bahamas Starfish	27	NS	0	0
Shaving Brush	55,108	NS	0	0
Brittle Starfish	11	NS	0	0
Harlequin Serpent Star	0	NS	0	0
Long Spine Urchin	4	NS	0	0
Corky Sea Fingers	3,950	NS	0	0
Fan Halimeda	29,231	NS	20	220
Red Rock Urchin	256	NS	0	0

N/A = Not Applicable NS = Not Sampled

Microhabitat and associated community variability was particularly pronounced within mangrove fringe areas around offshore islands. In these areas, the seaward environment is markedly different than the landward side, and the alternate ends of the islands generally supported different communities because of differences in solar exposure and prevailing water currents, and perhaps as well by prevailing wind and turbulence patterns. Gradations occurred among all these habitats, further complicating definition of the habitat type. In response, Phase II surveys of offshore island mangrove fringe communities were conducted around the entire island in each case. Species counts were then averaged to provide mean species counts per linear meter of shoreline in order to integrate results across all the habitat variations.

For the mangrove fringe surveys, all organisms encountered within one foot (0.3m) outside of the outermost mangrove prop root were counted. All organisms were counted landward of this point to the extent field personnel were able to penetrate

Figure 3-8. Surveying Mainland Mangrove Fringe Using Float to Swim Above Soft Sediments

the roots to discern individual specimens. Two observations were required to survey mangrove fringe habitats: one underwater using a dive mask, and one above water to count organisms on shore or on prop roots at and above the waterline. When practical, these observations were made concurrently by two separate observers to avoid duplicate counts. In lower energy habitats of many mainland mangrove areas, however, soft and deep sediments made dual observer counts impossible, so a single individual made the counts alone.

It is clear that very great differences in species densities exist between the two regions, with most species occurring at much lower densities in the Boquerón Region. The most obvious exceptions to this generality are the Shaving Brush Halimeda, the Fan Halimeda, and Corky Sea Fingers, each of which tends to be more tolerant of sedimentation than many other species. Significantly, it was reported by the most active invertebrate fisher (Wm. McMillan, personal communication) that the Boquerón Region was formerly a very productive collecting area, but that within recent years the habitat has apparently become so degraded that very little collecting is currently conducted here. It would seem, therefore, that Bahía Boquerón and its environs may be suffering seriously from factors other than fisheries activity.

3.2.2 Population Estimates

Total area for seagrass habitat within the La Parguera and Boquerón Regions as depicted in Figure 2-1 was estimated by querying the NOAA Benthic Habitat Survey database (NOAA 2002), as for the finfish surveys. Results of these computations are presented as hectares of habitat in Table 3-11.

Table 3-11.
Estimated Extent of Habitat Types of Interest
in the Invertebrate Sampling Regions

Region	Hectares		Linear Km	
	Seagrass	Shallow Flats	Island Mangrove	Mainland Mangrove
La Parguera	5,968	664	91,065	95,533
Boquerón	6,633	228	15,153	40,673

The same NOAA database was used to compute the extent of mangrove shoreline in these two regions. A distinction had to be made, however, between "mainland" mangrove shore and "offshore island" mangrove shore, because the offshore areas are higher energy shorelines providing quite different habitats and supporting very different biological communities than the lower energy, silty habitats of mainland mangrove shores. For purposes of Phase II analysis [only!], mangrove shores were designated "offshore mangroves" if they occurred >100 m offshore of the mainland, and were designated "mainland mangroves" if they occurred <100 m from the mainland shore. Although arbitrary, this appeared to be a reasonable estimated break point based upon field observations.

A different process was required to develop estimates of "shallow flats" areas, as this is not a designation available in the NOAA (2002) habitat database. Shallow flats generally occur around mangrove islands and as shoals in the areas studied. These may be observed in the

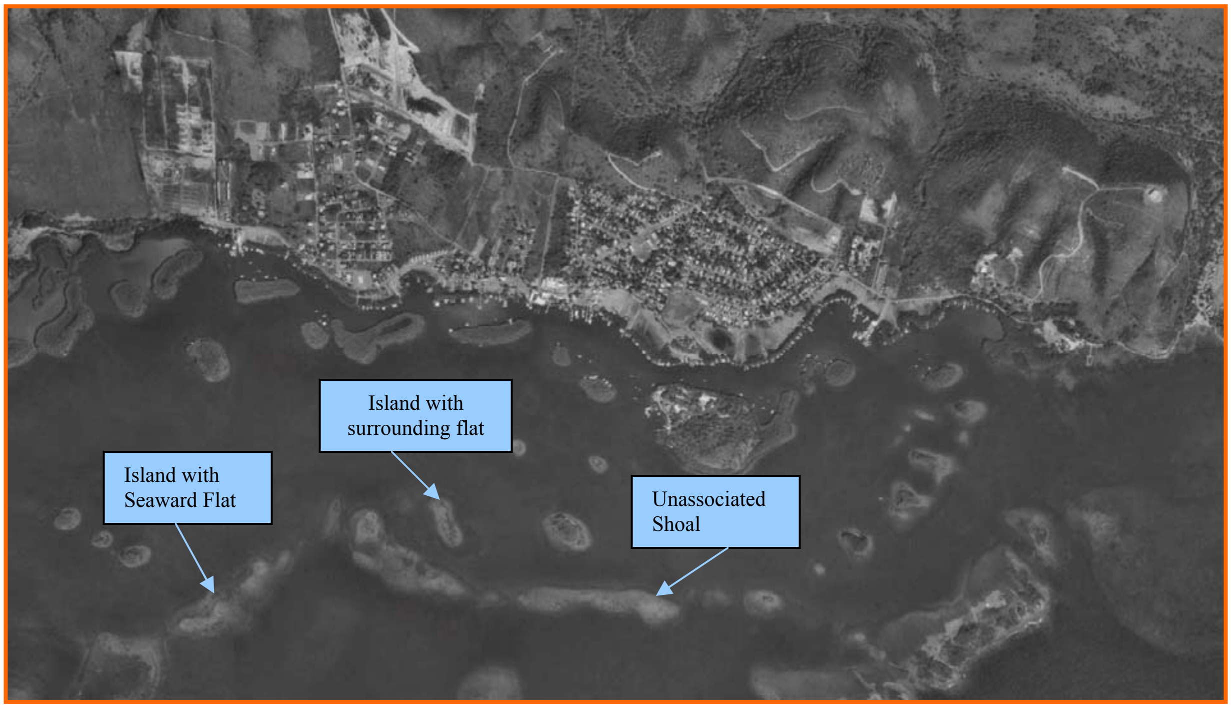

Figure 3-9. Aerial View of La Parguera Area

aerial photograph provided as Figure 3-9. In general, most of the offshore mangrove islands have associated flat areas equal to about 0.5 to 2.0 times the area of the island. In addition, the shoals unassociated with islands sometimes cover extensive areas, providing substantial areas of shallow flats. Resource limitations precluded a comprehensive definitive survey of these flats and their total area, so for purposes of this study, the area of "shallow flats" is estimated as equal to the area of the emergent offshore mangrove islands, an area that is obtainable from the NOAA database. This area estimate is considered very conservatively low, but for purposes of estimating minimum species populations for conservative fisheries management purposes, it is considered preferable to err on the side of conservatism than otherwise.

However, in addition to the offshore shallow flats, a mainland shallow flat of comparable productivity was located on the south side of Boqueron Bay, from Station IB-5 southward to Station IB-4, a distance of approximately 4km. This flat area is approximately an average of 10m wide, and the area of interest is therefore about 10m x 4,000m = 40,000m^2, or 4ha in size. This area was therefore added to the estimate of shallow flats area in the Boquerón Region.

Using these figures, the invertebrate mean density figures were used to prepare first-order estimates of species populations in each of the surveyed habitat types in each of the two study regions. All extrapolations were internal to each Region, in that only species density estimates from the La Parguera Region were used to extrapolate that Region's estimated populations, and only species density estimates from the Boquerón Region were used to extrapolate the Boquerón Region's estimated populations.

Results of these calculations are presented for the La Parguera and Boquerón Regions in Tables 3-12 and 3-13, respectively.

Table 3-12.
Invertebrate Population Estimates by Habitat Types
in the La Parguera Region

Common Name	Seagrass	Shallow Flats	Offshore Island Mangrove Fringe	Mainland Mangrove Fringe	Total Est.
Blue Legged Hermit Crab	0	475,803,144	12,390	0	475,815,534
Pink Tip Anemone	1,026,496	0	364	764	1,027,624
Feather Duster	5,192,160	0	1,002	6,112	5,199,274
Curly Cue Anemone	5,108,608	0	13,756	5,730	5,128,094
Flame Scallop	11,936	0	0	478	12,414
Sea Mat	N/A	N/A	N/A	N/A	N/A
Sea Cucumber	4,314,864	35,413,112	3,006	13,084	39,744,066
Emerald Crab	244,688	23,018,888	0	0	23,263,576
Red Thorn Starfish	173,072	0	0	0	173,072
Sunray Anemone	0	0	11,570	2,579	14,149
Pincushion Urchin	8,229,872	2,950,816	6,286	382	11,187,356
Carpet Anemone	1,921,696	0	25.326	669	1,947,691
Bahamas Starfish	167,104	0	0	0	167,104
Shaving Brush	150,029,552	0	91	49,756	150,079,399
Brittle Starfish	208,880	61,973,112	0	0	62,181,992
Harlequin Serpent Star	0	98,862,296	0	0	98,862,296
Long Spine Urchin	17,904	0	1,275	0	19,179
Corky Sea Fingers	3,091,424	0	0	0	3,091,424
Fan Halimeda	6,910,944	0	13,847	16,999	6,941,790
Red Rock Urchin	584,864	141,147,144	22,046	0	141,754,054

N/A =Not Applicable

3.2.3 Discussion

Comparisons of aggregated population estimates from both Regions against annualized harvest data derived from Year 2002 records (LeGore and Hardin 2002*a*) are provided in Table 3-14. These comparisons illustrate that the average annual export figures from the most recent year available generally represent very small percentages of the estimated populations found in this Phase II survey. Export of only three species represented more than 1% of the population estimates made here, namely the Pink Tip Anemone, the Flame Scallop, and the Sunray Anemone. In the cases of the Pink Tip Anemone and the Flame Scallop, however, these results are somewhat misleading, because in both of these cases, primary habitat was not sampled, and their population estimates are certainly low resulting in overstated harvest rates. The same cannot be stated with certainty of the Sunray Anemone.

Table 3-13. Invertebrate Population Estimates by Habitat Types in the Boquerón Region					
Common Name	**Seagrass**	**Shallow Flats**	**Offshore Island Mangrove Fringe**	**Mainland Mangrove Fringe**	**Total Est.**
Blue Legged Hermit Crab	1,691,415	152,000,076	0	0	153,691,491
Pink Tip Anemone	39,798	NS	0	0	39,798
Feather Duster	311,751	NS	0	814	312,565
Curly Cue Anemone	39,798	NS	0	0	39,798
Flame Scallop	0	NS	0	0	0
Sea Mat	N/A	N/A	N/A	N/A	N/A
Sea Cucumber	72,963	NS	304	0	73,267
Emerald Crab	13,266	NS	0	0	13,266
Red Thorn Starfish	0	NS	0	0	0
Sunray Anemone	0	NS	0	0	0
Pincushion Urchin	26,532	NS	0	0	26,532
Carpet Anemone	0	NS	0	0	0
Bahamas Starfish	179,091	NS	0	0	179,091
Shaving Brush	365,531,364	NS	0	0	365,531,364
Brittle Starfish	72,963	NS	0	0	72,963
Harlequin Serpent Star	0	NS	0	0	0
Long Spine Urchin	26,532	NS	0	0	26,532
Corky Sea Fingers	26,200,350	NS	0	0	26,200,350
Fan Halimeda	193,889,223	NS	304	8,954	193,889,223
Red Rock Urchin	1,698,048	NS	0	0	1,698,048

N/A = Not Applicable NS = Not Sampled

In the case of the Flame Scallop, its primary habitat was not sampled at all during Phase II. Dukeman *et al*. (2005) reported collecting Flame Scallops in rock and coral rubble at 0.5-7.0m depths, where they attach to the hard substrate with their byssal threads. McMillan (fisher, personal communication) reports that the primary collecting ground for this species is fringing reef front and hard rock boating channel edges at depths of 2.5-25m, with the prime collecting depth being about 6m. All of the Flame Scallops sampled in the Phase II surveys were therefore incidental to the primary population, because only seagrass, shallow flats and mangrove fringe habitat were surveyed. In all cases, Flame Scallops were only noted during Phase II attached to opportunistic pieces of hard substrate, such as rock or large pieces of debris occasionally found in the seagrass and mangrove fringe habitats. It is also likely that most Flame Scallops occurring in seagrass beds were overlooked, as they tend to attach to the undersides of rocks and debris, which were not examined while swimming over them during belt transects and swimming area searches. All such counts were surface counts only. No Flame Scallops were noted on the shallow flats. The 10.8% of the population represented by the fishery harvest, therefore, refers only to this incidental population, which is in addition to the Flame Scallop's presumably main populations located elsewhere.

Similar considerations relate to populations of the Pink Tip Anemone (*Condylactis gigantea*, also sometimes referred to as the Giant Caribbean Anemone), because a primary habitat for this species is the fringing reef (Kaplan 1982, 1988) or forereef (Stoletzki and Schierwater 2005), which were not surveyed in this Phase II effort. Therefore, the 1.64% harvest rate indicated in Table 3-14 only considers a part of the overall population of this species. A comprehensive survey of this species would undoubtedly result in a lower harvest percentage.

Table 3-14.
Aggregated Population Estimates *vs.* Invertebrate Harvest Numbers across the La Parguera - Boquerón Regions

Common Name	La Parguera Population Est.	Boquerón Population Est.	Aggregate Pop. Est.	Harvest per annum[1]	Per cent Harvested
Blue Legged Hermit Crab	475,815,534	153,691,491	629,507,025	18,936	<0.01%
Pink Tip Anemone	1,027,624	39,798	1,067,422	17,518	1.64% [2]
Feather Duster	5,199,274	312,565	5,511,839	1,550	0.03%
Curly Cue Anemone	5,128,094	39,798	5,167,892	1,300	0.03%
Flame Scallop	12,414	0	12,414	1,341	10.80% [2]
Sea Mat	N/A	N/A	N/A	1,594	N/A
Sea Cucumber	39,744,066	73,267	39,817,333	1,200	<0.01%
Emerald Crab	23,263,576	13,266	23,276,842	3,155	0.01%
Red Thorn Starfish	173,072	0	173,072	650	0.38% [2]
Sunray Anemone	14,149	0	14,149	600	4.24%
Pincushion Urchin	11,187,356	26,532	11,213,888	600	0.01%
Carpet Anemone	1,947,691	0	1,947,691	554	0.03%
Bahamas Starfish	167,104	179,091	346,195	300	0.09% [2]
Shaving Brush	150,079,399	365,531,364	515,610,763	240	<0.01%
Brittle Starfish	62,181,992	72,963	62,254,955	4,162	0.01%
Harlequin Serpent Star	98,862,296	0	98,862,296	424	<0.01%
Long Spine Urchin	19,179	26,532	45,711	200	0.44%
Corky Sea Fingers	3,091,424	26,200,350	29,291,774	190	<0.01%
Fan Halimeda	6,941,790	193,889,223	200,831,013	150	<0.01%
Red Rock Urchin	141,754,054	1,698,048	143,452,102	150	<0.01%

[1] = Annualized from 2002 data provided in LeGore and Hardin 2002*a*
[2] = Potentially overstated % Harvest; see discussion in text

This logic may not apply to results concerning the Sunray Anemone (*Actinostella flosculifera*, also sometimes referred to as the Collared Sand Anemone), however, because in this case the species' primary habitat was sampled. The annual harvest rate of 4.24% of the regional population may be more representative than is true of the Pink Tip Anemone and the Flame Scallop.

Despite the small harvest rate of 0.38% indicated in Table 3-14 for the Red Thorn Starfish (*Echinaster echinophorus*), this species was also probably undercounted. The Red Thorn Star tends to be active nocturnally, and is generally not found in high numbers during daylight hours. It commonly occurs on the inner, or low-energy, side of mangrove islands, but not in daylight hours, when it is said to move into the sheltered interior, and darker, parts of mangrove islands (Wm. McMillan, fisher, personal communication).

Because of its importance as a keystone species in coral reef communities, and the effects caused by its catastrophic mass mortality in the early 1980s (Knowlton 2001), the Long Spine Sea Urchin, *Diadema antillarum*, is worthy of explicit discussion. Table 3-14 indicates that the annualized harvest of 200 of these urchins represents 0.44% of the regional population. This is, however, overstated in much the same manner as for Flame Scallops and Pink Tip Anemones, because urchins on fringing and other reefs were not counted during the Phase II invertebrate assessment. This species was observed in these habitats, however, sometimes in very significant numbers, and it is apparent that the harvest rate of 0.44% indicated in Table 3-14 is overstated, and that the actual rate is significantly lower. Nevertheless, the particular importance of this species and the fact that its populations may still be in post-mortality recovery phase, may warrant specific attention.

Another species that must be explicitly considered is the Corky Sea Finger (*Briareum asbestinum*), despite the fact that <0.01% of the regional population is exploited by the current fishery. This species is a gorgonian, a type of soft coral, and the Coral Conservation Act of 1999 explicitly prohibits the taking of any hard or soft coral of any species. Regulation of the fishery for this species, therefore, currently appears to fall outside the purview of fishery management *per se*, as it is regulated as a component of a specifically protected taxonomic category.

It is notable that all specimens of the Bahamas Starfish (*Oreaster reticulatus*) seen in the Phase II surveys were large adult specimens occurring on shallow grass flats. These specimens are not collected, however, for the marine ornamental fishery, because they are too large to display in most home aquaria. Collected specimens are virtually all 2-4 inches (5-10cm) across from leg tip to leg tip, and are generally found at depths of 8-10m or so at the transition zone between seagrass and sand habitats (Wm. McMillan, fisher, personal communication). It would appear that the larger brood stock observed during these surveys is not at risk from the ornamental fishery, although impacts by recreational or domestic ornamental collectors may be another matter.

One target list species that has not been discussed is the "Sea Mat," *Zoanthus pulchellus*, which is a colonial anemone that grows like a carpet on suitable substrate. It consists of closely packed, or a dense mat, of anemone-like polyps (Meinkoth 1995), and was frequently seen to cover extensive areas. This growth pattern does not lend itself to efficient counting of individual polyps, and because they are a colonial species, defining the term "individual" is problematic in itself. This species is sold in the Puerto Rican ornamental trade not by individual polyps, but as pieces of the "mat," typically measuring 10-15cm square. The number 1,594 harvested (Table 3-14) refers to this number of mat pieces. If we assume each piece measures 15cm on a side, then this number represents the harvest of approximately 36m^2 of sea mat annually.

Sea Mat does not occur on all shallow flats in the studied regions, but when it occurs, it is plentiful. One flat on which Sea Mat formed an almost continuous growth over at least 50% of the flat area, located adjacent to Survey Station IP-001, measured >17,000m^2. This conservatively represents >8,500m^2 of Sea Mat, which dwarfs the 36m^2 harvested each year. The area of 17,000m^2 is also conservatively estimated, compounding the conservatism of this estimate, because the smallest width measurement was used to calculate it. If the mean (of three) width measurement were used, this flats area would be calculated as >22,000m^2, and the estimated area of the Sea Mat would then be >11,000m^2. Other shallow flats in addition to this one were noted to also support significant Sea Mat colonies. These observations indicated that the Sea Mat resource is not jeopardized by the current level of harvest, so the resources that would have been required to comprehensively evaluate this species were applied to other issues.

Finally, populations of a few species are underestimated because shorthand was sometimes used to record them when their numbers were "Too Numerous To Count," in which cases the acronym "TNTC" was recorded. When computations were made, the lowest number in the TNTC range was used. For example, if a density for hypothetical species X of >10 organisms/m^2 were considered TNTC, then for all subsequent calculations the number 10 would be used, even if in many cases that species actually occurred at higher densities. For Phase II, the following designated densities were used for the TNTC determination:

- *Halimeda* spp. TNTC = >15/m^2
- Corky Sea Fingers TNTC = >5/m^2
- Blue Legged Hermit Crabs TNTC <u>in Quadrat Samples</u> = >100/0.25 m^2
- Blue Legged Hermit Crabs TNTC <u>while swimming transects</u> = >10/m^2

4.0 FUTURE CONSIDERATIONS

4.1 RELEVANCE OF STUDY DATA TO FISHERY MANAGEMENT

Puerto Rico is in an enviable position relative to the potential for management of its marine ornamental fisheries. The existing fisheries are rather small compared to the island's population and the amount of its coastal habitat, with no more than 20-25 collectors currently active in the export trade. In comparison, there are more than 600 licensed collectors in Florida (J. O'Hop personal communication) and more than 4,000 in the Philippines (Barber and Pratt 1998). Future economic pressure for growth of the fishery in Puerto Rico will be felt. In the United States, for example, the number of hobby marine aquarists is growing, with more than 4% of homes now having marine aquaria, compared to only about 1% in 1982 (Chapman *et al*. 1997). Puerto Rico therefore has an excellent opportunity to conceive, develop and implement rational management policy in advance of these pressures, thereby assuring continued vigor of the wild populations of the exploited species and providing for sustainability of ornamental fishery income potential for its citizens, while still preserving these ornamental species for enjoyment by other stakeholders such as recreational divers and tourists.

The Phase II species population estimates provided in this report comprise a fundamental contribution to development of marine ornamental fishery management policy, because they provide a first-order estimate of fishery impacts on wild stocks. It is important to note that population estimates provided here are conservative, being on the low side of true population numbers. Estimates provided herein may be considered "minimum" estimates, in that there are at least as many individuals in the wild populations as indicated in this document, but the true populations are certainly somewhat higher. Because of resource limitations, these surveys examined a limited number of habitat types, while ignoring other habitats that may be expected to host some additional number of each species evaluated.

Low population estimates are useful in the context of applying the "Precautionary Approach," (Fox 1999; Griego 2004; NMFS 2002) which strives to balance competing interests in the face of uncertainty or limitations in data availability. Because the population estimates are low, estimates of impacts (i.e. % harvest) are high, introducing a measure of protective conservatism in resulting policy decisions.

As important as they are, however, population numbers provide only a part of the foundation for policy development, albeit an important part. It must be recognized that the Phase II surveys provide only a one-time "snapshot" rapid assessment. Annual reproduction or recruitment dynamics, species behavior, and environmental factors may place more or fewer individual organisms in these areas at other times of the year. Spawning aggregations, for example, may create moments or seasons of increased species susceptibility to fishing impacts. Information concerning the life histories of the involved species therefore is also important to formulating effective and rational management policy.

Phase II is the second of three planned phases to develop meaningful marine ornamental fishery policy in Puerto Rico. Phase III will provide management options and recommendations to resource managers for consideration, decision and implementation. Phase III will include several components building on Phases I and II:

- A literature search will be conducted to obtain and evaluate life cycle information concerning representative taxonomic groups, to the species level where appropriate and possible;
- Management policies and practices employed in other regions including island nations will be researched and compared, with emphasis on "lessons learned" experience concerning failure and success of approaches applied elsewhere;
- To the extent possible, stakeholder input will be sought to encourage consensus concerning management approaches, to promote acceptance and compliance by fishers while providing resource managers assurance of enforceable environmental protection and sustainable viability of ecosystems involved;
- Formulation of management recommendations in such manner as to minimize conflicts of interest among fishers and potentially competing resource users; and
- Inclusion of management recommendations providing a basis for regulating non-export marine ornamental fisheries, which are currently entirely unregulated.

4.2 ADDITIONAL RECOMMENDED STUDIES

The world of marine ornamental fisheries provides an abundance of areas appropriate for in-depth research, many of which are probably most appropriate within an academic purview. Many questions have yet to be clarified concerning life histories, fecundity, populations and population fluctuations, reproductive and other behaviors, recovery from population exploitation or physical damage, and effects of environmental variables, to name only a few. This is certainly true for the marine ornamental species of finfish, but even more so for invertebrate species, which exhibit widely varied life histories and biology. The authors would encourage graduate student and research faculty exploration of these potentially fruitful and interesting topics

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APPENDIX A

Detailed finfish survey data are provided in Tables A-1 and A-2, presented on the following pages.

Table A-1. Fish Species Densities by Habitat in the La Parguera Region							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Royal Gramma	Lin. Reef + Spur & Groove	1,171	0	3,556	3,566	1,335	114%
	Patch Reef	278	0	556	556	393	141%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Blue Chromis	Lin. Reef + Spur & Groove	4,860	0	15,611	15,611	6,550	135%
	Patch Reef	1,292	0	2,583	2,583	1,827	141%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Bluehead Wrasse	Lin. Reef + Spur & Groove	6,190	852	12,074	11,222	3,769	61%
	Patch Reef	2,713	2,704	2,722	19	13	0,5%
	Colonized Pavement	1,028	1,028	1,028	0	N/A	N/A
	Col. Pavement & Sand Channels	3,694	3,694	3,694	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Red Lip Blenny	Lin. Reef + Spur & Groove	17	0	37	37	19	112%
	Patch Reef	19	0	37	37	26	137%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Blackbar Soldier	Lin. Reef + Spur & Groove	352	0	1,111	1,111	446	127%
	Patch Reef	236	222	250	28	20	8%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	250	250	250	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A

Table A-1. Fish Species Densities by Habitat in the La Parguera Region							
Common Name	Habitat Type	Species Density/Hectare			Range	SD	CV
		Mean	Min	Max			
Blue Tang	Lin. Reef + Spur & Groove	341	56	1,296	1,241	472	138%
	Patch Reef	171	83	259	176	124	73%
	Colonized Pavement	83	83	83	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Neon Wrasse	Lin. Reef + Spur & Groove	302	0	889	889	401	133%
	Patch Reef	56	0	111	111	79	141%
	Colonized Pavement	194	194	194	0	N/A	N/A
	Col. Pavement & Sand Channels	28	28	28	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Rock Beauty	Lin. Reef + Spur & Groove	6	0	37	37	15	250%
	Patch Reef	14	0	28	28	20	143%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Yellowhead Jawfish	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	0	0	0	0	0	N/A
	Colonized Pavement	56	56	56	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
French Angel	Lin. Reef + Spur & Groove	9	0	56	56	23	256%
	Patch Reef	19	0	37	37	26	137%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A

Table A-1. Fish Species Densities by Habitat in the La Parguera Region							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Gray Angel	Lin. Reef + Spur & Groove	32	0	74	74	30	94%
	Patch Reef	51	28	74	46	33	65%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Spanish Hogfish	Lin. Reef + Spur & Groove	31	0	148	148	59	190%
	Patch Reef	14	0	28	28	20	143%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Beau-gregory	Lin. Reef + Spur & Groove	295	185	417	231	98	33%
	Patch Reef	144	37	250	213	151	105%
	Colonized Pavement	28	28	28	0	0	N/A
	Col. Pavement & Sand Channels	111	111	111	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Sharpnose Puffer	Lin. Reef + Spur & Groove	147	37	278	241	83	56%
	Patch Reef	106	74	139	65	46	43%
	Colonized Pavement	167	167	167	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A
Yellowtail Hamlet	Lin. Reef + Spur & Groove	73	0	185	185	76	104%
	Patch Reef	111	111	111	0	0	N/A
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A

Table A-1. Fish Species Densities by Habitat in the La Parguera Region							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Yellowtail Damsel	Lin. Reef + Spur & Groove	225	0	481	481	188	84%
	Patch Reef	292	28	556	528	373	128%
	Colonized Pavement	0	0	0	0	0	N/A
	Col. Pavement & Sand Channels	694	694	694	0	0	N/A
	Scattered Coral & Rock	NS	NS	NS	NS	N/A	N/A

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set

Table A-2. Fish Species Densities by Habitat in the Rincón Region							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Royal Gramma	Lin. Reef + Spur & Groove	1,463	1,111	1,815	704	498	34%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	294	0	889	889	402	137%
	Scattered Coral & Rock	736	103	1,370	1,268	896	122%
Blue Chromis	Lin. Reef + Spur & Groove	3,556	3,556	3,556	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	2,905	0	9,370	9,370	4,439	153%
	Scattered Coral & Rock	128	103	154	51	36	28%
Bluehead Wrasse	Lin. Reef + Spur & Groove	2,315	852	3,778	2,926	2,069	89%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	3,127	1,694	6,333	4,639	2,159	69%
	Scattered Coral & Rock	8,001	5,774	10,259	4,516	3,193	40%
Red Lip Blenny	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	426	0	852	852	602	141%
Blackbar Soldier	Lin. Reef + Spur & Groove	704	370	1,037	667	471	67%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	206	0	407	407	195	95%
	Scattered Coral & Rock	218	103	333	231	163	75%

Table A-2.
Fish Species Densities by Habitat in the Rincón Region

Common Name	Habitat Type	Species Density/Hectare			Range	SD	CV
		Mean	Min	Max			
Blue Tang	Lin. Reef + Spur & Groove	111	37	185	148	105	95%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	51	28	74	46	27	53%
	Scattered Coral & Rock	94	77	111	34	24	26%
Neon Wrasse	Lin. Reef + Spur & Groove	759	519	1,000	481	340	45%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	502	259	1,000	741	345	69%
	Scattered Coral & Rock	141	0	282	282	199	141%
Rock Beauty	Lin. Reef + Spur & Groove	19	0	37	37	26	137%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	30	0	56	56	23	77%
	Scattered Coral & Rock	81	51	111	60	42	52%
Yellowhead Jawfish	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	653	0	2,611	2,611	1,306	200%
	Scattered Coral & Rock	0	0	0	0	0	N/A
French Angel	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	9	0	37	37	19	211%
	Scattered Coral & Rock	37	0	74	74	52	141%

Table A-2. Fish Species Densities by Habitat in the Rincón Region							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Gray Angel	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	0	0	0	0	0	N/A
	Scattered Coral & Rock	0	0	0	0	0	N/A
Spanish Hogfish	Lin. Reef + Spur & Groove	74	0	148	148	105	142%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	32	0	74	74	38	119%
	Scattered Coral & Rock	56	0	111	111	79	141%
Beau-gregory	Lin. Reef + Spur & Groove	889	889	889	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	257	0	889	889	426	166%
	Scattered Coral & Rock	74	0	148	148	105	142%
Sharpnose Puffer	Lin. Reef + Spur & Groove	222	222	222	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	100	0	370	370	181	181%
	Scattered Coral & Rock	114	74	154	80	56	49%
Yellowtail Hamlet	Lin. Reef + Spur & Groove	37	0	74	74	52	141%
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	9	0	37	37	19	211%
	Scattered Coral & Rock	0	0	0	0	0	N/A

Table A-2.
Fish Species Densities by Habitat in the Rincón Region

Common Name	Habitat Type	Species Density/Hectare			Range	SD	CV
		Mean	Min	Max			
Yellowtail Damsel	Lin. Reef + Spur & Groove	0	0	0	0	0	N/A
	Patch Reef	NS	NS	NS	NS	N/A	N/A
	Colonized Pavement	NS	NS	NS	NS	N/A	N/A
	Col. Pavement & Sand Channels	9	0	37	37	19	211%
	Scattered Coral & Rock	0	0	0	0	0	N/A

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set

APPENDIX B

Detailed invertebrate survey data are provided in Tables B-1 through B-4, presented on the following pages.

Table B-1.
Invertebrate Species Densities in Seagrass and Shallow Flat Habitats of the La Parguera Region
(Statistics Computed Across Stations)

Common Name	Habitat Type	Species Density/Hectare			Range	SD	CV
		Mean	Min	Max			
Blue Leg Hermit	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	716,571	53,333	1,488,667	1,434,667	549,952	77%
Pink Tip Anemone	Seagrass	172	0	467	467	207	120%
	Shallow Flats	0	0	0	0	0	N/A
Feather Duster	Seagrass	870	22	2,968	2,946	1,124	129%
	Shallow Flats	0	0	0	0	0	N/A
Curly Cue Anemone	Seagrass	856	0	2,968	2,968	1,032	121%
	Shallow Flats	0	0	0	0	0	N/A
Flame Scallop	Seagrass	2	0	15	15	6	265%
	Shallow Flats	0	0	0	0	0	N/A
Sea Mat	Seagrass	N/A	N/A	N/A	N/A	N/A	N/A
	Shallow Flats	N/A	N/A	N/A	N/A	N/A	N/A
Sea Cucumber	Seagrass	723	178	1,720	1,543	521	72%
	Shallow Flats	53,333	20,000	100,000	80,000	41,683	78%
Emerald Crab	Seagrass	41	0	132	132	54	133%
	Shallow Flats	34,667	0	200,000	200,000	73,660	212%
Red Thorn Starfish	Seagrass	29	0	132	132	49	170%
	Shallow Flats	0	0	0	0	0	N/A
Sunray Anemone	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	0	0	0	0	0	N/A
Pincushion Urchin	Seagrass	1,379	44	3,570	3,525	1,317	96%
	Shallow Flats	4,444	0	13,333	13,333	7,698	173%
Carpet Anemone	Seagrass	322	0	1,622	1,622	598	186%
	Shallow Flats	0	0	0	0	0	N/A
Bahamas Starfish	Seagrass	28	0	132	132	49	171%
	Shallow Flats	0	0	0	0	0	N/A
Shaving Brush	Seagrass	25,139	0	150,000	150,000	55,398	220%
	Shallow Flats	0	0	0	0	0	N/a
Brittle Starfish	Seagrass	35	0	132	132	60	172%
	Shallow Flats	93,333	20,000	166,667	146,667	73,333	79%
Harlequin Serpent Starfish	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	148,889	0	240,000	240,000	130,014	87%
Long Spine Urchin	Seagrass	3	0	22	22	8	265%
	Shallow Flats	0	0	0	0	0	N/A
Corky Sea Fingers	Seagrass	518	0	1,556	1,556	675	130%
	Shallow Flats	0	0	0	0	0	N/A
Fan Halimeda	Seagrass	1,158	0	7,368	7,368	2,741	237%
	Shallow Flats	0	0	0	0	0	N/A
Red Rock Urchin	Seagrass	98	0	489	489	188	191%
	Shallow Flats	212,571	0	920,000	920,000	365,786	172%

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set

Table B-2. Invertebrate Species Densities in Seagrass and Shallow Flat Habitats of the Boquerón Region (Statistics Computed Across Stations)							
Common Name	**Habitat Type**	**Species Density/Hectare**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Blue Leg Hermit	Seagrass	255	0	1,760	1,760	664	261%
	Shallow Flats	666,667	666,667	666,667	0	N/A	N/A
Pink Tip Anemone	Seagrass	6	0	33	33	12	19%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Feather Duster	Seagrass	47	0	301	301	112	241%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Curly Cue Anemone	Seagrass	6	0	32	32	12	217%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Flame Scallop	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Sea Mat	Seagrass	N/A	N/A	N/A	N/A	N/A	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Sea Cucumber	Seagrass	11	0	54	54	20	178%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Emerald Crab	Seagrass	2	0	11	11	4	265%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Red Thorn Starfish	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Sunray Anemone	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Pincushion Urchin	Seagrass	4	0	30	30	11	265%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Carpet Anemone	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Bahamas Starfish	Seagrass	27	0	61	61	28	103%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Shaving Brush	Seagrass	55,108	0	114,261	114,261	52,454	95%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Brittle Starfish	Seagrass	11	0	65	65	24	225%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Harlequin Serpent Starfish	Seagrass	0	0	0	0	0	N/A
	Shallow Flats	NS	NS	NS	NS	NS	NS
Long Spine Urchin	Seagrass	4	0	26	26	10	265%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Corky Sea Fingers	Seagrass	3,950	0	27,344	27,344	10,316	261%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Fan Halimeda	Seagrass	29,231	0	113,926	113,926	50,168	172%
	Shallow Flats	NS	NS	NS	NS	NS	NS
Red Rock Urchin	Seagrass	256	0	907	907	394	154%
	Shallow Flats	NS	NS	NS	NS	NS	NS

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set

Table B-3. Invertebrate Species Densities in Mangrove Fringe Habitats of the La Parguera Region (Statistics Computed Across Stations)							
Common Name	**Habitat Type**	**Species Density/linear km**			**Range**	**SD**	**CV**
		Mean	**Min**	**Max**			
Blue Leg Hermit	Island Mangrove	136	0	545	545	272	200%
	Mainland Mangrove	0	0	0	0	0	N/A
Pink Tip Anemone	Island Mangrove	4	0	10	10	5	126%
	Mainland Mangrove	8	0	30	30	13	165%
Feather Duster	Island Mangrove	11	0	37	37	17	159%
	Mainland Mangrove	64	0	343	343	138	216%
Curly Cue Anemone	Island Mangrove	151	0	554	554	269	178%
	Mainland Mangrove	60	0	284	284	111	184%
Flame Scallop	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	5	0	20	20	8	177%
Sea Mat	Island Mangrove	N/A	N/A	N/A	N/A	N/A	N/A
	Mainland Mangrove	N/A	N/A	N/A	N/A	N/A	N/A
Sea Cucumber	Island Mangrove	33	0	81	81	35	108%
	Mainland Mangrove	137	20	510	490	187	137%
Emerald Crab	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Red Thorn Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Sunray Anemone	Island Mangrove	127	0	218	218	107	85%
	Mainland Mangrove	27	0	164	164	67	245%
Pincushion Urchin	Island Mangrove	69	0	164	164	71	102%
	Mainland Mangrove	4	0	15	15	7	159%
Carpet Anemone	Island Mangrove	278	24	768	744	349	126%
	Mainland Mangrove	7	0	20	20	10	155%
Bahamas Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Shaving Brush	Island Mangrove	1	0	2	2	0	200%
	Mainland Mangrove	521	0	1,400	1,400	582	112%
Brittle Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Harlequin Serpent Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Long Spine Urchin	Island Mangrove	14	0	49	49	23	169%
	Mainland Mangrove	0	0	0	0	0	N/A
Corky Sea Fingers	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Fan Halimeda	Island Mangrove	152	0	304	304	125	82%
	Mainland Mangrove	178	0	730	730	281	158%
Red Rock Urchin	Island Mangrove	242	61	406	345	168	69%
	Mainland Mangrove	0	0	0	0	0	N/A

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set

Table B-4.
Invertebrate Species Densities in Mangrove Fringe Habitats of the Boquerón Region (Statistics Computed Across Stations)

Common Name	Habitat Type	Species Density/linear km			Range	SD	CV
		Mean	Min	Max			
Blue Leg Hermit	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Pink Tip Anemone	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Feather Duster	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	20	20	20	0	0	N/A
Curly Cue Anemone	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Flame Scallop	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Sea Mat	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Sea Cucumber	Island Mangrove	20	20	20	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Emerald Crab	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Red Thorn Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Sunray Anemone	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Pincushion Urchin	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Carpet Anemone	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Bahamas Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Shaving Brush	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Brittle Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Harlequin Serpent Starfish	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Long Spine Urchin	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Corky Sea Fingers	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A
Fan Halimeda	Island Mangrove	20	20	20	0	0	N/A
	Mainland Mangrove	220	220	220	0	0	N/A
Red Rock Urchin	Island Mangrove	0	0	0	0	0	N/A
	Mainland Mangrove	0	0	0	0	0	N/A

SD = Standard Deviation NS = Not Sampled N/A = Not Applicable
CV = Coefficient of Variation = 100(SD)/Mean Value of Set