VIRGIN ISLANDS RESOURCE MANAGEMENT COOPERATIVE

BIOSPHERE RESERVE
RESEARCH REPORT NO.22

A BASIS FOR LONG-TERM MONITORING OF FISH AND SHELLFISH SPECIES IN THE VIRGIN ISLANDS NATIONAL PARK

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U.S. MAN AND THE BIOSPHERE PROGRAM

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Abstract

A long-term monitoring program was initiated for fish and invertebrate species of commercial importance within the Virgin Islands National Park/Biosphere Reserve. Additionally, generally surveys were made for lobsters and conch. Hopefully, the data obtained will begin to fulfill the need for quantitative baseline data to assess and manage these resources adequately.

A one-year study indicates that; 1) some species of reef fish may have seasonal trends in numbers; 2) the inshore spiny lobster (Panulirus argus) population shows summer and winter peaks at Fish Bay but not Reef Bay, where numbers are very low; 3) conch (Strombus gigas) show a definite seasonal trend in deeper water with low numbers during the summer reproductive season; 4) whelk (Cittarium pica) at one study site show a large annual cohort of juveniles decreasing in abundance with increasing size. Few adults are present due to natural mortality. General surveys for conch and lobster demonstrate that the populations are of low abundance and highly dispersed.

These data will be useful to assess population trends in the absence or presence of management actions on the species or species groups. Recommendations for monitoring methodologies and management actions are discussed.

Acknowledgements

I would like to acknowledge and extend my deep appreciation to University of the Virgin Islands students, Lauren Patterson and Sue Johnson, and National Park Service technicians, Vonnie Zullo and John Blount, for their very valuable assistance in the field. Special thanks to Jim Beets of the University of Georgia for his discussions on this study, his help in the field, and his analysis of the data. Statistical analyses of the data were completed using STATPRO on an Apple computer and SYSTAT on an IBM PC.

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Introduction

Fish and marine invertebrates in the Virgin Islands are being affected by a number of stresses. Foremost of these is the heavy fishing pressure exerted on most species. With a limited shelf area of approximately 160,000 hectares (St. Thomas and St. John) and a total of 255 registered commercial fishermen (St. Thomas and St. John) for 1984-85 (Clavijo, et al., 1986), not to mention an unknown number of recreational fishermen and sport divers, the reef fish, lobsters, conch and whelk are being harvested at a rate exceeding replacement. As a result the stocks are declining at an alarming rate (Caribbean Fisheries Management Council (CFMC), 1985), a fact corroborated by fishery landings data as well as by fishermen. Other stresses include effects of development (sedimentation, increased runoff, potential toxic pollutants) and habitat degradation through anchor and boat damage and large numbers of visitors utilizing and affecting the marine ecosystems.

As it is very difficult to estimate accurately the total potential fishery yield of tropical insular shelf marine environments, many fisheries have been overexploited both biologically and economically before the condition is realized. Management is, therefore, a necessary tool in mitigating adverse conditions in a fishery. A prerequisite to developing management plans is to have information on the status of the fishery unit in question. The Caribbean Fishery Management Council (1985) lists as its number one problem the insufficiency of data needed for long-range management. This need can be satisfied by obtaining these data through research and surveys. With this information, management actions can be formulated to restore and maintain adult stocks at levels that ensure adequate spawning and recruitment required to maintain the population. This is accomplished through the promulgation of laws which prevent the harvest of individuals of species of high value by enforcement of minimum size restrictions and/or closed seasons. Monitoring the effects of a management action is essential in order to determine the success of the action and to assess the need for modification of regulations.

While stresses due to adverse fishery conditions can be mitigated (although not without upsetting the segment of the population involved in the fishery), it is harder to control and mitigate the more subtle stresses of development. This is an area where control of continuing development is probably impossible and mitigation would be extremely costly. Our goal must be to measure the effects and work for establishment of restrictions on development in productive areas.

The main objective of this study was to select areas within the National Park for long-term monitoring of fish and marine invertebrates. Reef fish, lobster, conch, and whelk were selected as high value species to be monitored in bays associated with disturbed and undisturbed watersheds. The data to be collected are to be used as baseline data for formulating and monitoring recommended management actions. Monitoring methodologies were developed which could be easily used and taught to non-scientists yet yield accurate results. These methods could be used throughout the Caribbean to produce comparable data bases in areas with little technology or resources.

Reef fish

Methodology

Three main watershed areas have been selected within the National Park for long-term study. These include Reef Bay (a completely protected watershed), Fish Bay (a watershed under development), and Hawksnest Bay (potentially impacted by construction of the St. John Clinic and future development) (Figure 1). Therefore, these bays were selected for long-term reef fish monitoring. Primary reef fish habitats were selected for monitoring within each bay based on previous designation of fishery habitats (Boulon, 1985a).

Species of fish were selected for study on the basis of their importance in the local commercial fisheries (Table 1). Any species taken as a food fish by any means were considered. Nearly all species selected for this project are considered in the Fishery Management Plan for the Shallow-Water reef fish Fishery of Puerto Rico and the U.S. Virgin Islands (CFMC, 1985). The species considered in the Fishery Management Plan were selected out of approximately 180 species which are landed and used in quantity throughout the Caribbean.

A census was taken of fish species of commercial importance present in the selected habitat within each of these bays using a random point, visual census technique (Bohnsack and Bannerot, 1983). Census locations were selected on a random basis within a habitat. The attempt was to locate oneself in a site characteristic of the selected habitat. It is important to avoid mixing the habitats (e.g. lower forereef and sand) within a single census radius. At each census location, the observer would begin by facing in one particular direction and during a five-minute period, rotate clockwise 360°, sampling all fish within an eight meter radius cylinder surrounding the observer. Due to good water clarity, an 8m radius could be used in all study sites. As the observer rotated through the census, the number of individuals observed for each species was recorded on mylar over a preprinted form. The preprinted form saves time in writing down the species' name. After using this form a few times, the location of a species' name is easily remembered. Use of the preprinted form did not appear to produce a bias (Bohnsack and Bannerot, 1983) since the form is only looked at to write down fish just observed and does not cause the observer to select fish to look for. This method proved more reliable in our study. The chance of counting an individual twice was greatly reduced by strictly adhering to the 360° census with no overlap and avoidance of recounting in subsequent censuses obvious

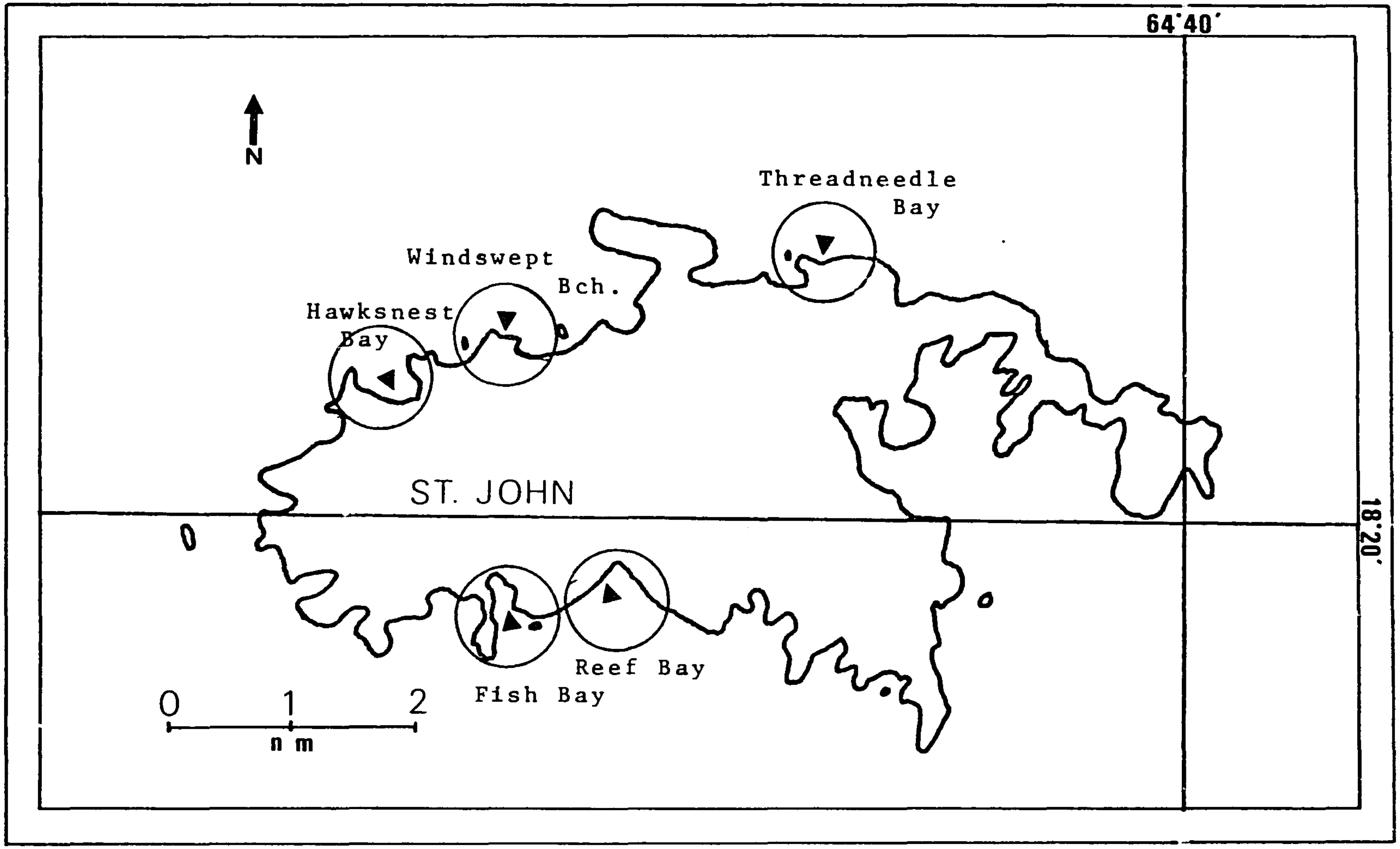

Figure 1. Map of St. John, USVI, showing location of study sites.

TABLE 1. Commercially important species of fish observed at the long-term monitoring study sites. Common and scientific names taken from Robins, et al. (1980). Local common names from J.A. LaPlace (pers. comm.).

COMMON NAME	LATIN NAME
COASTAL PELAGIC FISH:	
cero mackerel	*Scomberomorus maculatus*
horse-eye jack	*Caranx latus*
bar-jack-carang	*C. ruber*
DEMERSAL FIN FISH:	
queen triggerfish - old wife	*Balistes vetula*
bluestriped grunt	*Haemulon sciurus*
white grunt	*H. plumieri*
french grunt	*H. flavolineatum*
tomtate	*H. aurolineatum*
smallmouth grunt	*H. chrysargyreum*
spanish grunt	*H. macrostomum*
striped grunt	*H. striatum*
sailor's choice	*H. parra*
juvenile grunts	*H.* spp.
margate	*H. album*
mutton snapper - virgin snapper	*Lutjanus analis*
dog snapper - dogtooth snapper	*L. jocu*
grey snapper	*L. griseus*
schoolmaster - mango snapper	*L. apodus*
yellowtail snapper	*Ocyurus chrysurus*
mahogany snapper - burn tail	*L. mahogoni*
lane snapper - pot snapper	*L. synagris*
queen & french angelfish - swede angel	*Pomacanthus* spp.
grey angel - flatfish	*P. arcuatus*
rock beauty - black and yellow swede	*Holocanthus tricolor*
red hind - hind	*Epinephelus guttatus*
rock hind	*E. adscensionis*
graysby - butter socks	*Petrometopon cruentatum*
coney - butter fish	*Cephalopholis fulva*
nassau grouper	*Ephinephelus striatus*
black grouper	*Myctoperca bonaci*
tiger grouper	*M. tigris*
porgies	Sparidae
surgeonfish	*Acanthurus* spp.

Table 1. (Continued)

Commercially important species of fish observed at the long-term monitoring study sites. Common and scientific names taken from Robins, et al. (1980). Local common names from J.A. LaPlace. (pers. comm.).

COMMON NAME	LATIN NAME
DEMERSAL FIN FISH: (continued)	
blue tang - blue doctor	A. coeruleus
yellow goatfish - queen mullet	Mulloidichthys martinicus
spotted goatfish	Pseudupeneus maculatus
spanish hogfish - spanish piper	Bodianus rufus
hogfish - eaglemouth	Lachnolaimus maximus
parrotfish - goutou	Scaridae
trunkfish - shellfish	Ostraciontadae
sea chubs	Kyphosus spp.
barracuda	Sphyraena barracuda
squirrelfish	Holocentridae
glasseye/bigeye - bleareyes	Priacanthus spp.
mojarra - sand diggers	Gerreidae

of species that tend to be very mobile (e.g. mutton snapper, barracuda).

At the end of a sample period, the minimum and maximum lengths for each species were recorded. Where a clear dichotomy in sizes was observed, this was noted. These lengths are estimates based on pre-study tests and extensive field experience in which estimates were made of objects at various distances from the observer and then measured to determine accuracy. When other observers were used, size estimates were examined for consistency with data collected by the author and discrepancies were discussed with the other observer.

Most species of fish occurred in low numbers during a census. Schools of fish are counted as they appear in the sample radius and if large, are counted in 10s, 100s or even 1000s.

Advantages of this method are numerous. It is simple, rapid, unbiased and precise. It is easily performed by anyone with a minimum of instruction and practice. It requires no complicated accessories such as cameras, transect lines, compasses, etc. As such, it is very applicable to developing countries where technology is not available for higher-tech methods requiring many accessories. It is easily performed either by snorkeling or using SCUBA (for depths greater than 4m). A stationary observer has a better chance of observing more cryptic or wary species which would otherwise avoid a moving diver. There are also species which are attracted to a moving diver, thus biasing the data. Additionally, due to the small area actually sampled in one census, the chances of crossing habitats within a census are greatly reduced. The only requirement of this method is an underwater watch and an ability to identify fish species using external morphological or visual characteristics. This is easily accomplished after several practice censuses with review and reference of a good identification guide (e.g. Randall, 1968; Chaplin, 1972; Stokes, 1980).

Several disadvantages of this direct sampling method must be acknowledged. Using this method, nocturnal and highly cryptic species tend to go undetected. Being a random point census technique, the effects of schooling, territoriality or preference for specific microhabitats (all of which can cause nonrandom distribution of fish populations) can affect abundance estimates. Also, juvenile fishes tend to be underrepresented. However, ensuring that censuses are performed in habitat "core areas" (Boulon, 1985a) will eliminate the significance of these problems.

A preliminary test was made of this method to determine number of censuses necessary to accurately describe an area in terms of species composition. Ten successive censuses were made in one location. The results indicate that approximately 80 percent of the resident, nonmigratory and non-cryptic species are observed in four censuses (Figure 2). Species added in subsequent censuses include migratory species such as mackerel

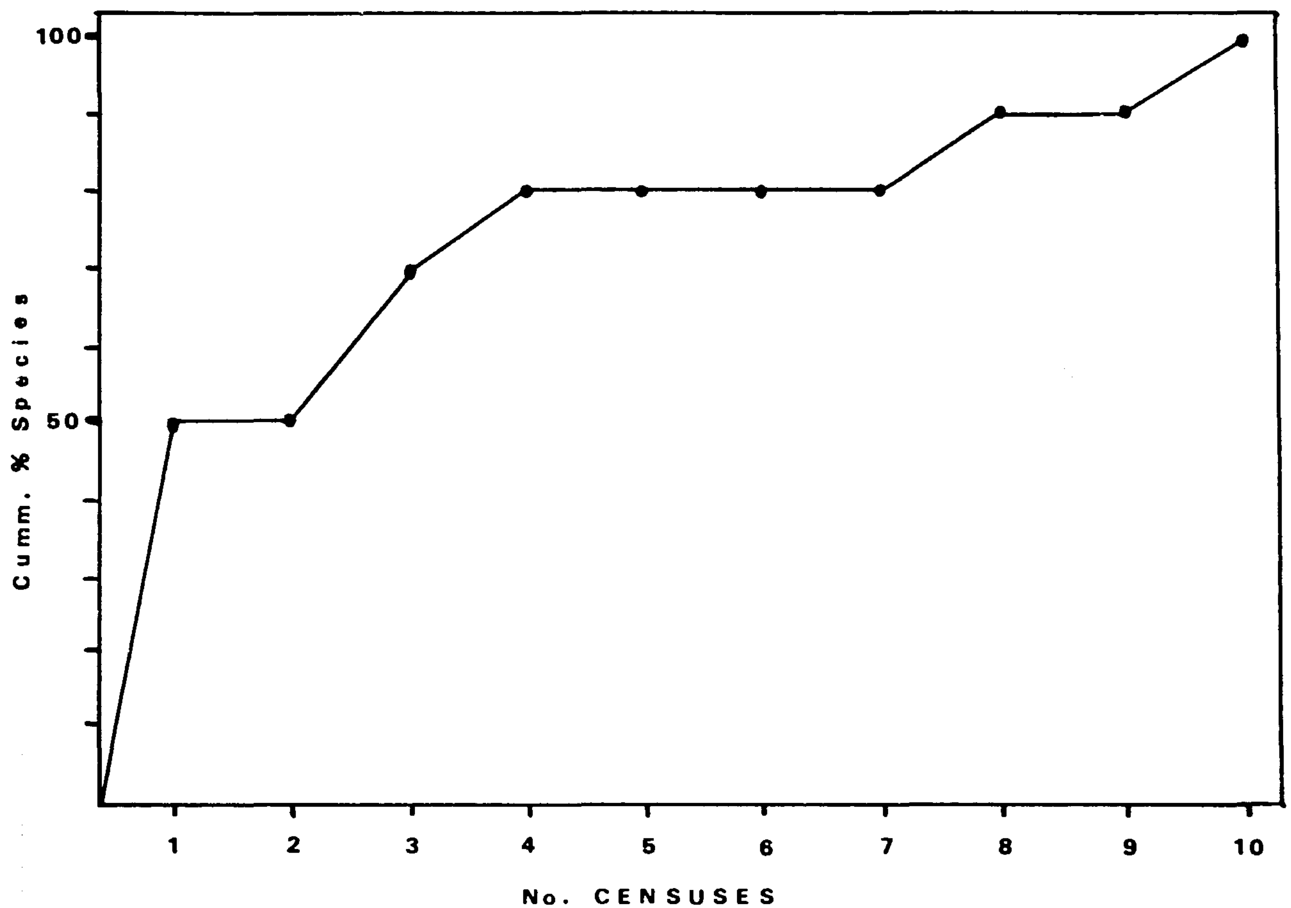

Figure 2. Cumulative percent species curve for ten repetitive fish censuses at one location in Fish Bay, St. John, USVI, on January 22, 1985.

(*Scomberomorus maculatus*) and cryptic species such as small coney (*Epinephelus fulvus*), whose behavior is to hide behind coral heads and peek out frequently unobserved. Based on this study and the size of most of the areas monitored, ten censuses per location per date was selected as an adequate sample size to yield a representative sample of the fish assemblage composition and abundance within that particular habitat. At certain selected locations the reef or habitat being sampled was smaller in size and fewer censuses were needed to adequately cover the area without overlap.

Hawksnest Bay

Hawksnest Bay, on the north shore of St. John (Figure 3) was chosen as a long-term monitoring site for two reasons. First, it is an area suspected of having been affected by sedimentation produced by the construction of the St. John Community Health Clinic in 1982 at the top of this watershed. Unstabilized sediment berms created by the excavation for the hospital have been steadily eroding since 1982 and may have raised the sediment load of the bay, decreasing visibility (light transmission) and taxing the sediment removal capabilities of benthic organisms. Changes in benthic communities would be reflected in long-term changes in reef fish assemblage composition and abundance. The second reason for selecting Hawksnest is that other long-term coral and sedimentation studies were initiated in the watershed and an integrated view is evolving. Three areas in the bay, representing two different habitat types, were selected for this study.

Shallow bay patch reef-SBpr

Located in the middle of Hawksnest Bay (Figure 3) this reef is approximately 75m long and 30m wide with the long axis oriented N.rth-South. It is characterized by having an east facing forereef which rises up from a 12m deep sand plain to about 9m. This forereef, with its vertical relief and moderate coral coverage, has the greatest abundance of fish on the reef. Behind this the reef is relatively flat with scattered corals, gorgonians, and sponges. The back of the reef (west side) is very sandy with sparse, scattered gorgonians,and few fish. The reef was characterized by monthly samples of five censuses along the forereef and five censuses along the middle portion of the reef.

Eleven monthly samples were made (Table 2) on this reef from March 1985 to February 1986. A total of 36 species of commercially important fish were observed on the reef during this period with a mean of 21.4 (sd=2.19) species seen on each sample date. A mean of 428 (sd=127) individual fish were seen on each sample date. Mean average fish size for the entire period was 5.8 (sd=0.6) inches. Of the 36 observed species, 20 species were present in eight (75%) or more samples and eight species were present in every sample.

No trends are evident for species abundance or average fish

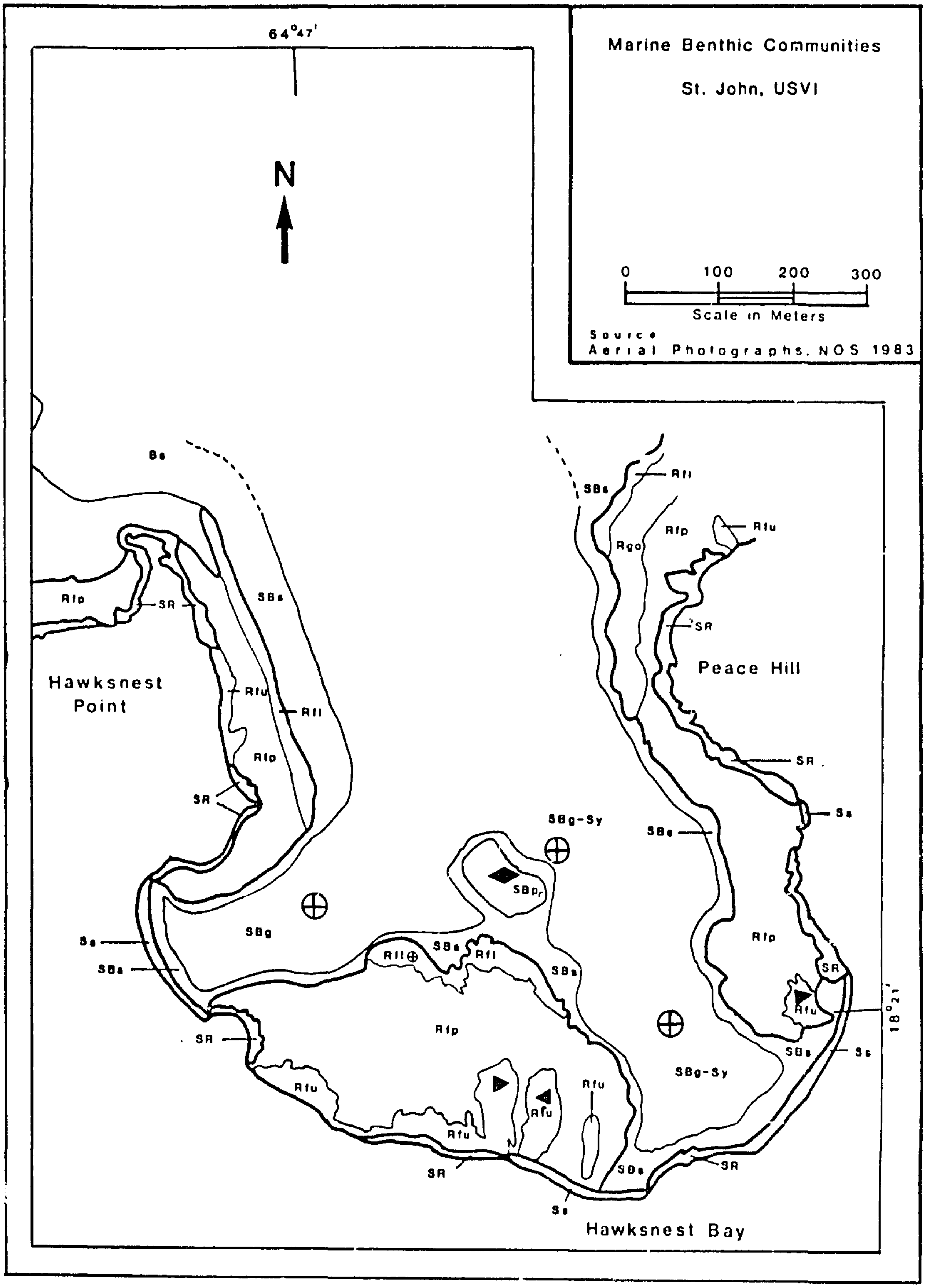

Figure 3. Hawksnest Bay, St. John, USVI, showing location of study areas for long-term monitoring of reeffish and lobster populations. ◀ - fish study areas, ◆ - lobster and fish study areas. ⊕ - conch survey areas. See Table 3 for acronyms.

TABLE 2. Average number of fish per census per species for Hawksnest Bay Shallow Bay Patch Reef (SBpr) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
queen triggerfish	.1		.1		.1						
bluestriped grunt			1.4		.6	1.6	.3			.2	.6
white grunt	.8	1.1	.1	.8		.7	.3		.3		.2
french grunt	1.2	1.2	.7	1.4	.9	1.1	1.2	.8	1.4	.9	1.5
tomtate	.1			.3	1.2	.1			.6		.1
small mouth grunt							.7	.5			
striped grunt								.6	.3	1.3	.5
juvenile grunt						2.0				2.5	
margate			.1								
mutton snapper	.3	.2		.2	.8		.3	.1	.3	.3	.2
dog snapper							.1				
yellowtail snapper	1.4	3.0	7.3	4.0	4.8	3.7	2.8	3.7	1.7	.9	1.6
mahogany snapper	.3	.4			2.2	1.3	1.1	.7	.5	.1	.2
lane snapper				1.3	.6	2.5	5.3	1.8	6.3	3.9	4.2
q. and fr. angelfish	.1	.1	.1		.3		.4	.2	.2	.2	.3
gray angelfish	.1	.2	.3	.1	.1	.1			.1	.1	
red hind	.2	.2	.7	.6	.5	.3	.5	.5	.5	.4	.3
rock hind				.2							

Table 2 (Continued)

Average number of fish per census per species for Hawksnest Bay Shallow Bay Patch Reef (SBpr) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
graysby			.1	.3	.2	.1	.1	.1	.2	.4	
coney	.4	.1			.2	.6	.2	.5	.1	.2	.2
nassau grouper		.2	.1	.3							
blue tang	2.3	5.1	4.9	5.9	7.4	4.8	7.1	2.4	4.7	1.8	5.7
surgeon-fish	1.4	1.8	1.4	1.0	3.7	1.4	1.0	.7	1.9	.3	.4
yellow goatfish		1.8	2.5	2.7	1.9	1.5	1.5	1.1	1.2	1.2	2.3
spotted goatfish	.7	.1	1.0	.3	.9	.6	.8	.2	.4	.1	.1
spanish hogfish			.1								
hogfish					.2						
porgies	.2	.4	.1	.2	1.2	.2	.4	.5	.1	.2	.1
parrot fish	27.7	18.3	14.0	10.6	43.5	33.8	18.9	20.5	15.3	12.1	24.0
trunk fish						.1			.2	.2	
barracuda	.1	.1	.2	.1						.1	
squirrel fish	.2		.2	.6	.4	.8	.6	.6	.4	.6	.5
glasseye/ bigeye										.2	
mojarra			.4	1.0	1.7		1.1	.1	3.4	2.9	1.7
mackerel		.6		.4					.4		
bar jack		.2			1.1	1.4	.3	.4	.7	1.0	.3
total # species	18	18	21	21	24	21	22	20	24	25	21

Table 2 (Continued)

Average number of fish per census per species for Hawksnest Bay Shallow Bay Patch Reef (SBpr) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
total # individuals	376	316	364	321	748	593	450	358	412	321	450
average size(in)	5.34	5.79	7.16	5.95	5.96	4.68	5.44	5.74	6.53	5.86	5.35

Table 3. Zone and subzone designations with acronyms.

A)	Shore Zone	S
	1) Beach rock	Sb
	2) Sand	Ss
	3) Mangrove	Sm
B)	Subtidal Bedrock	SR
C)	Lagoon	L
	1) Pavement	Lp
	2) Seagrass bed	Lg
D)	Shallow Bay	SB
	1) Sand	SBs
	2) Pavement	SBp
	3) Seagrass bed	SBg
	4) Patch reef	SBpr
	a) pavement	SBprp
	5) Algae	SBa
E)	Reef (fringing and barrier)	R
	1) Backreef	Rb
	a) head coral/groto	Rbh/Rbg
	b) pavement	Rbp
	2) Reef crest	Rc
	3) Fore reef	Rfu
	a) upper (arborescent)	Rfu
	b) lower (massive)	Rfl
	c) pavement	Rfp
	4) Sand	Rs
	5) Gorgonian-dominated pavement	Rgo
	6) Pavement	Rp
F)	Bank	B
	1) Gorgonian-dominated pavement	Bgo
	2) Pavement	Bp
	3) Sand	Bs
	4) Seagrass bed	Bg
	5) Patch reef	Bpr
	a) crest	Bprc
	b) fore reef upper/lower	Bpru/Bprl
	c) pavement	Bprp
	d) gorgonian-dominated pavement	Bprgo
	6) Algal plain	Ba

size during the study period. Total number of individuals may increase during the summer months (July to September). The primary contributors to this increase appear to be the herbivorous blue tang, surgeonfish and parrotfish. Other species show no clear seasonality in presence or numbers. This reef has a large number of foraging groups of juvenile (1 to 2 inch) parrotfish which some observers during this study may have overlooked. This may produce some of the fluctuations in numbers of parrotfish per census. (e.g. June, 1985).

During the study period, fish traps (2 to 3) were observed set on this reef. The potential impact of this fishing technique on a small, isolated reef is not fully understood. In order to quantify the impact it is necessary to have an intensive before and after census schedule and a total enumeration of species and numbers of fish harvested. It was noted from the census data in this study, that eighteen species of fish that are commonly caught in fish traps decreased slightly in numbers from before to after trapping. The small sample size does not enable any conclusive statements to be made regarding this observation.

Southern fringing patch reef-Rfu

Along the south side of Hawksnest Bay immediately off the public swimming beach are three patches of shallow water, upper-fore, fringing reef. The two larger, western reefs are primarily composed of Acropora Palmata with small amounts of other hard coral species. The two larger reefs were selected for the study due to their greater coral cover and 'healthier' nature. The smaller reef appears to be subjected to greater scouring action by winter swells and is generally more turbid making it difficult for visual censuses.

Eleven monthly samples were made (Table 4) on these reefs from March 1985 to February 1986. Five censuses were made on each reef each sample period which was felt to adequately cover each reef without any overlap of censuses. A total of 22 species of commercially important fish were observed on the reef during this period with a mean of 11.5 (sd=2.27) species seen on each sample date. A mean of 388 (sd=88.7) individual fish were seen on each sample date. Mean average fish size for the entire period was 4.56 (sd=.50) inches. Of the 22 observed species, seven species were present in every sample.

The only species showing evidence of a seasonal trend on these shallow patch reefs were yellow goatfish. During the months of September and October, large schools of juvenile yellow goatfish (3-5 inches long) were observed taking refuge in these reefs. As fast as they appeared, they disappeared and by November they were not in evidence. No seasonal trends are obvious for any other species either in numbers of individuals or size except for possibly sailor's choice and mahogany snapper which were only present during later summer and early fall. This reef has large numbers of juvenile herbivores, primarily parrotfish, blue tang and surgeonfish, which probably accounts for the smaller mean fish size for this reef compared to the SBpr.

TABLE 4. Average number of fish per census per species for Hawksnest Bay southern fringing patch reefs (Rfu) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
blue striped grunt	.1	.1	.2	.3	.3	.3		.3	.6	.2	.4
white grunt			.1								
french grunt	.7	.4	.7	.6	2.2	6.9	4.4	6.5	1.8	3.5	4.4
small mouth grunt								.2			
sailor's choice						.7	.1	.1			
yellowtail snapper	.1		.3	.4	.3	.1	.2	.3			
mahogany snapper					.8	.1	.1				
red hind		.2		.1			.1				.1
graysby				.1	.1			.1			
coney			.1					.2	.1	.1	
nassau grouper				.1							.1
blue tang	8.9	14.9	2.8	12.5	8.3	6.4	6.6	9.3	7.7	11.1	11.6
surgeon fish	4.3	3.7	5.2	8.5	7.5	5.5	5.5	5.6	4.9	8.8	7.5
yellow goatfish			.6		3.4	1.1	9.1	7.1	.2		.5
spotted goatfish		.1	.1	.4	.3		.2	.5	.2		
porgies							.1				
parrot fish	18.3	9.8	15.6	10.3	23.6	17.3	18.0	22.5	14.1	23.2	16.0
trunkfish	.1	.1	.1	.2				.1	.3		

Table 4 (Continued)

Average number of fish per census per species for Hawksnest Bay southern fringing patch reefs (Rfu) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
squirrel fish		.2	.1	.1	.1	.4	.4	.2	.2	.9	.2
mojarra			.5				.1	.2		.2	
mackerel	.8										
bar jack	1.0	.2	.2	4.0	.1		.3	.7		.3	.8
total # species	9	10	14	13	12	10	14	16	10	9	10
total # individuals	309	271	266	377	470	391	453	539	298	483	416
average size(in)	5.73	3.89	5.15	4.39	4.54	4.25	4.18	4.83	4.45	4.62	4.11

Eastern fringing patch reef-Rfu

Directly off the northeastern end of the privately owned beach in Hawksnest Bay is a small patch of shallow water, upper-fore, fringing reef. This reef is not as developed as the southern fringing reefs possibly due to lower energy levels and being near the major gut draining this watershed (Hubbard, et. al. 1986).

Eleven monthly samples were made (Table 5) on this reef from March 1985 to February 1986. Due to the size of this reef, four censuses were deemed adequate to sample the fish assemblage present there. A total of 19 species of commercially important fish were observed on the reef during this period with a mean of 11.6 (sd=1.07) species seen on each sample date. A mean of 363 (sd=140) individual fish were seen on each sample date. Mean average fish size for the entire period was 4.87 (sd=.57) inches. Of the 19 observed species, eight species were present in eight (75%) or more samples and five species were present in every sample.

The only species showing evidence of a seasonal trend on this reef were yellow goatfish and possibly tomtate. As with the southern patch reefs large schools of juvenile yellow goatfish (3-5 inches long) were observed taking refuge here during the months of September and October. As opposed to the southern reefs, however, a higher year-round background level of yellow goatfish exists on this reef. This large number of yellow goatfish is responsible for the peak in total number of individuals for these two months. Tomtate were only observed from May to September which may or may not be a seasonal trend. Fewer very small herbivores were observed on this reef which results in a slightly higher mean fish size than for the southern reefs.

TABLE 5. Average number of fish per census per species for Hawksnest Bay eastern fringing patch reef (Rfu) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
blue striped grunt		.3	.5	.3				.3			1.0
french grunt	39.5	51.5	40.3	50.8	50.8	25.8	38.5	65.3	42.3	39.5	29.3
tomtate			1.5	6.5		1.8	1.8				
small mouth grunt		.8			4.0			4.8	4.3	3.8	1.3
spanish grunt		.3			.3		.3				.3
school master	.3	.3	.3	.3							
yellowtail snapper	.3	1.0	1.8	2.0	.5	2.0	2.8	4.3	3.3	2.3	1.5
mahogany snapper			.5	2.8	.8	.5			.5	.8	.3
coney										.5	
blue tang	3.5	4.8	15.3	5.5	1.8	8.8	12.3	6.0	7.8	14.5	3.0
surgeon fish	2.8	5.5	3.3	2.0	5.0	1.8	7.8	2.0	4.3	10.0	3.8
yellow goatfish	1.3	4.3	6.5	4.0	5.0	10.8	64.3	65.0	7.3	4.5	
spotted goatfish	.3	.3		1.0		.3				.5	
parrot-fish	12.3	5.0	9.8	8.5	6.3	8.3	11.5	14.8	9.0	15.0	15.8
trunkfish	.3						.3		.5		.5
squirrel fish	.3	.5	1.8	1.8	1.8	1.0	1.8	1.3	.8	1.0	3.0

Table 5 (Continued)

Average number of fish per Census per species for Hawksnest Bay eastern fringing patch reef (Rfu) from March 1985 to February 1986. (Total # fish/# censuses).

Species	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	2/86
mojarra							.3			1.3	
sea chubs							2.5				
bar jack	2.5	.8	.5		1.0	.5	.8	12.5		2.5	.5
total # species	11	13	12	12	11	11	13	10	10	13	12
total # individuals	252	291	327	341	308	251	578	704	309	387	240
average size(in)	6.28	4.33	4.44	4.55	4.04	5.16	4.90	4.78	5.14	4.75	5.19

Reef Bay

Reef Bay, on the south shore of St. John (Figure 4), was chosen as a long-term monitoring site for two reasons. First, being a relatively protected watershed with no chance for development, it may act as an indicator of general marine "health". Secondly, like Hawksnest Bay, the combination of this study with other long-term research creates a more complete picture of the bay. An area that is being studied for changes in coral composition and abundance (Rogers and Zullo, 1986) was selected for the reef fish monitoring study.

The study area in Reef Bay is along the lower forereef portion of the western fringing reef. The reef at this site is very steep, going from the surface to 11m in depth with a slope averaging approximately 45 degrees. Several buttress-like formations in the study area have the greatest coral cover and the greatest numbers of fish. The study area includes the 50m stretch of reef described in Rogers and Zullo (1986) and an additional 50m of reef to the west of it. This 100m study area was characterized by monthly samples of 10 censuses each. Since there were some clumping of fish on the buttress-like formations, these were censused every month. Other censuses were randomly distributed through the study area.

Poor weather (waves, visibility) and logistical problems only enabled nine samples to be made (Table 6) at this site from February 1985 to January 1986. A total of 34 species of commercially important fish were observed in the study area during this period with a mean of 21.0 (sd=2.4) species seen on each sample date. A mean of 657 (sd=185) individual fish was seen on each sample date. Mean average fish size for the entire period was 5.82 (sd=.51) inches. Of the 34 observed species, sixteen species were present in seven (75%) or more samples and thirteen species were present in every sample.

The general fluctuation of number of individuals per species from sample to sample does not indicate any easily observable seasonal trends. The only possible exception to this is spotted goatfish which do show a peak in abundance for September with the majority of those seen being relatively small (4-5 inches). There is a peak in total numbers of individuals during the period of June to September. The major contributors to this are white grunt, juvenile grunt, mahogany snapper and blue tang, with different ones in different months being responsible for elevating the total number of individuals.

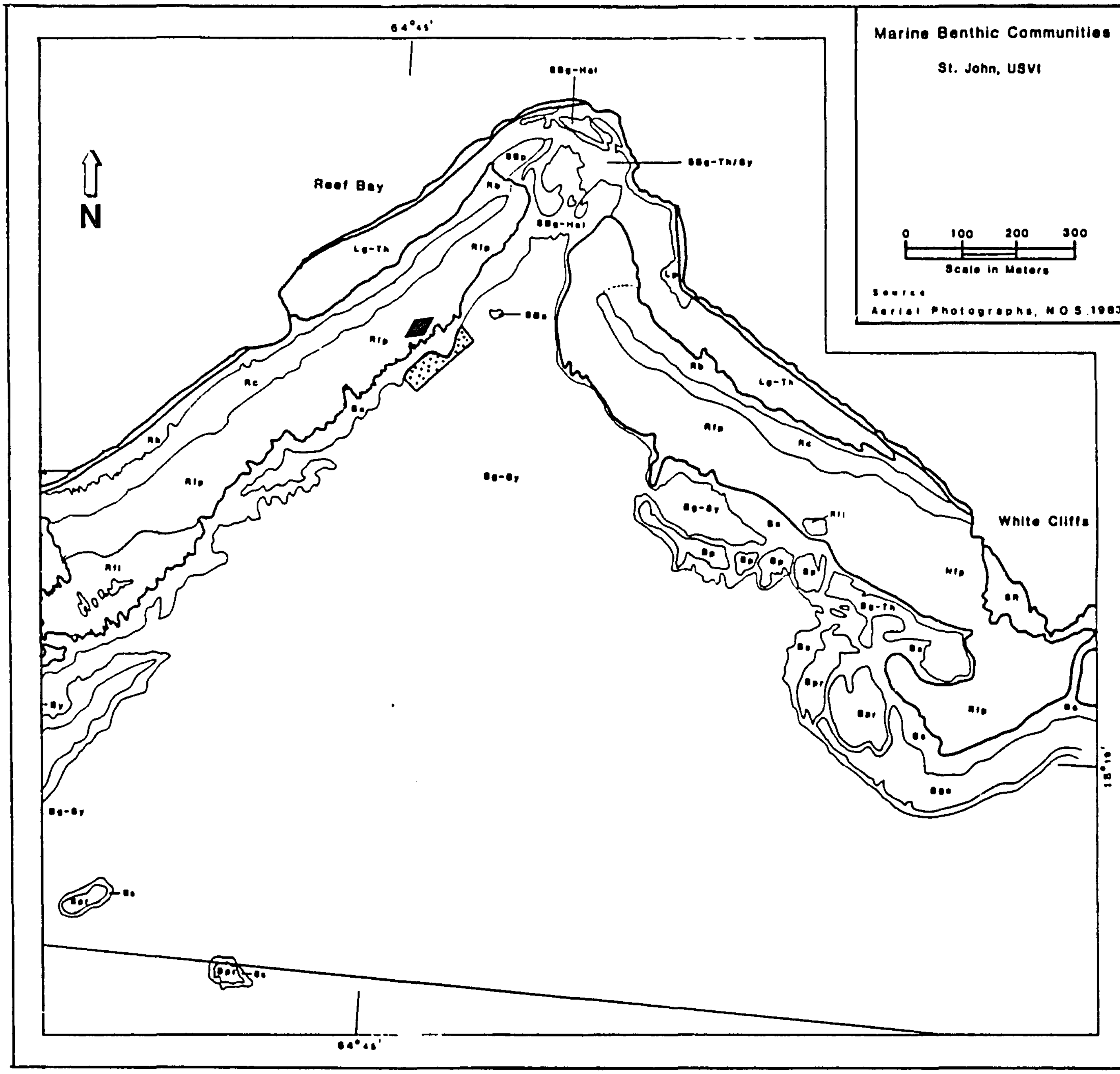

Figure 4. Reef Bay, St. John, USVI, showing location of study site for long-term monitoring of reef fish and lobster populations. ◆ - study area. [dotted box] - conch survey area. See Table 3 for acronyms.

TABLE 6. Average number of fish per census per species for Reef Bay lower fore reef (Rf1) from February 1985 to January 1986. (Total # fish/# censuses).

Species	2/85	4/85	6/85	7/85	8/85	9/85	10/85	12/85	1/85
queen triggerfish								.1	
blue striped grunt	2.8	2.4	3.3	2.0	3.3	3.3	3.8	2.0	1.2
white grunt	4.2	6.9	16.9	16.1	8.2	15.9	14.9	6.1	5.3
french grunt	4.8	9.1	11.2	8.2	6.4	13.1	7.3	3.9	5.0
tomtate	.2								
small mouth grunt		.6	.5			1.4			
spanish grunt	.2	.5	.5	.7	.2	.6	.2	.2	.2
juvenile grunts	2.8			16.7		6.0			
mutton snapper	.1	.3	.1						.1
dog snapper			.1	.1		.1			
gray snapper		.3							
lane snapper			.1						
school master	.9	.4	.7	.2	1.0	1.1	.6	.4	.4
yellowtail snapper	4.7	3.8	2.4	3.8	1.8	4.7	3.3	4.9	2.5
mahogany snapper	.2	2.8	9.2	8.3	2.1	1.0	1.3	5.3	3.8
q & fr angelfish	.1		.1		.1	.2	.1	.2	
gray angelfish	.2		.1	.2		.4			
red hind								.1	
coney			.2			.2	.1	.1	
nassau grouper						.1	.1		.1
black grouper						.1		.2	
tiger grouper		.1	.1			.1	.1	.1	.1
blue tang	4.2	12.9	30.2	11.7	22.7	11.5	7.6	11.1	16.9

Table 6 (Continued)

Average number of fish per census per species for Reef Bay lower forereef (Rfl) from February 1985 to January 1986. (Total # fish/# censuses).

Species	2/85	4/85	6/85	7/85	8/85	9/85	10/85	12/85	1/86
surgeon fish	1.8	6.5	4.6	9.1	11.6	5.4	2.1	4.0	4.1
yellow goatfish	1.4		1.7	3.0	2.5	2.5	3.9	.6	1.1
spotted goatfish	.2	.5	.6	.8	1.5	5.8	1.7	2.0	.5
spanish hogfish	.3	.5	.4	.1	.2	.6	.1	.2	
parrot fish	5.8	11.1	11.7	8.0	11.7	6.2	8.9	11.8	12.1
trunkfish	.1				.2			.1	
barracuda	.1	.3							
squirrel fish	.1	.5	1.1	.6	.8	1.6	1.0	1.2	.6
mojarra	.1	.1	.1	.3				.1	
mackerel		.1				.1		1.6	
bar jack	2.1	.4	1.1		.3	1.0	1.9	1.1	.2
total # species	22	21	22	20	17	25	19	24	19
total # individuals	344	475	964	826	750	815	596	586	555
average size(in)	6.89	5.81	5.77	5.42	6.01	5.01	5.38	6.22	5.86

Fish Bay

Fish Bay, on the south shore of St. John (Figure 5), was chosen as a long-term monitoring site for two major seasons. First, this is a large watershed which is still relatively pristine but is planned for major residential development (over 200 lots) in the lower part of the watershed. The middle part is owned by the National Park Service and The Nature Conservancy and the upper part is private with potential for additional development. There is therefore potential for major impact on the marine resources of this bay. Secondly, like Hawksnest and Reef Bays, the combination of this study with other long-term research creates a more complete picture of the bay. Two habitats were selected as being the major habitats of importance for reef fish. These include the lower forereef and backreef habitats. The mangroves along the coastline were surveyed for juvenile nursery potential but the extreme shallowness of the water (only a few inches at low tide) makes it unsuitable for fish to reside there. Only a very few fish were observed and those were in small hollows where the gut enters the bay. Visibility in these hollows is not much better than half a meter which makes any survey method nearly impossible.

Lower Forereef-Rf1

The lower forereef in Fish Bay is a series of spurs oriented northwest to southeast with sand between them (Figure 5). Maximum relief of the spurs is approximately 2m. The study area covers approximately 50 percent of the lower forereef habitat and is 11m in depth with a well developed and diverse coral community (Rogers and Zullo, 1986).

Ten monthly samples were made (Table 7) on this reef from January 1985 to January 1986. A total of 34 species of commercially important fish were observed on the reef during this period with a mean of 16.5 (sd=1.75) species seen on each sample date. A mean of 298 (sd=110) individual fish were seen on each sample date. Mean average fish size for the entire period was 5.49 (sd=.39) inches. Of the 34 observed species, 12 species were present in eight (75%) or more samples and five species were present in every sample. Eleven species were seen only once during the study period.

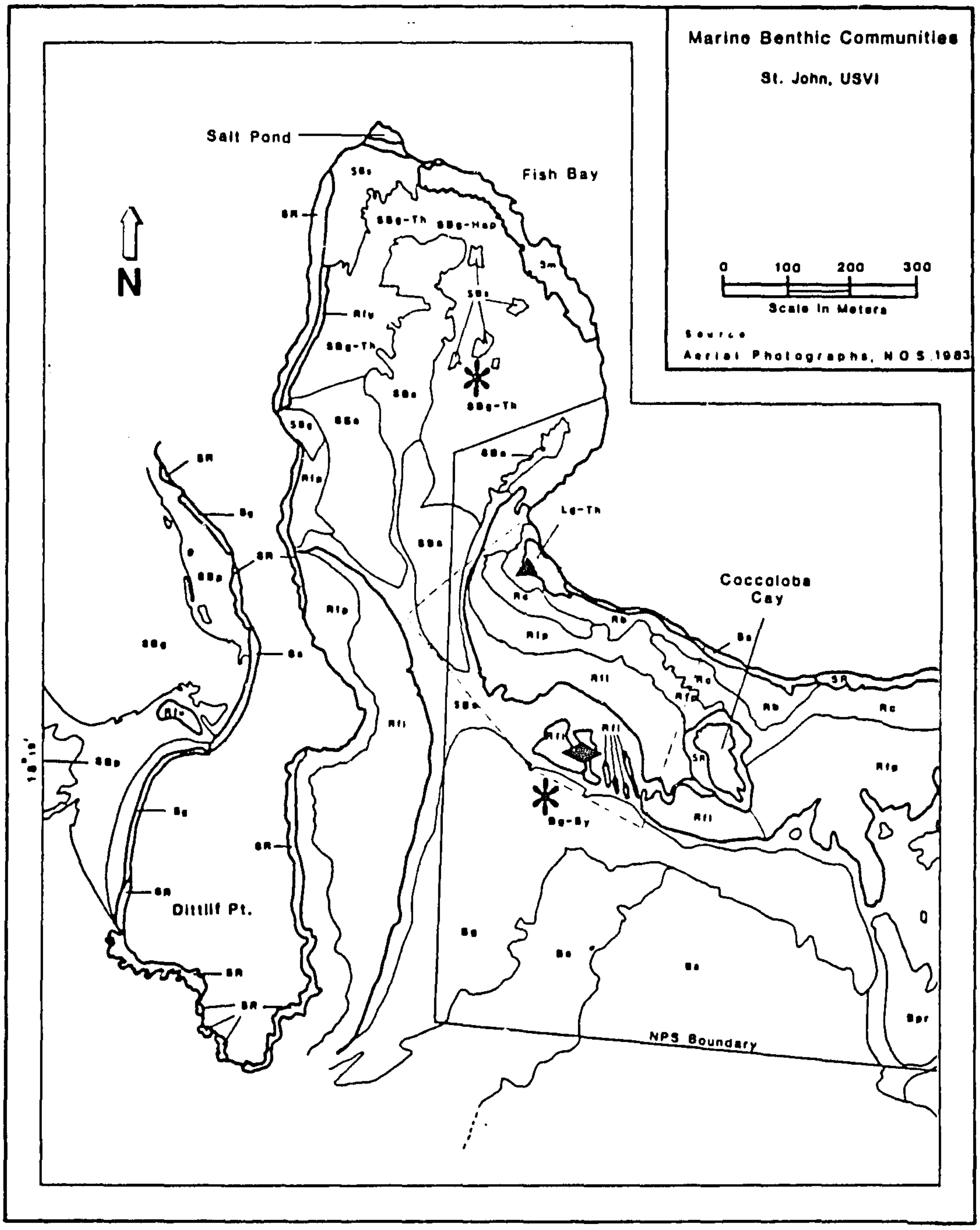

Figure 5. Fish Bay, St. John, USVI, showing location of study sites for long-term monitoring of reef fish, lobster and conch populations. ◀ - fish study areas, ◆ - fish and lobster study areas, ✱ - conch study areas. See Table 3 for acronyms.

TABLE 7. Average number of fish per census per species for Fish Bay lower forereef (Rfl) from January 1985 to January 1986. (Total # fish/# censuses).

Species	1/85	3/85	4/85	6/85	7/85	8/85	9/85	10/85	11/85	1/86
queen triggerfish				.1						
bluestriped grunt		.2		5.1	.3	.4	.4	.1	.5	.3
white grunt		2.0	4.4	1.5	.3	1.7	1.3	.8	.4	1.2
french grunt	1.4	.4	1.1	.7	1.7	1.7	1.5	1.9	2.0	.5
tomtate				5.5						
spanish grunt						.1				
margate	.1									
mutton snapper						.1				.1
schoolmaster	.1	.1	.3		.2	.5	.4	.4	.1	.3
yellowtail snapper	1.7	2.4	.8	1.5	1.2	.8	1.3	.9	1.0	.3
mahogany snapper				1.6	.2	.3	.3			
q & fr. angelfish								.1	.1	.1
rock beauty			.2			.1				
red hind	.1		.1	.1	.1			.1		
graysby			.3	.1	.1	.1				.1
coney		.1	.1	.2		.1	.3	.3	.2	
nassau grouper							.1			
black grouper							.1			
tiger grouper								.1		.2
blue tang	2.5	11.0	4.3	21.6	1.6	4.5	5.0	7.7	4.3	2.4
surgeonfish	3.0	7.5	4.6	8.2	3.3	4.1	6.3	5.6	4.6	5.1
yellow goatfish	1.5			.6	.2	.3	.2		.4	
spotted goatfish	.6	1.4	.2	.9	1.4	1.0	6.6	1.2	1.2	
spanish hogfish	.1	.4	.5	.3		.2	.3	.3	.1	.2
hogfish	.1									
porgies							.1		.2	
parrotfish	4.7	9.4	7.8	9.2	12.3	14.9	6.7	7.5	9.3	6.1
trunkfish					.1		.1		.2	
barracuda	.1									.1
squirrelfish	.3		.7	.5	.5	.3	.5	.4	.6	.3
mojarra					.1					
mackerel								.2		
bar jack	1.0	1.1	.2		.5	1.8	.8	.3	.8	.2
horseeye jack		.1								
total # species	15	13	15	17	17	19	19	17	17	16
total # individuals	173	361	256	577	242	330	324	279	260	175
average size (in)	6.32	4.91	5.91	5.48	5.76	5.36	5.46	5.11	5.31	5.29

The only species showing any evidence of a seasonal trend at this study site were spotted goatfish and possibly parrotfish. As with the Reef Bay site, spotted goatfish show a peak in September with many being relatively small (2-5 inches). Parrotfish do show a peak in July and August although this was not due to an increase in number of juveniles. Many species at this site occur infrequently and sporadically, providing no evidence for seasonality. Total number of species shows a peak in August and September but this is probably due to a coincident occurrence of some of the species normally having a sporadic or infrequent occurrence.

Backreef-Rb

On the east side of Fish Bay is a fringing reef (Figure 5). Periodic storms have created an emergent boulder ramparts composed primarily of old broken plates of Acropora palmata. This emergent reef crest has created a relatively protected, shallow backreef lagoon with colonies of Montastrea annularis, Porites porites and areas of Thalassia testudinum. The submerged portions of the boulder ramparts contain numerous spaces to serve as refuge for fish.

Eleven monthly samples were made (Table 8) in this backreef lagoon from January 1985 to January 1986. Only two censuses were done each month as the primary fish habitat is very limited. A total of 18 species of commercially important fish were observed in this backreef during this period with mean of 11.4 (sd=1.3) species seen on each sample date. A mean of 116 (sd=13.3) individual fish were seen on each sample date. Mean average fish size for the entire period was 4.88 (sd=.24) inches. Of the 18 observed species, eight species were present in eight or more samples (75%) and seven species were present in every sample.

The most notable thing about this site is the large, resident school of schoolmaster snapper. Only two species show any observable indication of a seasonal trend in abundance. French grunt have a definite peak in September/October and squirrelfish appear to be most abundant in July to September. Although the average size for the schoolmaster seen was approximately 6.5 inches, the abundance of very small surgeonfish, tang and parrotfish depressed the mean average size.

General Conclusions

One year of monitoring the fish assemblages in six locations around St. John allowed for statistical analysis of differences in numbers of individuals and species among bays and among dates.

TABLE 8 Average number of fish per census per species for Fish Cay backreef (Rb) from January 1985 to January 1986. (Total # fish/# censuses).

Species	1/85	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	12/85	1/86
blue-striped grunt						1.5	1.0	2.0	2.5	1.5	2.0
french grunt	7.0	4.5	3.5	7.0	2.0	2.5	7.0	21.0	13.0	9.5	11.5
tomtate	2.0	1.5	1.5	1.5	1.5	1.0	2.0	1.5	2.0	4.0	1.0
small-mouth grunt										2.0	
school master	13.0	14.0	19.0	14.5	24.5	13.5	17.5	13.0	12.0	15.5	10.0
yellow-tail snapper	4.0	1.5	2.0	1.0	1.0	2.0	1.0	.5			
mahogany snapper	3.5	1.0		1.0		.5	.5				
blue tang	4.5	4.0	3.0	6.0	2.5	2.5	3.5	3.5	7.0	6.0	2.0
surgeon fish	7.5	10.0	14.5	6.0	11.5	19.0	10.0	13.0	8.0	9.0	12.0
yellow goatfish	5.5	1.5	3.5	1.0						.5	
spotted goatfish						.5	2.0	.5	.5		.5
porgies	.5										
parrotfish	4.0	10.0	13.0	9.5	12.0	8.5	10.5	13.0	6.0	8.0	10.0
trunkfish					.5			.5			.5
barracuda		.5		.5		1.5		.5	.5		
squirrel fish	.5	3.0	1.5	2.5	2.5	5.5	4.0	5.0	2.5	2.0	1.5
mojarra	.5			1.0			1.0	1.5	.5	1.5	.5

Table 8 (Continued)

Average number of fish per census per species for Fish Bay backreef (Rb) from January 1985 to February 1986. (Total # fish/# censuses).

Species	1/85	3/85	4/85	5/85	6/85	7/85	8/85	9/85	10/85	12/85	1/86
bar jack		.5				1.5					
total # species	12	12	9	12	9	13	12	13	11	11	11
total # individuals	105	104	123	103	116	120	118	151	109	119	103
average size (in)	5.31	4.76	4.69	4.96	4.73	5.35	4.95	4.63	4.91	4.72	4.66

Significant differences were demonstrated in number of individuals and species per census among study sites (Table 9). Reef Bay, with a total of 34 species observed, has the highest number of individuals (KRUSKAL-WALLIS, $H=82.42$, $DF=2$, $P<.001$) and species (KRUSKAL-WALLIS, $H=48.92$, $DF=2$, $P<.001$) for the three deeper water sites (Hawksnest SBpr, Reef Rf1, Fish Rf1). This is probably related to the high relief of the site providing more abundant shelter. In comparison, Fish Bay yielded the same number of species but demonstrated a very low mean number of individuals observed per sample date. This is probably due to the low vertical relief of the site.

Significant differences existed in number of individuals and species per census among sample dates for the three deep sites combined. Numbers of individuals differed significantly among dates (KRUSKAL-WALLIS, $H=24.37$, $DF=11$, $P<.05$) with larger means occurring from June to September. Number of species also differed significantly among dates (ANOVA, $F=2.45$, $DF=11$, $P<.01$) with no clear temporal pattern.

Total number of species differed between shallow and deep habitats with upper forereef and backreef areas having the lowest number of species and the lower forereef and shallow bay patch reef having the greatest (Table 9). This is consistent with the results obtained from a fishery habitat mapping study (Boulon, 1985a). The shallow bay patch reef had the greatest number of species and this is probably related to the nature of patch reefs to concentrate species from surrounding less productive or low relief areas which do not provide adequate shelter.

The only species demonstrating any evidence of a seasonal variation in numbers are yellow and spotted goatfish. The inshore upper forereef had a dramatic increase in schools of small yellow goatfish in September and October. The two lower forereef sites on the south shore had peaks in numbers of spotted goatfish in September. It appears that juvenile yellow goatfish aggregate in shallow water while juvenile spotted goatfish tend to stay in deeper water. No obvious variations are evident for other species. Small fluctuations which appeared to be differences were treated with caution for such fluctuations could be a product of observer biases (see Summary Conclusion).

With the observed differences among bays and dates during the period of this study, the data provides a base to measure long-term changes in the fish assemblages at these sites. Future samples of replicated censuses conducted during a defined period should provide information on stability or decline of the fish assemblages. At present there are no comparable studies for other areas in the United States Virgin Islands which would enable statements to be made regarding state of these populations (i.e. are we looking at primarily juvenile, heavily overfished populations, etc.?) Commercial biostatistical sampling data for the U.S.V.I. has never been

TABLE 9. Sample statistics for each of the long-term reef fish monitoring sites on St. John, USVI.

	Hawksnest Bay			Reef Bay	Fish Bay	
Statistic	SBpr	Southern Rfu	Eastern Rfu	Rfl	Rfl	Rb
Total No. Species	36	22	19	34	34	18
$\bar{X}$ Species/sample (sd)	21.4 (2.19)	11.5 (2.27)	11.6 (1.07)	21.0 (2.40)	16.5 (1.75)	11.4 (1.30
$\bar{X}$ Fish/sample (sd)	428 (127)	388 (89)	363 (140)	657 (185)	298 (110)	116 (13)

analyzed for size by species so comparisons cannot be made as to what is being taken out of the resource.

Lobster - Panulirus argus and P. guttatus

Methodology

The same three watersheds were selected for long-term lobster population monitoring for the same reasons as with reef fish. The method used for monitoring the populations was simply to delineate an area to be studied and then thoroughly canvass it on a monthly basis. All ledges, crevices, and holes were carefully examined and all spiny (Panulirus argus) and spotted (P. guttatus) lobsters were counted. For each lobster an estimate was made as to carapace size (measured from the ridge between the horns to the posterior edge of carapace). A flashlight was used to examine the tops and backs of the deeper caves. Spiny lobsters are usually easily seen because they generally are found on the floor of the caves. Spotted lobsters are more difficult to find because they seem to prefer the tops of the caves. Due also to their smaller size, it is very likely that their abundance is underestimated. Capture of the lobsters for determination of sex and reproductive state was not performed due to the potential for injury or trauma to the lobster.

Underwater maps were drawn of the study areas (Appendix Ia and Ib) and locations of lobster were marked on mylar overlays. By comparing monthly surveys as to size and location, some idea of residency can be determined.

Reef Bay

The lobster monitoring site at Reef Bay was located within the reef fish monitoring site (Figure 4). The study area was located on the seaward side of the fringing reef and includes the 50m coral monitoring site (Rogers and Zullo, 1986) (Appendix Ia) plus an additional 100m section of reef contiguous to and west of the 50m coral monitoring site. The study area is approximately 15m wide from the bottom of the reef at 11m to approximately 3m in depth. The total area monitored was approximately 2250m .

This site is exposed to the predominant wind and waves from the south and southeast and is frequently rough. Nine monthly samples were made at this site from April 1985 to February 1986 (Table 10). Numbers of spiny lobster found during this period ranged from zero to four per sample with all being less than 3.5 inches in carapace length and all being found in the 100m extended portion of the study area. No spiny lobster (Panulirus argus) were found on four of the sample dates. Numbers of spotted lobster (P. guttatus) found during this period ranged from zero to 10 per sampling date. Seventy-four percent (74%) of

TABLE 10. Numbers of spiny and spotted lobster by two size classes per sample date for two long-term monitoring sites, St. John, USVI. Dashes indicate no data available.

						1985					1986	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Reef Bay	Spiny (>3.5")	0	0	0	0	0	0	0	-	0	-	0
	(<3.5")	0	0	0	2	1	4	2	-	1	-	0
	Spotted (>2")	0	0	1	0	2	2	7	-	6	-	5
	(<2")	0	1	0	1	0	0	0	-	4	-	2
Sea conditions: +		2	2	1	1	1	1	1	3	1	3	1
Visibility:		15'	15'	20'	30'	30'	30'	20'	-	30'	-	30'
Fish Bay	Spiny (>3.5")	0	0	0	3	5	2	1	-	1	2	3
	(<3.5")	2*	0	1	5	2	6	0	-	1	10	1
	Spotted (>2")	0	0	0	1	2	3	2	-	2	5	4
	(<2")	0	0	0	0	1	1	2	-	1	3	0
Sea Conditions: +		2	2	2	1	1	1	2	3	2	1	1
Visibility:		15'	20'	20	60	30'	40'	20'	-	20	30'	20'

\+ 1 - calm (waves <2')
2 - rough (waves 2'-4')
3 - very rough (waves >4')

* Both were molts

the spotted lobsters found had carapace sizes greater than or equal to two inches, a size chosen by the author as a possible size representing maturity as the size range observed was 1.5 to 3 inches. Only one sample contained no spotted lobsters.

During the study period, there appears to be some indication of seasonality of abundance for both species (Figure 6). Spiny lobsters were not seen for the first three months of the study. Their numbers increased to a peak in September and then decreased to zero again in February 1986. Spotted lobster showed a gradual increase in numbers from zero at the beginning of the study to a peak in December and then an apparent decrease after that. Caution should be exercised in interpretation of the observed trends due to the small sample size and the monthly gaps in the data set at the end of the study.

Fish Bay

The lobster monitoring site at Fish Bay was located within the reef fish monitoring site (Figure 5). The study area is located in the lower forereef spur system where many undercuts and coral overhangs occur along the interfaces between the spurs and the sand separating them. Due to the topography of this reef system (see Appendix Ib), the boundaries do not form a simple geometric shape resulting in difficult areal computation. A rough estimate of area within the boundaries is approximately 1600m .

Ten monthly samples were made at this site from April 1985 to February 1986 (Table 10). Numbers of spiny lobster found during this period ranged from zero to twelve per sample date with 40% being 3.5 inches or larger in carapace length. No live spiny lobsters were found on two occasions although two molts were found on one of these occasions. Numbers of spotted lobster found during this period ranged from zero to eight with 70% having carapace sizes greater than or equal to two inches. Three samples contained no spotted lobsters.

During the study period, there appears to be some indication of seasonality of abundance for both species of lobsters (Figure 6). For spiny lobsters there appear to be two peaks in abundance, one in the summer as was seen at Reef Bay, and another one in the winter, which was not observed at Reef Bay. Spotted lobsters show a seasonal trend very similar to that observed at Reef Bay. None were observed at the start of the study and numbers then increased to a peak in January and dropped off rapidly after that.

Hawknest Bay

The shallow bay patch reef in Hawksnest Bay was selected as a long-term monitoring site for lobster due to its location in the bay and the presence of suitable lobster habitat. The reef was surveyed monthly along its forereef side only as the rest of

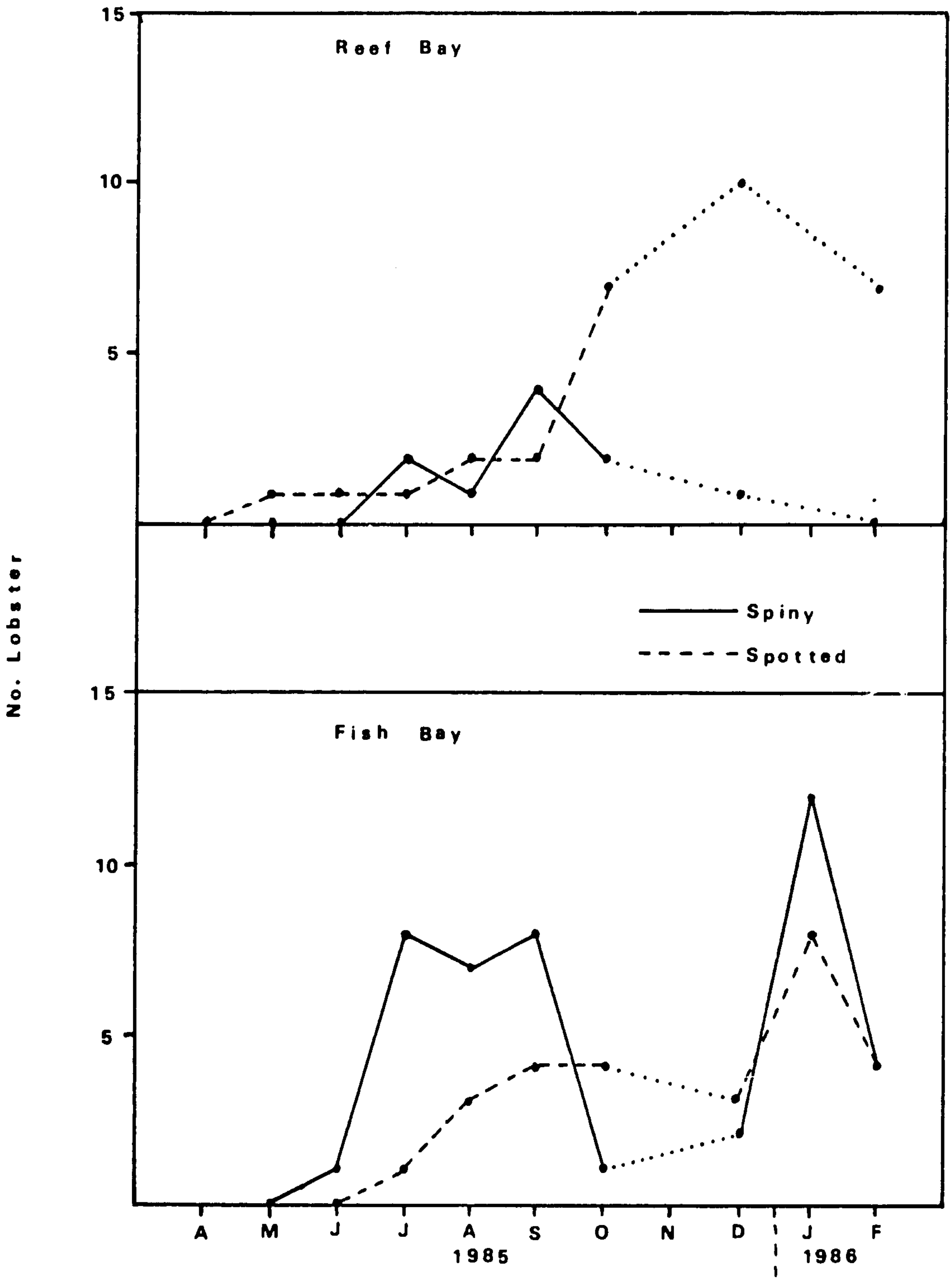

Figure 6. Numbers of spiny and spotted lobster per sample date for two long-term monitoring sites, St. John, USVI. Dotted lines indicate months where no sample was obtained.

the reef provides no significant habitat for lobsters. In all cases these surveys were conducted on the same date as fish censuses.

Eleven visits were made to this reef during the study period. Only one spiny lobster (carapace length approximately five inches) was observed on the reef (August '85). No spotted lobster was ever observed on the reef.

General Surveys

During the months of July and August 1985, nine additional sites around St. John were surveyed for lobster abundance (Figure 7). Sites were surveyed either using a measuring tape or by swimming an area and estimating the size. Minimum estimated area is indicated by a plus sign in Table 11 (e.g. 1000m +).

Spotted lobsters were very common in all general surveys carried out in Reef Bay. Many areas containing good lobster habitat (Ram Head, western Hawksnest Bay and Western Haulover Bay) were surprisingly depauperate of lobsters. No juvenile lobsters were observed in the mangroves in Hurricane Hole. Three of the spiny lobsters observed in Mary's Creek were beneath undercut portions of shallow Thalassia grass beds in the bay. All three were from 1.5 to 2 inches in total body length. Observations based on general surveys east and west of the long-term study site in Fish Bay demonstrated that the selected monitoring site was the optimum (or at least preferred) lobster habitat.

General Conclusions

Although there is some evidence of seasonal variations in abundance for both spiny and spotted lobster at Fish Bay and Reef Bay, another factor became evident during the study, which may influence the observed differences. Abundance of observed lobsters appears to be affected by sea conditions. Table 10 shows sea condition and visibility for each survey date. The presence of a swell or surge of sufficient magnitude to cause sediment suspension and movement causes visibility to decrease. The lower number of lobsters observed under these conditions may be due to lobsters becoming more difficult to observe or lobsters moving deep into caves or into deeper, more protected water. A combination of the first two possibilities seems more likely as movement into deeper water would not be a rapid process, would be very energy intensive, and could be necessary frequently depending on the frequency of swells.

Although no fishermen were observed at either of these sites during the study period, it is known that recreational fishermen (including sport divers) and some St. Thomas commercial fishermen do dive here and take lobster. Many people have mentioned that these areas are good lobstering spots which would indicate general knowledge. Interpretation of any results from these areas must therefore acknowledge the potential for harvest.

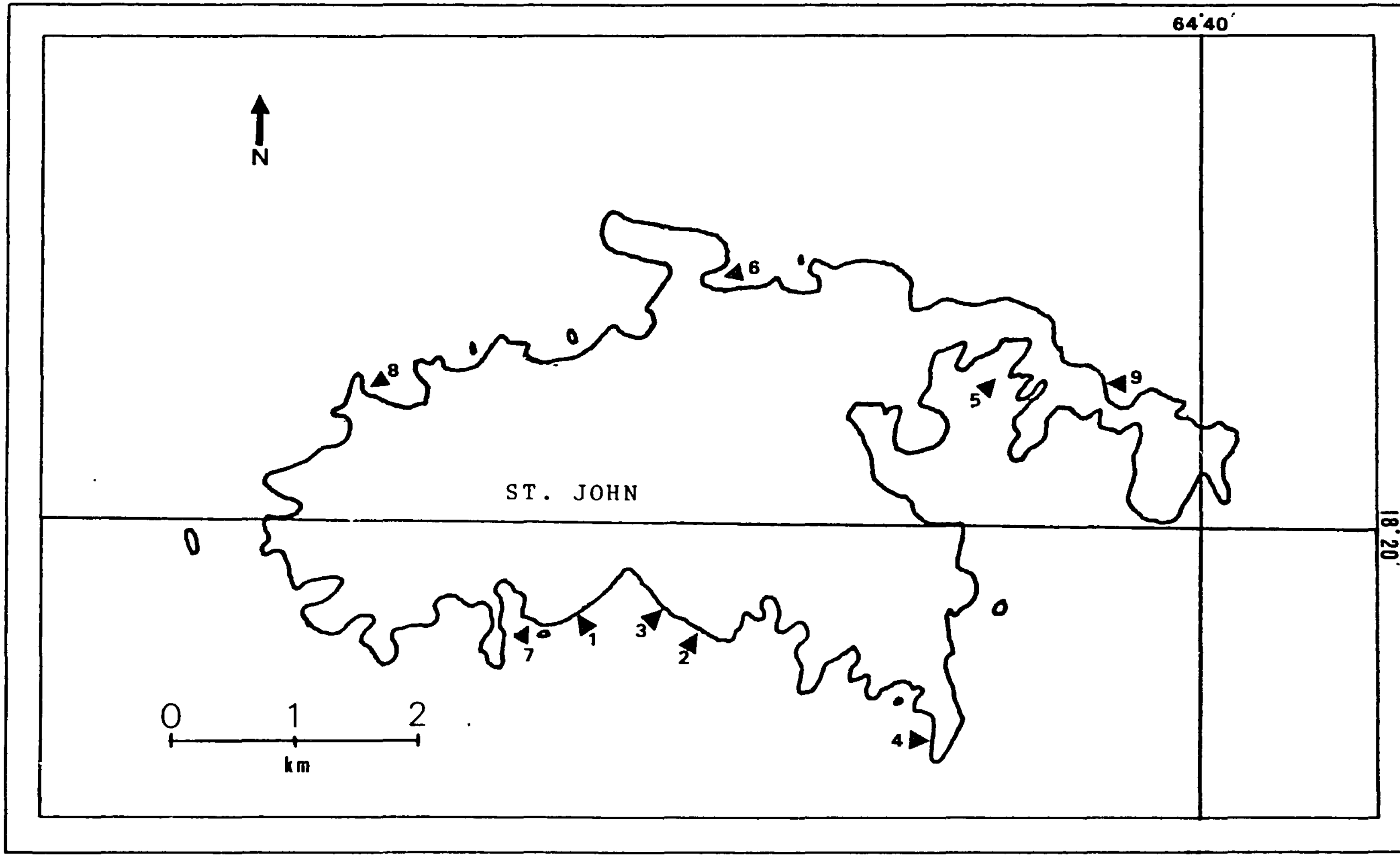

Figure 7. Location of general lobster surveys , St. John, USVI.
Refer to Table 11 for location names.

TABLE 11. Results of general lobster survey around St. John, USVI, during the summer of 1985. Refer to Figure 7 for locations.

Location	Date	Approximate area surveyed	Numbers by Carapace Size Spiny <3.5"	Spiny >3.5"	Spotted <2"	Spotted >2"
1. Western Reef Bay	7/1/85	300m^2	1	0	1	8
2. Eastern Reef Bay (White Cliffs)	7/1/85	1900m^2	0	1	0	3
3. Eastern Reef Bay (west of White Cliffs)	7/1/85	1900m^2	0	0	1	4
4. West Ram Head	7/12/85	500m^2	0	0	0	0
5. Hurricane Hole (Mangroves)	7/17/85	500m^2	0	0	0	0
6. Mary's Creek (mangroves/grass beds)	7/25/85	500m^2	4	0	0	0
7. Fish Bay (west & east of study area)	7/31/85	500m^2	0	1	2	0
8. Hawksnest Bay (western shore)	7/27/85	1000m^2	2	0	0	0
9. Haulover Bay	8/6/85	1000m^2	1	0	0	1

The three sites surveyed appear to have different potentials for lobster presence and abundance. The Hawksnest Bay site has the least potential due to limited habitat coupled with its location in a deep embayment (reduced circulation lowers recruitment and food supply). Although the largest lobster of the entire study was seen here, large lobsters may be very mobile and are probably transient.

Fish Bay appears to have the best lobster habitat of the three long-term monitoring sites. It has good water circulation, and many good refuges for lobster. This site had significantly more spiny lobster greater than 3.5 inches in carapace length than Reef Bay (Mann-Whitney U=76.5, P=.05). No significant differences were observed in total numbers of spiny lobster or spotted lobster among Fish and Reef Bays.

Spotted lobster may be more abundant than observed in this study. They are difficult to observe because they are usually on the roofs of caves and their smaller size allows them to be cryptically hidden in the smaller caves and crevices in a reef system. They are more cryptic than spiny lobsters. Fisherman generally do not take them since they are small and there is no market for them. These factors, combined with their total protection in park waters, probably makes them more abundant than spiny lobsters.

None of the spiny lobsters observed were long-term residents of one particular hole. In Fish Bay, where actual locations of lobster sightings were recorded, no single spiny lobster was observed for more than two months in the same hole. No single hole had spiny lobsters present in it for more than a three-month period. Spotted lobster appear to be more resident. Residency could only be documented with a tagging study.

Conch - *Strombus gigas*

Methodology

Five sites were originally selected for long-term monitoring of queen conch(*Strombus gigas*) populations. These include Reef Bay, Outer Fish Bay, Inner Fish Bay, Hawksnest Bay and the small bay east of Leinster Bay which will be referred to from now on as Threadneedle Bay (it is bounded by Leinster Point to the west and Threadneedle Point to the east) (Figure 1).

Visual swimming strip transects were used to estimate conch densities and determine abundance and adult to juvenile ratios. A one-hundred meter long, fiberglass tape measure, weighted at both ends, was laid out on the bottom. A diver then swam the transect line, counting all conch within 2m of each side of the line. Conch were recorded as adult or juvenile, based on the

presence or absence, respectively, of a flared lip.
Number of strip transects varied between sites, depending on size and nature of the site, but the same number of transects were made on each sample date at each site. SCUBA was used at deeper sites (>3m) or where visibility is such that repeated free diving would cause inaccuracies in the counting of conch.

Reef Bay

Seaward of the fringing reef along the west side of Reef Bay is a rather extensive seagrass bed (Figure 4). The grassbed is composed of sparse to moderate density *Syringodium filiforme* and appears to be good habitat for conch. However, this area was spot-checked a number of times during the entire study period and not a single queen conch (*Strombus gigas*) was observed. As queen conch tend to aggregate near the sand-grass interface, this was checked nearly every time fish surveys were completed at this study site. On several occasions forays were made up to 20m into the grassbed to determine if conch were present in the interior parts of the grassbed.

Hawksnest Bay

Hawksnest Bay has been reported to have large areas of dense seagrasses within the bay (Kumpf and Randall, 1971; E. Gibney, pers. comm.). Although these areas are still reported to exist, the density of seagrasses within these areas is reported to be low to moderate (Beets, et al., 1985) and very much reduced, presumably due to heavy anchoring in the area (E. Gibney, pers. comm.).

In both April and August of 1985 large portions of the bay were surveyed by swimming and towing. No conch except for a few West Indian fighting conch (*Strombus pugilis*) were observed. The grassbed to the east of the shallow bay patch reef was spot-checked several times during the entire study period in conjunction with fish surveys at this site. No queen conch were ever seen at this site.

Fish Bay

Inner Fish Bay

The inner part of Fish Bay is a shallow seagrass bed of moderate to dense *Thalassia testudinum* (Figure 5). This bay is reported to have had large populations of juvenile conch (no flared lip). Unfortunately, harvesting of these juvenile conch has severely diminished the numbers. Piles of empty juvenile shells in places along the shoreline yield evidence of the harvesting.

In the middle of the bay is a large mooring buoy that has been unused for at least two years. This mooring was used as the apex for two 100m long by four meter wide strip transects. These two transects yielded 800m^2 of area surveyed per sample date. Eleven monthly samples were made from March 1985 to February 1986 (Table 12). While numbers of both adult and juvenile conch were very low, there does appear to be a trend during the study period (Figure 8, top). Both adults and juveniles peaked in abundance in late Spring and then declined through the rest of the study period. Juveniles were more abundant than adults throughout the study period.

Outer Fish Bay

Seaward of the lower forereef described in previous sections there is a seagrass bed (11m deep) that is composed of moderate to dense Syringodium (Figure 5). This seagrass bed parallels the shoreline in this area and is at least 100m wide. Seaward, this grass bed grades into an algal plain. To the east, the grass bed extends around Cocoloba Cay and into Reef Bay. The grass bed to the east of Cocoloba Cay was surveyed in September 1985 and found to have a lower density of conch than the study area selected just seaward of the lower forereef in Fish Bay.

Four parallel 100m by four meter strip transects were traversed approximately 10m apart from each other on each sample date. The four transects were made in the same general location on each sample date. These yielded 1600m of area surveyed per sample date. Ten monthly samples were made from February 1985 to January 1986 (Table 12). Rough seas and poor visibility prevented missing samples from being taken. Throughout the study period, numbers of juvenile conch remained very low. Numbers of adult conch exhibited a very distinct seasonal variation with a peak in the winter and a low during the summer (Figure 8, middle). Summer is the reproductive season with numbers of conch observed copulating only in July and laying egg masses in August.

In general, conch in this grass bed were associated with the grass/sand "blowouts" in the grass bed. Conch were not extremely common in the interior dense seagrass areas, except for the last sample which also had the greatest number of conch observed during the study period. Numbers of adult milk conch (Strombus costatus) were observed in interior parts of the grass bed where a greater abundance of macroalgae occurs.

Threadneedle Bay

To the east of Leinster Bay on the north shore of St. John, there is a small shallow bay located between Leinster Point and Threadneedle Point (Figure 9). The seagrass bed parallels the shoreline and is bounded inshore by a fringing reef and offshore by sand grading into a deep water algal plain and rubble bottom. The seagrass bed is composed of moderate to dense Thalassia and is approximately 300m long and 30m wide. Two 100m strip transects were made at this site on each sample date. The transects were started at the approximate center of the grass bed

TABLE 12. Numbers of adult and Juvenile conch per sampling date for three long-term monitoring sites, St. John, USVI. Dashes indicate that no sample was taken.

Months	Inner Fish Bay (800m^2)			Outer Fish Bay (1600m^2)			Threadneedle Bay (800m^2)		
	*N/A	+N/J	D	N/A	N/J	D	N/A	N/J	D
Feb. (1985)	-	-	-	208	2	.13	0	1	.001
Mar.	0	0	.0	198	0	.12	0	0	0
Apr.	6	4	.01	127	3	.08	1	10	.01
May	-	-	-	-	-	-	8	26	.04
June	2	13	.02	102	5	.07	2	27	.04
July	3	5	.01	71	6	.05	4	11	.02
Aug.	1	3	.004	88	7	.06	0	10	.01
Sept.	0	3	.005	120	4	.08	0	3	.004
Oct.	0	5	.006	147	7	.10	1	21	.03
Nov.	0	2	.003	131	7	.09	1	22	.03
Dec.	0	2	.003	-	-	-	1	0	.001
Jan.	1	3	.005	282	1	.18	-	-	-
Feb.(1986)	0	2	.003	-	-	-	136	401+	.67
$\bar{X}$	1.18	3.82		147.4	4.2		12.8	14.3	
sd	1.88	3.37		64.3	2.62		38.86	12.9	

*N/A = Number of Adults
+N/J = Number of Juveniles
D = Density (Conch/m2)

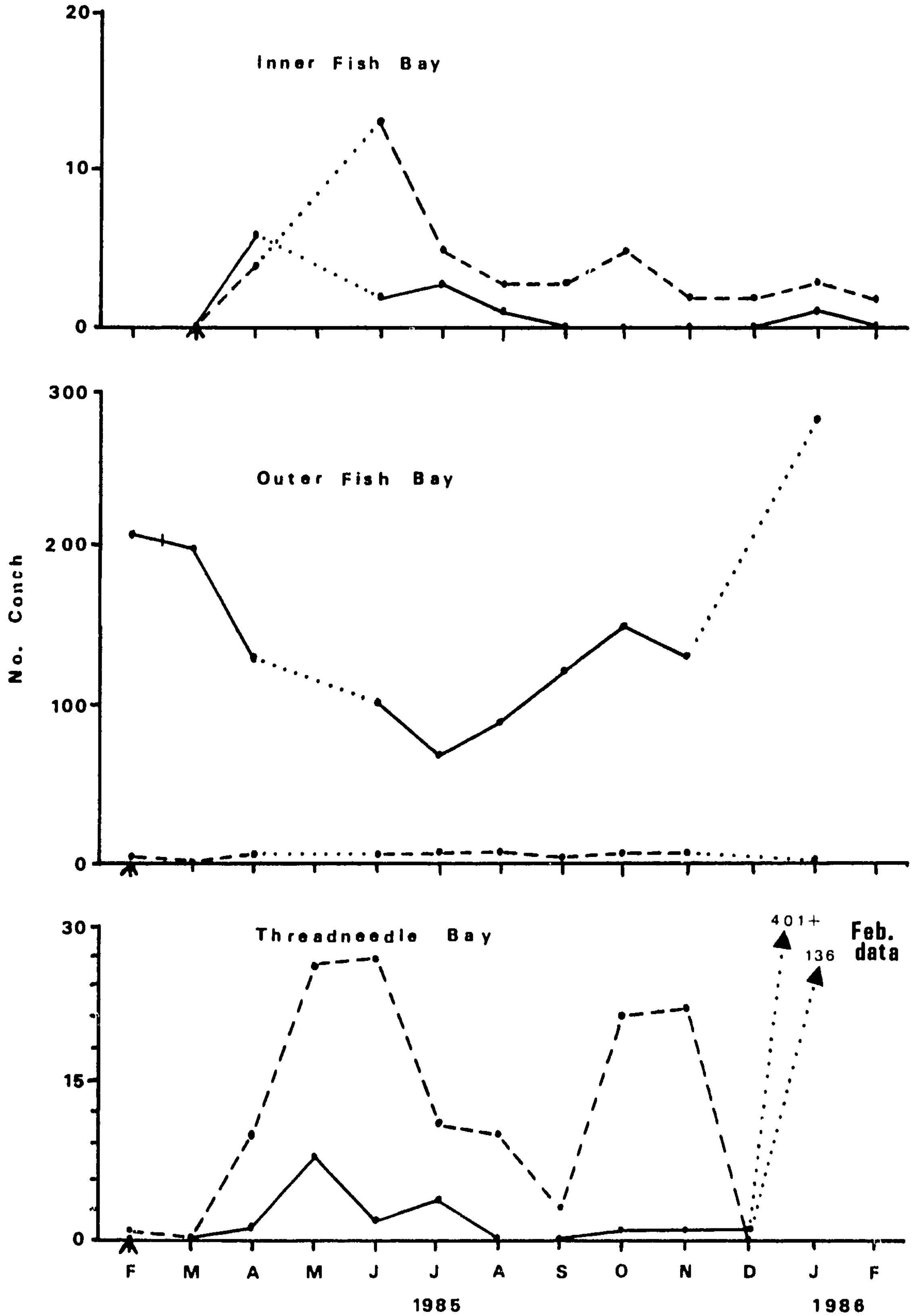

Figure 8. Numbers of adult and juvenile conch for three long-term monitoring sites on St. John, USVI. Arrow indicates date of first sample. Solid lines represent adults, dashed lines represent juveniles and dotted lines indicate months where no sample was obtained.

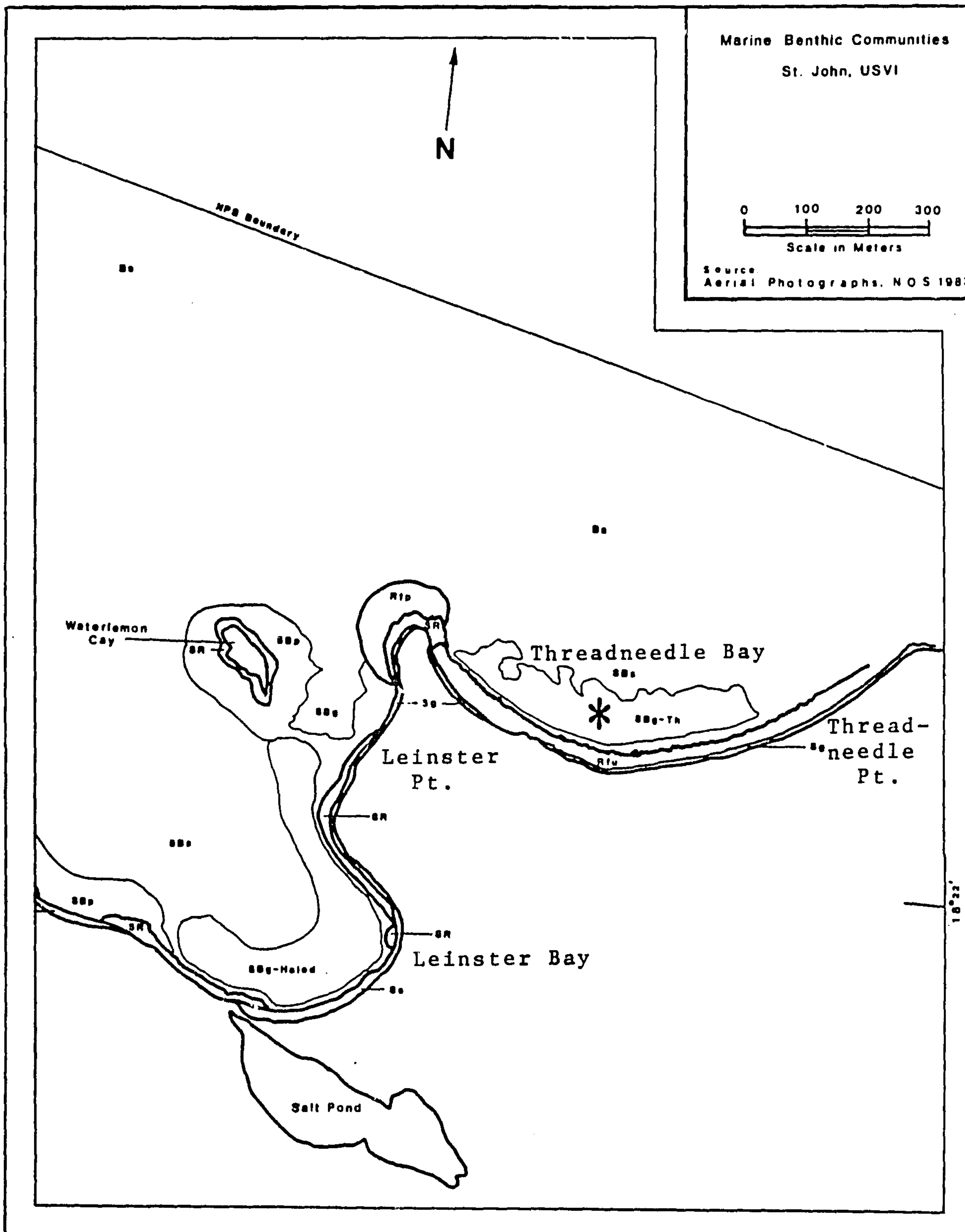

Figure 9. Threadneedle Bay, St. John, USVI, showing location of study site for long-term monitoring of conch population. * denotes study area. See Table 3 for acronyms.

and run 100m in each direction (east and west) approximately 10m in from the shoreward edge of the grass bed to yield 800m^2 to area surveyed per sample.

Twelve monthly samples were obtained at this site during the period from February 1985 to February 1986 (Table 12). Few conch were actually observed in this bay during all but the last month of the study. The majority of conch counted were juveniles. During the first eleven samples, numbers fluctuated considerably yielding no visible seasonal trends (Figure 8, bottom). There are two peaks which coincide roughly with the two peaks observed at the Inner Fish Bay site. Abundance of adult conch showed a similar pattern as well to the adult conch observed at the Inner Fish Bay site. On the last sample of the study period, however, the populations of both adult and juvenile conch increased tenfold. One hundred and thirty six adults were observed, of which over 90 percent were old, heavily eroded, thick-lipped "bullet" conch. The juveniles were mostly in the seven to twelve centimeter range and covered the bottom in large, dense patches.

General Surveys

General surveys for distribution of conch populations around St. John were conducted in two ways. The first was a repeat of a series of conch tows that were made in 1981 (Wood and Olsen, 1983). The second was a series of spot surveys in sites where conch habitat was known to exist or conch were known to have been found in the past.

Nine conch tows were made attempting to duplicate as closely as possible, through bearings and distances, the exact locations and lengths of tows made by Wood and Olsen (1983) (Figure 10). Tows were made using a diving sled (pictured in Kumpf and Randall, 1971) towed by a boat. The sled was manipulated by the diver in such a way that it was maintained close enough to the bottom so that all conch could be counted within a swath approximately four meters wide.

Numbers of conch observed in 1985 were not significantly different from numbers observed in 1981 (Mann-Whitney U Test, $U_{.05}=60.0$) (Table 13). In 1981 four of the nine tows had more conch than in 1985. All of these were within National Park boundaries. In 1985, two tows had more conch than in 1981. Both of these were outside National Park boundaries.

Fourteen sites were spot-checked for conch (Figure 10, Table 14). This consisted of selecting a site and having divers swim over it noting bottom type and numbers of conch observed. Approximate area of surveys was estimated. Few to no juveniles were observed at sites which can be considered good juvenile habitat (shallow, protected, with ample food resources) (sites 1, 2, 5, 6, 7, 10, 11, 12 and 13). Very few adults were observed at sites which can be considered adequate or good adult habitat (sites 2, 3, 4, 8, 9, 12 and 14). Many harvested conch were observed at several sites.

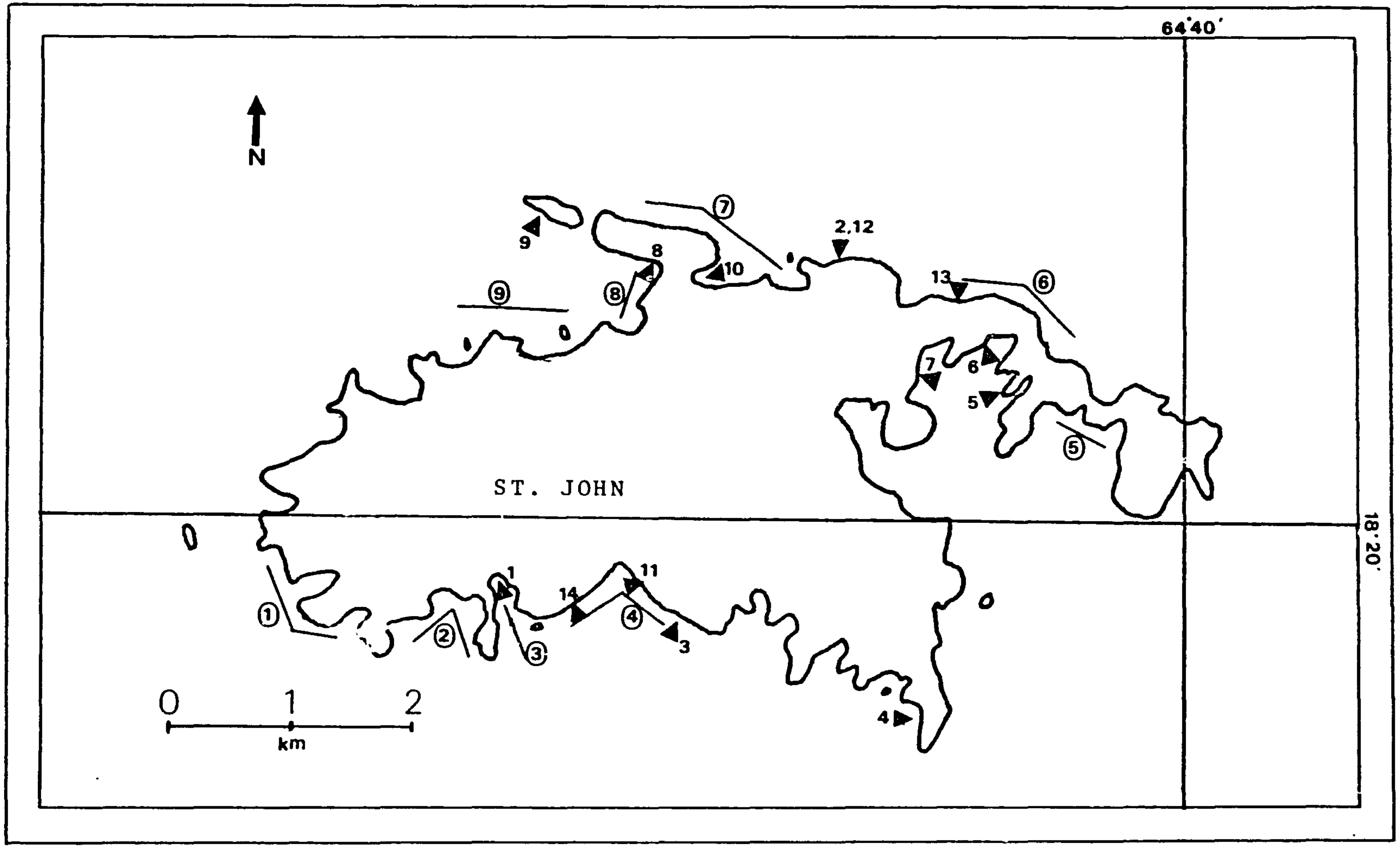

Figure 10. Location of conch tows and general surveys (◀), St. John, USVI. Refer to Tables 15 and 16 for location names. Circled numbers represent conch tows.

TABLE 13. Results of conch tows duplicating those made in 1981 by Wood and Olsen (1983). Refer to Figure 10 for locations. Numbers in parentheses are densities in conch per square meter.

Location	Date	Approximate Area Surveyed(m^2)	No.Conch	No.Conch in 1981
1. Turner Bay to Chocolate Hole	8/20/85	9000	34(.003)	25(.003)
2. Rendezvous Bay	8/20/85	7500	68(.009)	32(.004)
3. Fish Bay	8/20/85	3000	8(.003)	26(.009)
4. Reef Bay	8/21/85	12500	34(.003)	45(.004)
5. Round Bay	8/21/85	2500	-0-(0)	-0-(0)
6. West of Haulover Bay	8/7/85	9600	61(.006)	167(.017)
7. Leinster Bay/ Mary's Point	8/7/85	16500	59(.004)	128(.008)
8. Francis Bay	8/7/85	2100	-0-(0)	-0-(0)
9. Cinnamon Bay to Trunk Bay	8/7/85	9200	-0-(0)	-0-(0)

TABLE 14. Results of general conch surveys around St. John, USVI, during the summer of 1985. Refer to figure 10 for locations.

Location	Date	Approx. Area Surveyed	Numbers Observed	Bottom Type*
1. Inner Fish Bay	7/2/85	Inside long-term transect to shore	None	Dense Th
2. Bay E. of Leinster	7/2/85	Seaward of long-term study area	3 adults	Moderate Th
3. Eastern Reef Bay	7/12/85	3000m	1 adult	Moderate Th/Sy
4. West Ram Head	7/12/85	1000m	6 old adults	Sparse Sy
5. Otter Creek/ Water Creek	7/17/85	1000m +	None	Algae on sand
6. Borck Creek/ Popilleau Bay	7/17/85	1000m +	None	Moderate Th/Sy
7. Princess Bay	7/17/85	1000m +	61 harvested shells	Moderate Th
8. Francis Bay (Northside)	7/25/85	1000m +	None	Sparse Sy/Hal
9. Whistling Cay	7/25/85	500m +	None	Sparse Sy
10. Mary's Creek	7/25/85	1000m +	2 juveniles	Th and coral rubble
11. Reef Bay (Lg)	7/24/85	500m +	1 juvenile	Dense Th
12. Bay E. of Leinster	8/6/85	500m + (E. of L-T study area)	15 adults 5 juveniles	Moderate Th/Sy
13. Bay E. of Brown Bay	8/7/85	1000m +	3 juveniles 50 harvested shells	Moderate Th/Sy

Table 14. (Continued)

Results of general conch surveys around St. John, USVI during the summer of 1985. Refer to Figure 10 for locations.

Location	Date	Approx. Area Surveyed	Numbers Observed	Bottom Type*
14. Western Reef Bay	9/3/85	$500m^{2+}$	Low density	Moderate Sy

* Th - _Thalassia testudinum_
Sy - _Syringodium filiforme_
Hal - _Halodule wright_

General Conclusions

The five long-term monitoring sites provide information on variation in conch abundances among locations around St. John. Hawksnest Bay, reported by residents to once have had an unquantified abundance of conch, now appears to have none. This may be due to past heavy harvesting coupled with past and present habitat degradation, primarly due to heavy anchoring impacts on the seagrass beds. Reef Bay presents a perplexing situation in that the grassbed surveyed appears to be adequate habitat for queen conch and yet no conch were ever observed there.

Inner Fish Bay has adequate habitat for juvenile conch as evidenced by past observations (Boulon, 1985b). Present low numbers may be due to movement of the conch, harvest of the juveniles or inadequate recruitment. Piles of harvested juvenile shells on shore attest to the fact that harvest may occur there. Outer Fish Bay has the greatest abundance of conch observed anywhere in National Park waters. This area should probably be entirely closed to harvest of conch to protect it. A significant difference was observed among months for numbers of conch at this site (KRUSKAL-WALLIS, H=20473, DF=9, $P<.05$) with June to August having the lowest number of conch. The seasonal trend observed here in 1985 is very similar to the trend observed in the four samples taken between March and June 1984 (Boulon, 1985b). A comparison of the two sets of samples for that period shows a decline in numbers to lowest abundance in July 1985.

Observations on mating and egg laying during July and August suggests that a peak reproductive season exists. That this coincides with the low peak in numbers of inshore conch suggests that they may be migrating offshore into deeper water to mate and lay their eggs. This movement pattern would bring them into contact with other individuals in the population, provide greater protection from storm-induced sediment movement for the egg masses and/or enhance larval dispersal by ocean currents. This movement pattern is similar to that described by Hesse (1979) for the Bahamas but may occur somewhat earlier in the year. She described the offshore migration in September and October. Coulston, et. al. (1985) describe an offshore movement of conch during the period from November to March at Salt River, St. Croix, U.S.V.I. This observation differs from ours and demonstrates the variation that apparently exists among sites. Coulston, et. al. (1985) reports a reproductive period from March to November in shallow water (50 to 70 feet).

Threadneedle Bay does not appear to have a stable population of conch. The 1984 data showed evidence of rapid population changes going from 80% (165) adult and 20% (44) juvenile in one sample to 99% (253) juvenile and 1% (2) adult six weeks later (Boulon, 1985b). This year's data suggested that a low abundance of primarily juveniles inhabited the bay.

However, the last sample increased these numbers by tenfold. The older "bullet" conch observed in this sample may have moved inshore from deeper water (15-20m) populations known to exist immediately offshore of this site. The juveniles may be the year class from the 1984 reproductive season just becoming evident in the inshore habitat. Several investigators have estimated mean lengths for yearling conch to be from 7.6 to 10.8cm (Brownell, 1977; Berg, 1976). Prior to inshore movement and after settlement, these conch may have been dwelling offshore in the nearby deeper algal plain habitat, which may be advantageous in terms of growth and mortality (Appeldoorn and Ballantine, 1982). While a significant difference was observed among months at this site (KRUSKAL-WALLIS, H=18.709, DF=10, P<.05) no trends were evident.

Disregarding the final sample at Threadneedle Bay, the population fluctuations observed in this bay and in inner Fish Bay are somewhat similar. These patterns may reflect the background levels of conch and their fluctuations in shallow, inshore waters.

The results of the conch tows suggests that there has been no net difference in numbers of conch since 1981 in the deepwater areas. However, the comparison needs to be treated with caution due to possible differences in relocation of transects, observers, small sample size and differential harvest inshore and offshore.

In general it appears that the abundance of deeper water conch may be presently stable. This is probably due to lower fishing pressure in these less accessible areas. These individuals may be responsible for maintaining the inshore abundances. Shallow water individuals appear to be in trouble as evidenced by the quantity of available habitat and the paucity of conch inhabiting it. The continued harvest of subadult conch will lead to the gradual decline and eventual near extirpation of local populations.

Whelk - *Cittarium pica*

Methodology

The site selected for long-term monitoring of a whelk population within the Virgin Islands Biosphere Reserve is located along the north coast of St. John between Windswept Beach and Peter Bay (Figure 11). This section of coastline is bordered on its landward side by private property. The site was selected due to accessibility and known low levels of fishing pressure.

The site is composed of good whelk habitat varying from solid bedrock sheets extending down into the water to scattered boulders with occasional tide pools. Seaward of this site is a narrow fringing reef. Benthic filamentous algae appeared to be plentiful as a food resource for the whelks. The study area

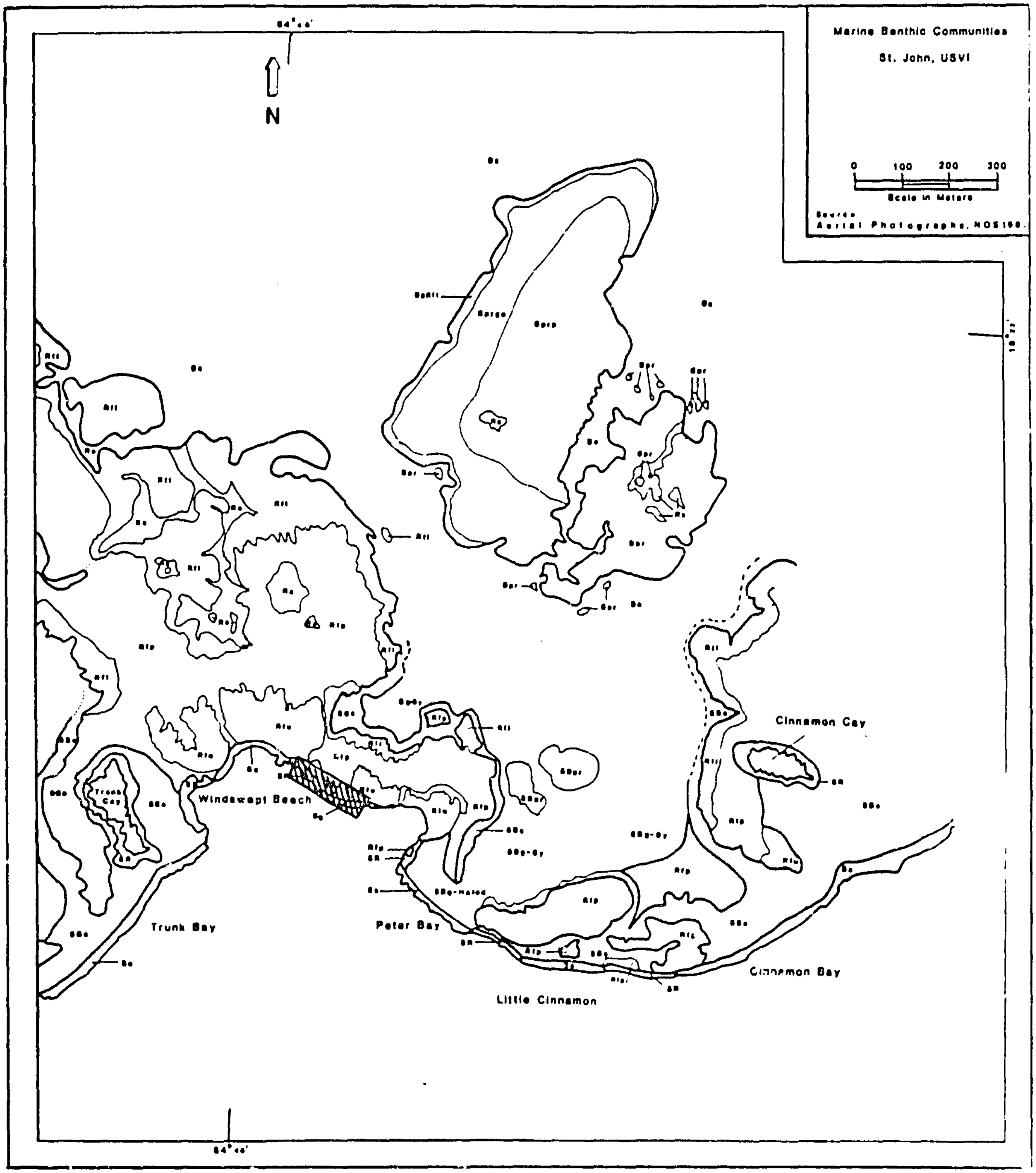

Figure 11. Windswept Beach, St. John, USVI, showing location of study site for long-term monitoring of whelk populations. [hatched box] denotes study area. See Table 3 for acronyms.

included approximately 100m of coastline.

Along this strip of coastline 10 randomly selected sampling sites were chosen. At each sampling site a one-meter wide strip transect was run perpendicular to the shoreline from above the high water mark to approximately one meter in depth seaward of the furthest offshore emergent boulders along the transect. All whelks were collected within this strip transect. Underwater portions of the transect were surveyed using mask and snorkle. After collection, all whelks were measured from tip of spire to distal edge of the lip and released at the capture site.

Results

Four quarterly samples were made during the study period with a mean of 33.5 (sd =6.28) whelks per strip transect (per meter of coastline) or a mean of 335 (sd =62.8) whelks per sample date (Table 15). There appears to be a greater number of whelks in the summer/early fall sampling than in the winter/spring samples. Although the number of whelks per sampling date varied, relative proportions of whelks in the larger size classes (greater than 2.5 cm) remained relatively stable for the study period (Table 15).

The greatest difference among samples occurred in the first four size classes (Figure 12). The first sample had the greatest number of whelks in the 0 to .49 cm size class. The second sample had the peak in the .50 to .99 cm size class. In the third sample the peak was in the .50 to 1.49 cm size classes and by the fourth sample the peak was in the 1.0 to 1.99 cm size classes.

Table 15. Numbers and relative abundance of whelk per size class on four sample dates at Windswept Beach, St. John, USVI. Density is expressed as number of whelk per meter of coastline.

Size Class (cm)			4/22/85	7/11/85	9/4/85	12/16/85
1.	0	- .499	84 (.36)	48 (.12)	13 (.04)	11 (.03)
2.	.5	- .999	43 (.18)	117 (.29)	104 (.29)	26 (.08)
3.	1.0	-1.499	39 (.17)	66 (.16)	98 (.27)	113 (.33)
4.	1.5	-1.999	21 (.09)	32 (.08)	32 (.09)	102 (.30)
5.	2.0	-2.499	13 (.06)	21 (.05)	19 (.05)	33 (.10)
6.	2.5	-2.999	7 (.03)	36 (.09)	20 (.06)	14 (.04)
7.	3.0	-3.499	5 (.02)	26 (.06)	18 (.05)	12 (.04)
8.	3.5	-3.999	4 (.02)	15 (.04)	14 (.04)	12 (.04)
9.	4.0	-4.499	4 (.02)	10 (.02)	6 (.02)	5 (.01)
10.	4.5	-4.999	3 (.01)	11 (.03)	8 (.02)	-0- (0)
11.	5.0	-5.499	1 (.004)	4 (.01)	4 (.01)	-0- (0)
12.	5.5	-5.999	-0- (0)	1 (.002)	1 (.003)	2 (.006)
13.	6.0	-6.499	-0- (0)	2 (.005)	1 (.003)	2 (.006)
14.	6.5	-6.999	1 (.004)	1 (.002)	1 (.003)	1 (.003)
15.	7.0	-7.499	-0- (0)	3 (.007)	2 (.006)	1 (.003)
16.	7.5	-7.999	-0- (0)	2 (.005)	4 (.01)	2 (.006)
17.	8.0	-8.499	2 (.008)	-0- (0)	-0- (0)	-0- (0)
18.	8.5	-8.999	4 (.02)	2 (.005)	2 (.006)	-0- (0)
19.	9.0	-9.499	3 (.01)	7 (.02)	4 (.01)	-0- (0)
20.	9.5	-9.999	-0- (0)	2 (.005)	3 (.008)	2 (.006)
21.	10.0	-10.499	1 (.004)	3 (.007)	2 (.006)	-0- (0)
22.	10.5	-10.999	-0- (0)	-0- (0)	-0- (0)	1 (.003)
23.	11.0	-11.499	1 (.004)	-0- (0)	1 (.003)	-0- (0)
24.	11.5	-11.999	-0- (0)	-0- (0)	-0- (0)	-0- (0)
	Total		236	409	357	339
	Density		23.6	40.9	35.7	33.9

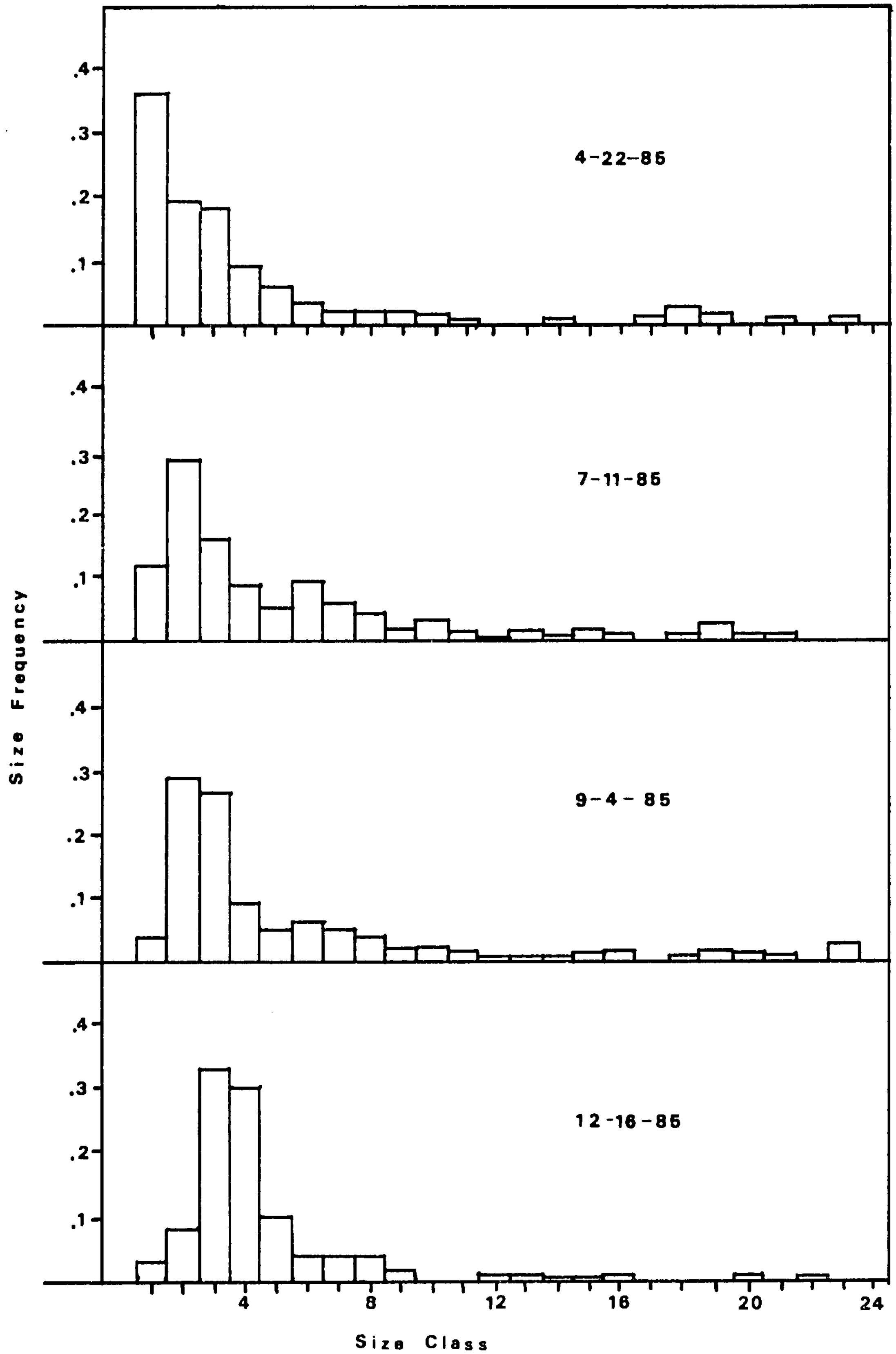

Figure 12. Size frequency of whelks collected at Windswept Beach, St. John, USVI, on four sampling occasions. X-axis numbers refer to size classes shown in Table 15.

General Conclusions

The data suggest a seasonal variation in numbers of whelks observed during the study period. A peak abundance in summer with lower numbers during the winter months may be a response to the increased frequency of high wave energy in the winter months. The whelk may move into more protected areas (deeper water or bays) or deeper into rock crevices where they are harder to observe.

The most interesting aspect of these data is the presence of a very visible annual cohort. The April sample reveals the presence of post-recruits and the December sample shows yearlings in the 1.0 cm to 1.99 cm size class. This agrees well with Randall's (1964) estimate of growth rates of 1.06 mm per month for whelk ranging in size from 1.5mm to 8.2mm. Additionally, the size class distribution for juvenile whelk under 1.0 cm in the present study agrees very closely with the distribution observed by Randall (1964) in Europa Bay, St. John in 1959 and 1960. Her data for April, 1960 demonstrates the peak numbers of juveniles in the 0 to .5 cm size class as does this study. Randall (1964) also demonstrated that recruitment occurred in January.

The majority of the individuals during the study were juveniles and subadults (<5cm). Most marine invertebrates have high reproductive output to compensate for the high mortality of larvae and juveniles. However, the middle range of adult size classes (5 to 8 cm) is represented by very low numbers. This is indicative of very high predation or mortality. Harvest mortality appears to be responsible for most mortality of adults in the Virgin Islands. There is a small number of large adults (>9cm) which has escaped predation by residing in the deeper portion of the transects. These large individuals may be responsible for the majority of the reproductive output in this area and for maintaining the present population.

Summary Conclusions

Management of a species or population depends on knowing the status of the species or population (present condition), where it is going (trends) and what is causing those trends (impacts). Management involves synthesizing this information and developing measures to mitigate negative impacts and reverse or stabilize downward trends. Obtaining this basic information involves development of a long-term monitoring technique which will best produce the necessary information for the species in question. The technique utilized depends on the size, mobility and general nature of the species as well as what information is being sought.

Frequency of monitoring on the time frame of the questions being asked. In general, where information on basic population size and fluctuations during one year is desired, monthly samples may be deemed adequate. The primary constraints on sampling frequency are financial resources and availability of qualified personnel. Some methods are very weather dependent and must be opportunistic in order to obtain adequate samples within the time frame of the study. Data produced over a single, one-year period will be useful for comparing to a similar unit of time in the future for determining long-term trends.

Monitoring Recommendations

When selecting or developing techniques for long-term monitoring of fish and invertebrate species, an attempt was made to use techniques that were simple, easily learned, relatively free from observer bias, did not require excessive equipment, and produced accurate quantitative data that could be used as a baseline data set for measuring changes in population levels or structure over a long period of time. The methods could easily be used in other Caribbean islands to produce comparable data sets. Although methods may be simple and easily taught, a basic recommendation is that, within any particular study, the same person(s) should conduct all the data collection to avoid individual observer bias.

The random point, visual census technique used for assessing fish populations is good in that it is simple, easy to learn and accurate. A potential problem with this method arises from using different observers during the course of a study. When using a number of different observers, the data decrease in reliability. Various inconsistencies or biases due to observer differences can produce a high within-sample variability which can mask among-sample variation and obscure subtle trends or differences. Some of the inconsistencies which have to be considered include:

1. Misidentification of species - can be corrected if data is reviewed with the observer immediately after collection,

2. Overlooking of juveniles of some species (parrotfish, surgeonfish) which lowers the number of individuals observed and increases average size estimates.

3. Over or underestimation of size - usually consistent for each observer, and,

4. Lack of care in recording information (sizes or numbers of individuals).

While the preliminary test of this method suggests that

80 percent of the species in an area are detected in the first four censuses (Figure 2), it is advisable to use at least ten censuses (for statistical reliability) within a habitat type unless the selected habitat is small and can be adequately covered with fewer censuses. Given the residence patterns of most reef fish species, monthly samples may be adequate to assess seasonal variation. The effects of fishing pressure (eg. fish traps on Hawksnest Bay SBpr) can also be detected with monthly samples, but more frequent sampling should yield more accurate analysis.

The canvass method for surveying lobsters in an area is extremely simple and avoids random sampling error. The important consideration is extreme dedication to searching all possible refugia for lobsters. A flashlight is very useful in detecting lobsters in deep caves. Additionally, it is essential to initially map out the area to be surveyed. This enables a complete canvass of an area without missing or overlapping segments, as well as documenting the location and movement of lobsters within an area. Unfortunately, reproductive state of the lobsters is difficult to detect in a dimly lit cave so reproductive seasonality is difficult to obtain. Lobsters do appear to be somewhat sensitive to surge and sediment suspension. The sediment clouds washing in and out of their caves may affect them. This needs to be accounted for in any lobster survey. Lastly, it is important to determine the area surveyed in order to estimate densities.

The strip transect methods used for conch and whelk are basic, simple and accurate. A possible improvement on the method might be to mark half transect widths (2m for conch, individuals who are on the edge of the strip transects) With conch, it is advisable to check all shells in which either movement or eyes protruding from the siphonal canal are not observed. With conch, if visibility is less than about 3m, the method is difficult and time consuming. The whelk survey method is impossible to conduct in high wave action. Wave wash makes it impossible to detect the very small (<1cm) whelk which live in the small crevices in the intertidal (pink) zone. Only under calm conditions is it possible to carefully go over all the rocks and crevices without being washed around and having foam obscure your vision. Selecting a more protected area for the study may not provide a representative sample as whelk tend to prefer higher energy points and coastlines.

Management Recommendations

It is a well-known fact that fishery landings have been seriously declining in Puerto Rico and the U.S. Virgin Islands both in terms of catch-per-unit-effort (CPUE) and in size of individuals (CFMC, 1985). In order to stabilize or reverse this trend before the fishery is entirely decimated, a number of very strict management actions will have to be developed and enforced. For the species or species groups monitored in this study, the following recommendations are made. These recommendations are made primarily for the National Park Service but with U.S.V.I. Government legislation could be extended to all Territorial waters:

A. Reef fish - All of the commercially important species of fish are declining in numbers and sizes from overfishing (CFMC, 1985). As long as individuals are caught before sexual maturity, replacement is not achieved and the stocks decline. Currently, federal regulations in the Exclusive Economic Zone (EEZ) establish a minimum size limit of eight inches for yellowtail snapper and 12 inches for nassau grouper with a one inch per year increase to 12 inches for yellowtail and 24 inches for nassau grouper. Additionally, a closed season is set for nassau grouper from January 1 to March 31 of each year, when reproduction takes place. However, without Territorial adoption and implementation of these regulations, enforcement is nearly impossible. Within the Park there are three proposed strategies: 1. Complete closure of fishery. No fishing with traps or nets within the Park, only handline fishing allowed. 2. Temporary closure, five year minimum. Open on a restricted basis (eg. only two traps per fishermen, no beach seines, limited amount of baitfish). 3. Rotating area closures - close north shore for three years, then south shore for three years. Restricted fishing when open (as in no. 2). The optimum strategy for recovery of the populations is complete closure. However, it may be more politically expedient to use a less drastic measure initially to demonstrate the potential for recovery. The National Park Service could serve as a model for this in the Caribbean.

B. Lobster - The current allowable take for lobsters in National Park waters is greater than the population can tolerate given the number of lobster observed in this study. Populations appear very limited, even in the best inshore habitats (Fish Bay). A bag limit of two lobster per person per day, with four people in a boat, could easily wipe out a good reef area which could take months to repopulate. The recommendation is to close lobsters to all harvest in Park waters. If, after a period of time, monitoring indicates a sizeable number of large individuals has reestablished itself, then a season could be opened or harvest restrictions relaxed. Spotted lobster are currently completely protected in Park waters. They will most likely never be a target species due to their size and the difficulty of catching them.

C. Conch. - Currently it appears that the most stable abundance of conch are those residing in the deeper algal plains on the shelf. These are somewhat protected by the depth at which they are found. Inshore numbers have been devastated. Continued harvesting of juveniles and subadults will result in a continued stock decline leading to local extirpation. The recommendation is to restrict all harvest of conch during the reproductive period (June to September), maintain the current bag limit (two per person per day) during open season and to restrict take to only those individuals having an eroding flared lip (sexually mature). This will prevent the harvest of juveniles and allow them to reach reproductive size. The open season could additionally be restricted to open areas within the Park if a rotating area closure system were initiated.

D. Whelk. - The whelk populations in the Virgin Islands appear extremely overharvested. Heavy fishing pressure coupled with the taking of smaller and smaller whelk, as the large ones become scarcer, has resulted in a small number of older, reproductively active adults in deeper water which are supplying recruits. The small individuals are harvested, probably before reaching sexual maturity. As the older whelks die off, recruitment will decline further until it is minimal and may result in local extirpation. The recommendation is to close immediately all park coastlines to the harvest of whelk until the population has recovered (minimum of five years). Once monitoring indicates that a sufficient population size exists to withstand limited harvest, a season may be reestablished retaining the current bag limit of two quarts of whelk (in the shell) per person per day. At this time a size limit should be implemented to stop the harvest of immature whelk. The smallest mature individuals found by Randall (1964) were 33.7mm (female) and 32.4mm (male) in length (tip of spire to distal edge of lip).

A safe size limit to ensure at least one reproductive season would be failure to pass through a 50.8 mm (2 inch) inside diameter ring. Only whelks failing to pass through could be retained. Not enough is known about the reproductive cycle of whelk to establish a closed reproductive season.

It is very clear to biologists that management strategies must be implemented if populations of marine fisheries species are to survive and if the commercial fisheries of the Virgin Islands are to continue on a viable basis. While fishermen are the first to tell you of the decline in fisheries, they are usually the most opposed to any management actions. As a precursor to implementation of any strategy, there must be a public forum to attempt to have the fishermen understand the need and biological basis for any action taken. They must also be made to feel that they are contributing to the management decisions. Following establishment of any management action, there must be a strong and consistent enforcement effort.

The data collected in this study will be very useful in determining the effect of any management action. In the event that several years transpire between this report and implementation of any management action, it is suggested that a monitoring program be reinitiated to establish current populations of the species or species group to be managed.

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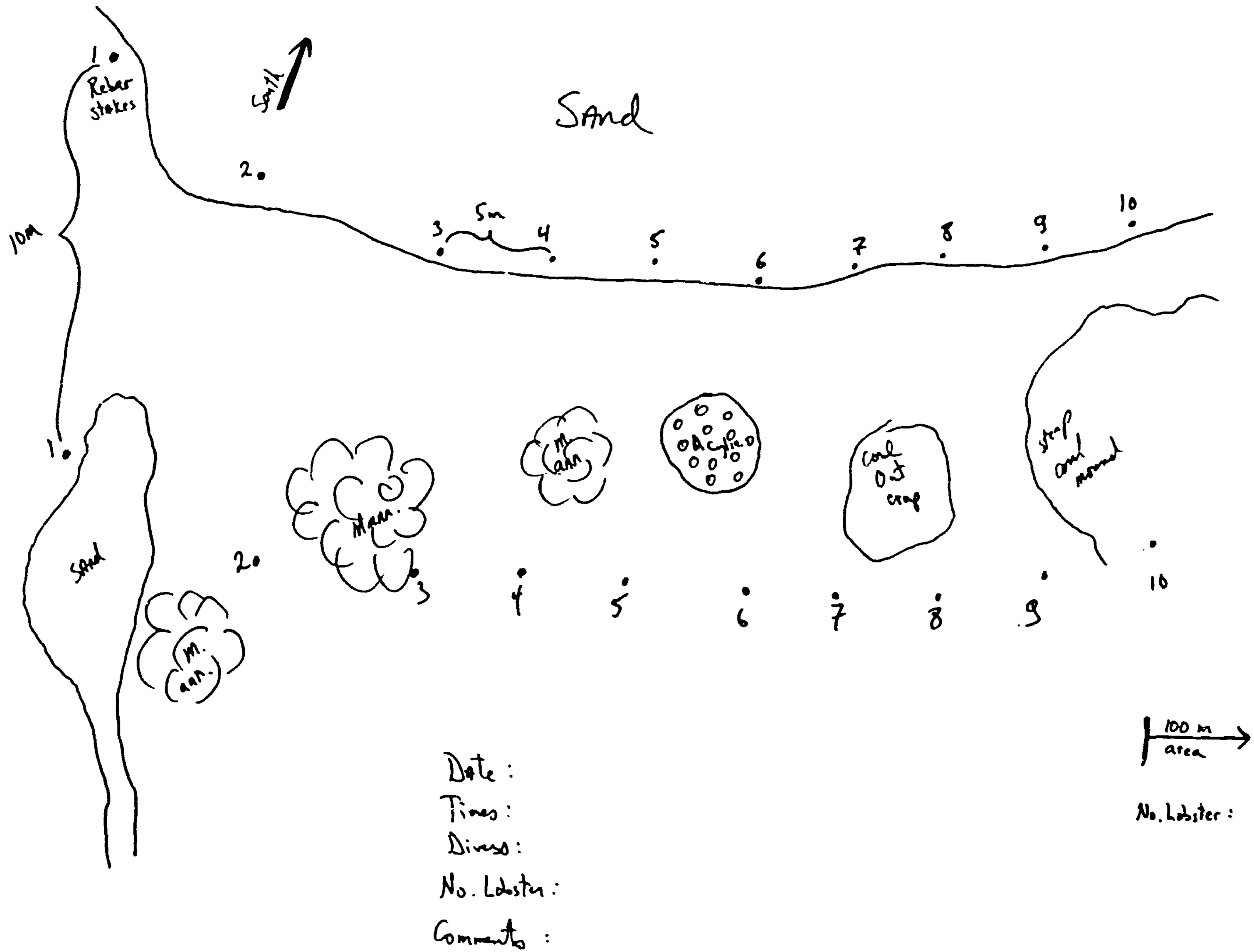
Appendix Ia. Reef Bay lobster study site diagram.



Appendix Ib. Fish Bay lobster study site diagram.