Red Mangrove Prop-Root Habitat as a Finfish Nursery Area: A Case Study of Salt River Bay, St. Croix, U.S.V.I.

AARON J. ADAMS and WILLIAM J. TOBIAS
Government of the Virgin Islands
Department of Planning and Natural Resources
Division of Fish and Wildlife
Room 203, Lagoon Street Complex
Frederiksted, St. Croix
U.S.V.I. 00840

ABSTRACT

The mangrove prop-root habitat of Salt River Bay, St. Croix, U.S. Virgin Islands, was sampled monthly from October 1990 to April 1993 to assess the importance of mangroves as nursery habitat for economically important finfish species. The mangrove fringe of turbid areas were sampled with standardized baited fish traps, while less turbid areas were sampled with visual transects. Trap sampling sites were defined based on habitat type, extent of human activity, and development; two sites had undeveloped, extensively-covered mangrove shorelines, while two sites had reduced mangrove cover and were partially impacted by development. Transect sites encompassed available mangrove shorelines with low turbidity.

Individuals caught in traps represented 40 species and 19families. The most common families were Gerreidae (36% relative abundance, two species), Pomadasyidae (20%, seven species), Lutjanidae (16%, six species), and Chaetodontidae (14%, two species). Individuals observed in transects represented 48 species and 26 families. The most common families were Lutjanidae (38%, six species), Pomadasyidae (34%, eight species), Gerreidae (10%, two species), and Pomacentridae (5%, seven species). Species relative abundance varied by site among both trap and transect areas. Mean number of species and individuals per trap were higher in sites with reduced mangrove cover. This was likely due to less available shelter, making the traps more attractive in areas with less prop-root habitat. This hypothesis was supported by transect data; mean number of species and individuals per transect were higher in areas with more mangrove habitat. The majority of species were represented by juveniles, and mean length was stable over time. One species (*Acanthurus chirurgus*) exhibited an annual peak in abundance, while several other species had a single abundance maxima. The Salt River Bay mangrove habitat provides important mangrove nursery habitats for many fish species, most notably economically important species, and should be included in fisheries management plans.

INTRODUCTION

Mangrove lagoons are an important habitat for juveniles of many fish species (Cintron-Molero, 1987; Thayer *et al.*, 1987; Boulon, 1992), and can provide nursery areas for estuarine as well as reef fishes (Odum *et al.*, 1982; Boulon, 1992). The mangrove prop-root habitat is important for many reasons. Many juveniles use detritus and mangrove-associated invertebrates and fish as a food source (Zieman *et al.*, 1984; Thayer *et al.*, 1987). The complex prop-root habitat may also provide protection from predation (Orth *et al.*, 1984; Sogard and Olla, 1993). Furthermore, in addition to providing important habitat, mangroves filter terrigenous sediment and help maintain the integrity of the lagoon seagrass habitat (Cintron-Molero, 1987), also an important nursery area (Dennis, 1992).

Of particular concern to fisheries managers are economically important species (*i.e.*, species targeted by recreational and commercial fishermen). The utilization of mangrove habitats by these economically important species and their prey species is important (Robertson and Duke, 1987). The documentation of mangroves as nursery areas for recreationally and commercially valuable species, and their prey species, provides impetus for including mangrove habitats in fisheries management plans.

Mangrove habitat in the U.S. Virgin Islands is primarily mangrove fringe along lagoons and oceanic bays (Boulon, 1992). On St. Croix, the southern-most of the U.S. Virgin Islands, the fringing mangroves have a well-developed, permanently submerged prop-root system that provides potential nursery habitat. There are three prominent mangrove systems on St. Croix: Salt River, Altona Lagoon, and Great Pond.

This study was designed to quantitatively measure finfish utilization of the mangrove prop-root habitat fringe of St. Croix with an emphasis on economically important species, and to examine the effect of variable mangrove cover on species composition. Reported here are the results of the Salt River portion of the study. Altona Lagoon is currently under study, and Great Pond will follow in 1995.

METHODS AND MATERIALS

Site Description

The Salt River estuary is a mangrove-fringed lagoon on the north shore of St. Croix, U.S.V.I., separated from the open ocean by a fringing reef. Salt River is adjacent to deep ocean waters in that it lies at the head of Salt River Canyon. The shallow (4 m) estuary is composed of an outer bay and two parallel inner bays (Triton Bay and Sugar Bay), and contains a small marina (Figure 1). The majority of mangrove habitat is along the shorelines of the inner bays, with only limited growth on the western shore of the outer embayment.

Field Sampling

The mangrove prop-root habitat of Salt River estuary was sampled monthly with standardized fish traps and visual transects over a 30 month period. Data were analyzed for the 25 month period of March 1991 - April 1993 following a five month pilot study. The total mangrove fringing shoreline was partitioned into five sites based on the extent of mangrove cover, human impact, and turbidity.

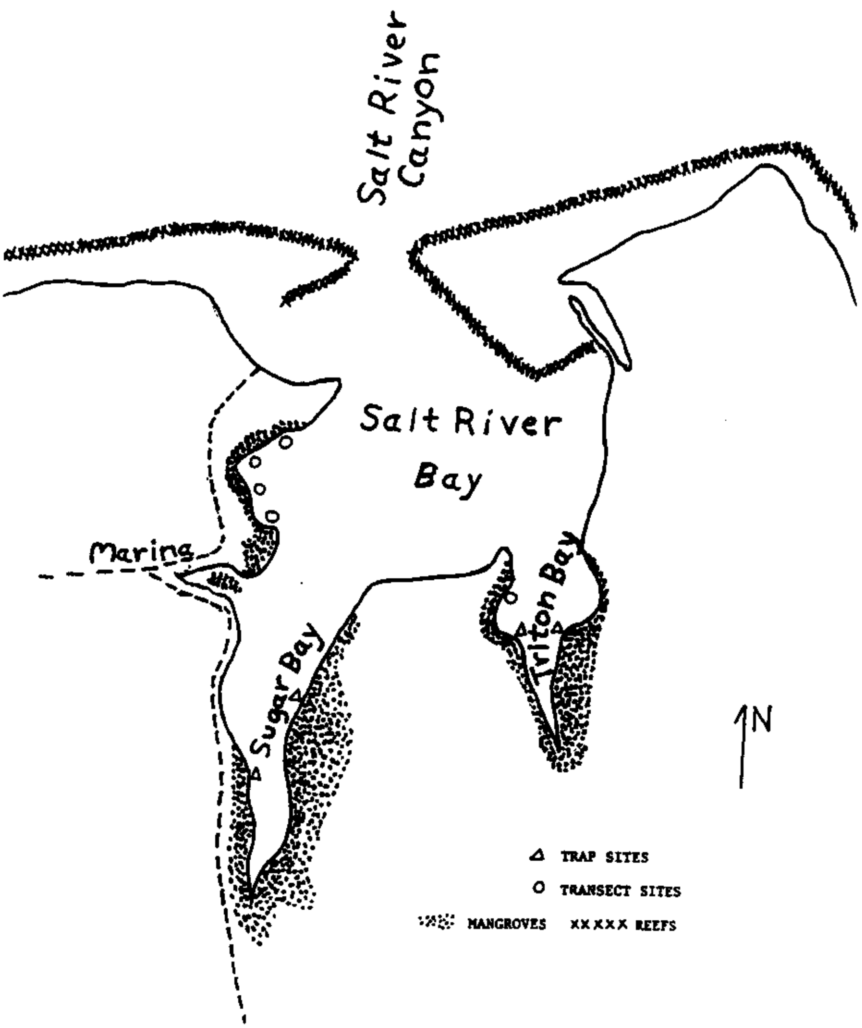

Figure 1. Diagram of Salt River Estuary, with location of trap and transect sites.

The turbid shorelines of Triton Bay and Sugar Bay were sampled with standardized baited fish traps. Each bay was divided into two sites, resulting in four total trap sampling sites (Figure 1). Triton Bay East and Sugar Bay East have undeveloped, extensively-covered mangrove shorelines, while Triton Bay West and Sugar Bay West are partially impacted by development and have reduced mangrove cover. Each site was sampled over a twenty-four hour period with twelve standardized rectangular fish traps, 92 cm x 57 cm x 19 cm, made from vinyl-coated 1.3 cm wire mesh. The traps were baited with herring and set at 50 m intervals along the mangrove fringe. All four sites were sampled within a five day sampling period. All individuals caught in the traps were identified, enumerated, measured (fork length and total length), and returned to the capture site.

An undeveloped shoreline of narrow mangrove fringe along an outer embayment was sampled monthly with four 100 m x 3 m visual transects. In addition, a fifth 100 m x 3 m transect was located along an outer section of Triton Bay West (Figure 1). All transects were conducted by swimming with snorkel gear along the edge of the mangrove prop-root habitat. Two individuals snorkeled each transect, resulting in two samples per transect per month. All transects were completed on a single day within the five day trap-sampling period. All fish species and number of adults and juveniles of each species were recorded for each transect.

Analyses

Numbers of species and individuals caught per trap were examined by area with a Kruskal-Wallis one-way non-parametric test (Sokal and Rohlf, 1981). Species were ranked in order of total abundance, and the six most abundant economically important species were examined for seasonal and inter-site variation in abundance and size. Finally, data from all sites were pooled by month, and monthly variation in overall abundance and number of species was examined with least-squares regression analysis.

Total number of species and individuals per transect were examined by site with a one-way ANOVA after data were square-root transformed to achieve normality and homogeneity of variances. Species were ranked in order of abundance, and the six most abundant economically important species and one family (Scaridae) were analyzed for seasonal and between-site variation in overall abundance and juvenile abundance. Scarids were abundant as a family, but not as individual species, and were included in these analyses due to the economic importance of the family. Finally, data from all sites were pooled by month, and monthly variation in overall abundance and number of species was examined with least-squares regression analysis.

RESULTS

A total of 3,462 individuals were caught in traps, representing 40 species and nineteen families (Table 1). The family in highest abundance was Gerreidae (36%) (Figure 2), represented by two species, *Eucinostomus jonesi* and *Gerres cinereus*, in almost equal abundance. The second most abundant family was Pomadasyidae (20%), which was represented by seven species. *Haemulon flavolineatum* accounted for 94.6% and *Haemulon sciurus* for 3.6% of all Pomadasyids. Lutjanidae was third most abundant (16%), and was represented by six species. *Lutjanus apodus* (64.8%) and *Ocyurus chrysurus* (29.5%) accounted for the majority of Lutjanids. Chaetodontidae was fourth in abundance (14%), and was represented by two species. *Chaetodon capistratus* accounted for all but one individual (99.8%) of the chaetodonts. All other families each had a relative abundance of 2%.

Table 1. Species caught in fish traps, with total abundance (all sites combined) for each species. Families listed in decreasing order of abundance.

Family Name	Common Name	Species Name	Total Abundance
Gerreidae			
	Slender mojarra	*Eucinostomus jonesi*	668
	Yellowfin mojarra	*Gerres cinereus*	599
Pomadasyidae			
	French grunt	*Haemulon flavolineatum*	663
	Bluestriped grunt	*Haemulon sciurus*	25
	Smallmouth grunt	*Haemulon chrysargyreum*	4
	White grunt	*Haemulon plumieri*	4
	Tomtate	*Haemulon aurolineatum*	2
	Caesar grunt	*Haemulon carbonarium*	2
	Sailors choice	*Haemulon parrai*	1
Lutjanidae			
	Schoolmaster snapper	*Lutjanus apodus*	365
	Yellowtail snapper	*Ocyurus chrysurus*	166
	Gray snapper	*Lutjanus griseus*	15
	Dog snapper	*Lutjanus joco*	11
	Mutton snapper	*Lutjanus analis*	5
	Mahogony snapper	*Lutjanus mahogoni*	1
Chaetodontidae			
	Foureye butterfly	*Chaetodon capistratus*	483
	Banded butterfly	*Chaetodon striatus*	1
Sciaenidae			
	Reef croaker	*Odontoscion dentex*	70
	Spotted drum	*Equetus punctatus*	3

Sciaenidae	High hat	*Equetus acuminatus*	2
Sparidae	Seabream	*Archosargus rhomboidalis*	71
Scaridae	Bucktooth parrotfish	*Sparisoma radians*	57
	Redtail parrotfish	*Sparisoma chrysopterum*	5
	Redband parrotfish	*Sparisoma aurofrenatum*	3
	Emerald parrotfish	*Nicholsina usta*	2
	Queen parrotfish	*Scarus vetula*	1
Tetraodontidae	Checkered puffer	*Sphoeroides testudineus*	59
	Bandtail puffer	*Sphoeroides spengleri*	1
Holocentridae	Squirrelfish spp.		48
Pomacentridae	Damsel spp.		26
	Yellowtail damsel	*Microspathodon chrysurus*	10
(Table 1. cont.)	Beaugregory	*Stegastes leucostictus*	2
Labridae	Clown wrasse	*Halichoeres maculipinna*	18
	Slippery dick	*Halichoeres bivittatus*	9
	Wrasse spp.		2
	Creole wrasse	*Clepticus parra*	1
Clinidae	Hairy blennie	*Labrisomus nuchipinnis*	15
Sphyraenidae	Barracuda	*Sphyraena barracuda*1	3
Carangidae	Horseye jack	*Caranx latus*	5
	Jack	*Caranx spp.*	4
Carangidae	Barjack	*Caranx ruber*	1
Centropomidae	Snook	*Centropomus undecimalis*	8
Acanthuridae	Doctorfish	*Acanthurs chirurgus*	7
Muraenidae	Green Moray eel	*Gymnothorax funebris*	3
Scorpaenidae	spp.		1
Serranidae	Grouper spp.		1

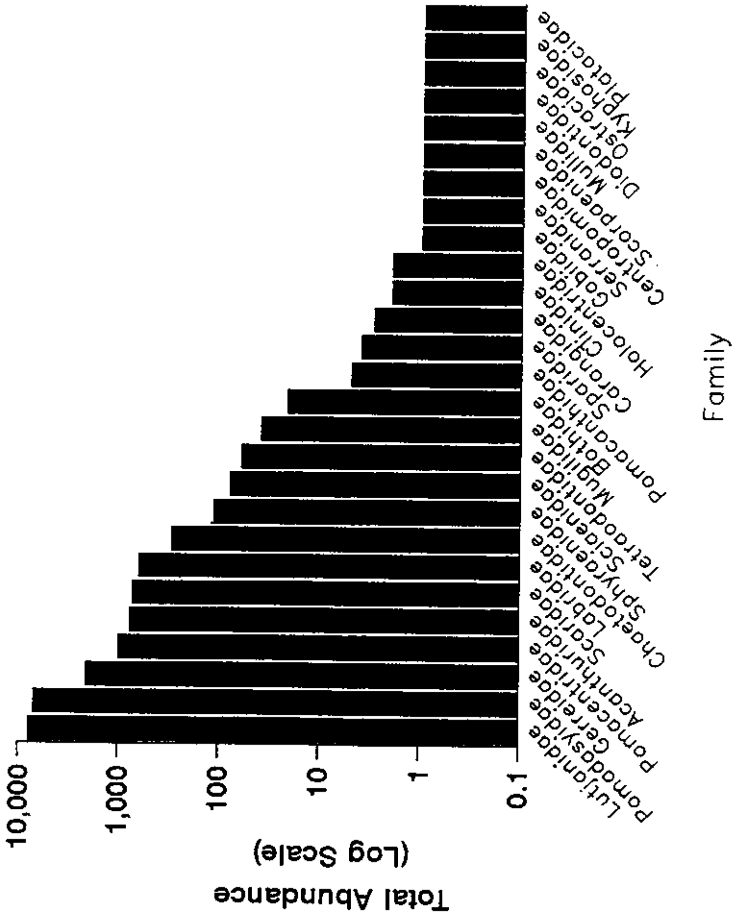

Figure 2. Total abundance by family of fishes caught in traps for all sites combined.

Number of species and number of individuals (Table 2) were significantly higher in the impacted, reduced-growth sites than in the unimpacted extensive-cover sites. Total number of species was highest in Sugar Bay, with a total of 33 species in both Sugar Bay East and Sugar Bay West. There were 28 total species in Triton Bay West and 24 in Triton Bay East. *E. jonesi*, *G. cinereus*, *H. flavolineatum*, *C. capistratus*, *L. apodus*, and *O. chrysurus* were the six most abundant species, in varying orders of abundance, in all sites except Triton Bay East, where *L. apodus* was ranked eighth. *E. jonesi* and *G. cinereus* were the two most abundant species in Triton Bay East and Sugar Bay East, the extensive-mangrove-coverage and undeveloped sites. *H. flavolineatum* was the most abundant species in both sites with reduced mangrove coverage and partially developed shoreline, Triton Bay West and Sugar Bay West. Among lutjanids, *O. chrysurus* was in similar abundance in all four sites, but *L. apodus* was more abundant at the Sugar Bay sites than in the Triton Bay sites. *C. capistratus* was most abundant in Triton Bay West and least abundant in Sugar Bay East.

There was no significant linear relationship between month and overall mean number of species ($R^2 = 0.095$, $F = 2.403$, df = 1,23, $p > 0.1$) or individuals ($R^2 = 0.066$, $F = 1.621$, df = 1, 23 , $p > 0.1$) caught in traps.

The five species listed in Table 3 were each dominated by juveniles. The size distribution was skewed toward smaller individuals (Figure 3) and mean size was similar between months for all species.

There was no apparent annual recruitment for any species caught in traps, although some species had single peaks in abundance. There was a single period of peak abundance for *L. apodus* (July - October, 1991), *G. cinereus* (April - July, 1992), and *O. chrysurus* (June - August, 1992). Monthly abundance of *H. flavolineatum* was highly variable.

A total of 20,606 individuals were observed in transects, representing 48 species and 26 families (Table 4). The family with the highest relative abundance was Lutjanidae (37.9%) (Figure 4), represented by six species. *Lutjanus apodus* accounted for 89.8%, and *Lutjanus griseus* 9.4%, of all lutjanids. The second most abundant family was Pomadasyidae (33.8%), represented by eight species. *Haemulon flavolineatum* accounted for 99.1% of all pomadasyids. Gerreidae was third highest in abundance (9.9%), and was represented by two species, *Eucinostomus jonesi* and *Gerres cinereus*, representing 75.4% and 24.6%, respectively. Pomacentridae was fourth in relative abundance (4.9%), and was represented by seven species. *Abudefduf saxatilis* (52.3%) and *Stegastes dorsopunicans* (29.5%) were the most abundant pomacentrids. All other families each had a relative abundance of < 4%.

There were significant differences between sites in both number of species and number of individuals per transect, and only a few species were in high relative abundance in all transects. Columbus #4 transect was ranked highest and

Table 2. Kruskal-Wallis comparison of square-root-transformed number of species and number of individuals (Abundance) per trap by area. Values listed are non-transformed mean number per trap (+ SE).

Area				
Triton Bay		Sugar Bay		
East	West	East	West	K-W
Species				
1.14 (0.06)	1.55 (0.08)	1.32 (0.07)	1.65 (0.08)	25.92*
Abundance				
2.55 (0.24)	3.27 (0.23)	2.90 (0.23)	3.76 (0.32)	21.57*

*P<0.001

Table 3. Mean sizes (total length, mm) (+SE) by site and for all sites combined (Total), and minimum and maximum lengths for all sites combined, for the five most abundant recreationally targeted species caught in traps. Species listed in decreasing order of abundance.

	Site						
	Triton Bay		Sugar Bay				
Species	East	West	East	West	Total	Min.	Max.
E. jonesi	71.18 (0.77)	71.38 (0.83)	67.96 (0.62)	73.30 (1.04)	70.73 (0.40)	44.0	135.0
H. flavolineatum	78.50 (2.25)	81.84 (1.27)	83.07 (1.81)	76.36 (1.02)	79.72 (0.72)	40.0	140.0
G. cinereus	72.63 (1.84)	79.82 (2.04)	86.57 (1.57)	85.48 (1.73)	81.15 (0.92)	36.0	170.0
L. apodus	84.54 (6.76)	112.58 (7.31)	87.73 (2.06)	107.04 (2.76)	97.72 (1.73)	20.0	210.0
O. chrysurus	90.96 (3.91)	94.97 (4.50)	103.44 (5.77)	87.97 (3.73)	94.25 (2.32)	40.0	194.0

Columbus #1 lowest in both number of species (Table 5) and individuals (Table 6, Figure 5). *L. apodus*, *H. flavolineatum*, and *E. jonesi* were the only species ranked among the five most abundant in all five transects. *Acanthurus chirurgus* was among the most abundant species in the four Columbus transects in the outer embayment, but was in low abundance in Dyck's Beach within Triton Bay. *Halichoeres bivittatus* was in high abundance only in Columbus #1 and

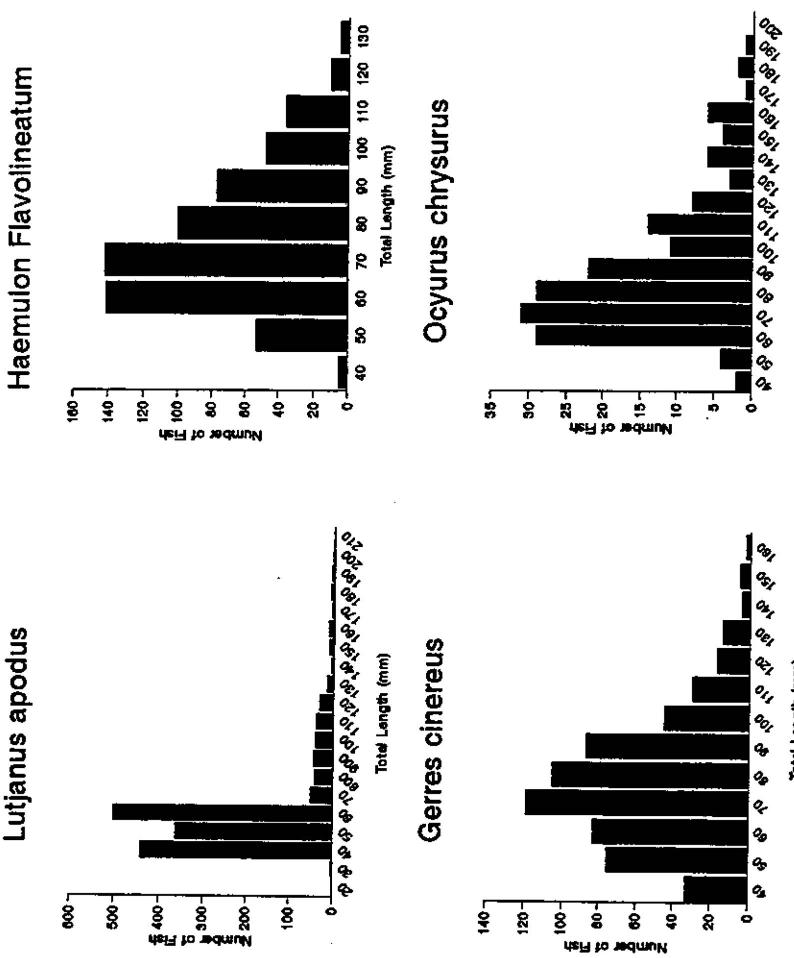

Figure 3. Length-frequency histograms for four of the most abundant species caught in traps.

Table 4. Species observed in visual transects, with total abundance (all transects combined) and percentage of the total that were juveniles for each species. Families listed in decreasing order of abundance.

Family Name Common Name Species Name	Total Abundance	Percent Juvenile
Lutjanidae		
Schoolmaster		
Lutjanus apodus	7022	81.5
Gray Snapper		
Lutjanus griseus	736	60.0
Dog Snapper		
Lutjanus joco	3	0
Lane Snapper		
Lutjanus synagris	20	100.0
Yellowtail Snapper		
Ocyurus chrysurus	30	100.0
Mahogany Snapper		
Lutjanus mahogoni	7	80.0
Pomadasyidae		
French Grunt		
Haemulon flavolineatum	6896	88.2
Caesar Grunt		
Haemulon carbonarium	2	50.0
Bluestriped Grunt		
Haemulon sciurus	48	45.8
Spanish Grunt		
Haemulonmacrostomum	1	100.0
Sailors Choice		
Haemulon parrai	2	0
Striped Grunt		
Haemulon striatum	1	0
Porkfish		
Anisotremus virginicus	9	44.0
Gerreidae		
Slender Mojarra		
Eucinostomus jonesi	1544	95.2
Yellowfin Mojarra		
Gerres cinereus	503	69.8
Pomacentridae		
Dusky Damsel		
Stegastes dorsopunicans	298	61.3
Beaugregory		
Stegastes luecostictus	81	89.7

Table 4. Continued

Sergeant Major		
Abudefduf saxatilis	530	88.7
Yellowtail Damsel		
Microspathodon chrysurus	73	85.7
Damsel (spp.)	15	100.0
Bicolor Damsel		
Stegastes partitus	6	100.0
Coco Damsel		
Stegastes variabilis	7	71.4
Acanthuridae		
Doctorfish		
Acanthurus chirurgus	770	94.0
Blue Tang		
Acanthurus coeruleus	5	100.0
Scaridae		
Redtail Parrotfish		
Sparisoma chrysopterum	69	76.1
Emerald Parrotfish		
Nicholsina usta	65	89.7
Redband Parrotfish		
Sparisoma aurofrenatum	144	75.6
Striped Parrotfish		
Scarus iserti	131	99.2
Bucktooth parrotfish		
Sparisoma radians	263	99.1
Parrotfish (spp.)	38	100.0
Stoplight Parrotfish		
Sparisoma viride	8	100.0
Yellowtail Parrotfish		
Sparisoma rubripinne	5	0
Labridae		
Slippery Dick		
Halichoeres bivittatus	604	97.6
Wrasse spp.	30	50.0
Chaetodontidae		
Foureye butterfly		
Chaetodon capristratus	300	82.4
Banded butterfly		
Chaetodon striatus	1	0
Sphyraenidae		
Barracuda		
Sphyraena barracuda	114	86.8
Sciaenidae		
Spotted drum		
Equetus puncatus	38	93.9

Table 4. Continued

High Hat		
Equetus acuminatus	30	53.3
Drum		
Equetus spp.	7	57.1
Reef Croaker		
Odontoscion dentex	3	100.0
Tetraodontidae		
Puffer spp.	6	0
Checkered Puffer		
Sphoeroides testudineus	53	42.1
Bandtail Puffer		
Sphoeroides spengleri	2	100.0
Mugilidae		
White Mullet		
Mugil curema	38	85.7
Bothidae spp.	21	100.0
Pomacanthidae		
French Angel		
Pomacanthus paru	5	100.0
Sparidae		
Seabream		
Archosargus rhomboidalis	4	0
Carangidae		
Horseye Jack		
Caranx latus	3	100.0
Clinidae		
Hairy Blenny		
Labrisomus nuchipinnis	2	0
Holocentridae		
Squirrelfish (spp.)	2	100.0
Gobiidae		
Goby (spp.)	1	0
Serranidae		
Hamlet		
Hypoplectrus spp.	1	100.0
Centropomidae		
Snook		
Centropomus undecimalis	1	100.0
Scorpaenidae		
Scorpionfish spp.	1	0
Mullidae		
Yellowtail Goatfish		
Mulloidichthys martinicus	1	100.0
Diodontidae		
Porcupinefish		

Table 4. Continued

	Diodon hystrix	1	0
Ostraciidae			
Trunkfish			
	Lactophrys spp.	1	0
Kyphosidae			
Chub			
	Kyphosus spp.	1	0
Platacidae*			
Leaf Fish			
	Platax orbicularis	1	100.0

*Not a native species. Source of introduction unknown.

Dyck's Beach transects. In contrast, *Lutjanus griseus* was in high abundance only in Columbus #4, #3, and #2 transects, in the outer embayment.

There was no significant linear relationship between overall number of individuals and month ($R^2 = 0.014$, $F = 2.405$, $df = 1{,}165$, $p > 0.1$). Although the relationship between overall number of species and month was significant, the relationship was very weak ($R^2 = 0.046$, $F = 7.986$, $df = 1{,}165$, $p < 0.01$).

The majority of individuals of all species were juveniles (Table 4). Only three of the 48 species were represented by a majority of adults. Among the six species and one family examined within transects, only one, *L. griseus*, was represented by a high percentage of adults (Table 7).

As with the fishes caught in traps, some species exhibited single peaks in abundance, but one species had annual abundance maxima. *G. cinereus* (August - October, 1992) and *L. griseus* (July - August, 1992) had single abundance maxima, while *L. apodus*, *H. flavolineatum*, *E. jonesi*, and Scaridae abundance did not display a distinct pattern. Only *A. chirurgus* showed a distinct annual recruitment pattern, with abundance maxima in February - April of each year.

Dyck's Beach transect was partially within the Triton Bay West sampling site. Thus, only qualitative comparisons were possible. There were 28 total species, or species groups, recorded for both the trap samples and the transect, of which fifteen (54%) were present in both. Four of the six most abundant species in the trap samples were also among the six most abundant species observed in the transect, and *H. flavolineatum* was the most abundant species in both methods.

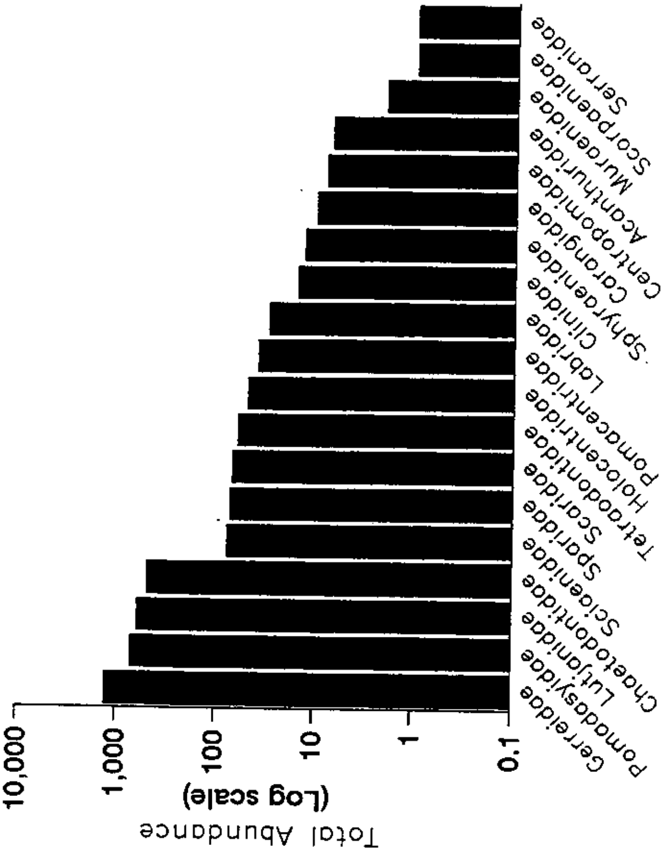

Figure 4. Total abundance by family of fishes observed in transects for all sites combined.

Table 5. Effect of transect location on square-root-transformed number of species.

a) One-way ANOVA

Source of Variation	SS	df	MS	F
Transect	585.88	4	146.47	14.15*
Error	1532.56	148	10.36	

b) Tukey-Kramer multiple comparisons test of square-root-transformed number of species by transect.Treatments that are not significantly different at the 0.05 level share an underline. Treatments are arranged in increasing number of species.

Columbus #1	Dyck's Beach	Columbus #2	Columbus #3	Columbus #4

*P<0.001

Table 6. Effect of transect location on square-root-transformed number of individuals.

a) One-way ANOVA

Source of Variation	SS	df	MS	F
Transect	1208.15	4	302.04	30.32*
Error	1474.11	148	9.96	

b) Tukey-Kramer multiple comparisons test of square-root-transformed number of individuals by transect. Treatments that are not significantly different at the 0.05 level share an underline. Treatments are arranged in increasing order of abundance.

Columbus #1	Dyck's Beach	Columbus #2	Columbus #3	Columbus #4

*P<0.001

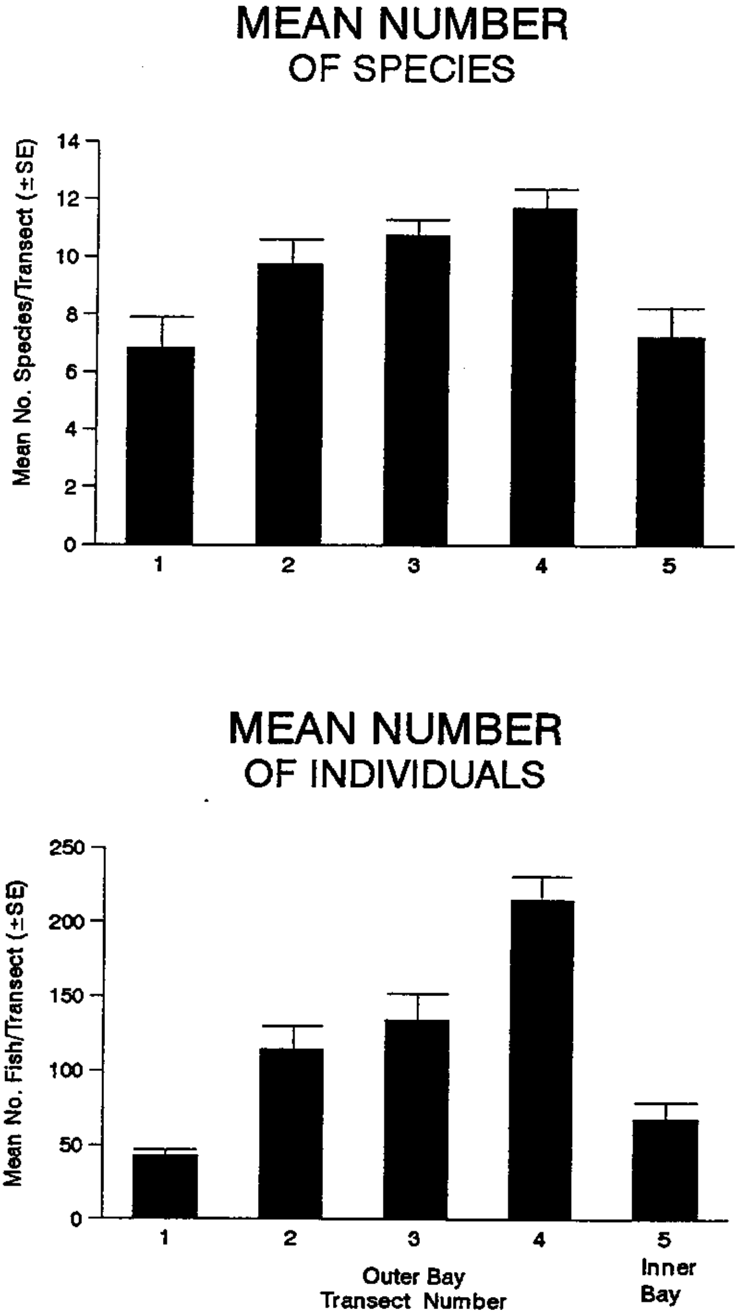

Figure 5. Mean number of species and individuals per transect (± SE).

Table 7. Percent of total abundance represented by juveniles within each visual transect for the six most abundant recreationally targeted species and one family.Values are means (+ SE). Groups listed in decreasing order of abundance.

	Transect				
Species or Family	Columbus #1	Columbus #2	Columbus #3	Columbus #4	Dyck's
L. apodus	88.8	91.2	80.3	76.6	84.2
	(3.6)	(1.9)	(2.5)	(1.6)	(6.8)
H. flavolineatum	72.2	76.7	92.7	89.8	89.1
	(11.0)	(7.1)	(2.7)	(1.6)	(7.1)
E. jonesi	96.2	93.5	93.2	96.5	98.1
	(2.9)	(3.5)	(2.5)	(1.7)	(1.9)
A. chirurgus	89.1	92.3	76.4	90.0	100.0
	(9.8)	(3.9)	(13.2)	(4.1)	(1.1)
L. griseus	100.0	56.8	32.5	34.5	33.3
	(0.4)	(9.7)	(9.9)	(9.6)	(33.3)
Scaridae	92.9	72.6	82.3	82.1	97.8
	(4.3)	(11.0)	(9.6)	(8.4)	(2.2)
G. cinereus	47.9	43.8	58.8	61.6	83.6
	(13.2)	(10.4)	(10.4)	(7.8)	(11.1)

When species richness levels were compared between outer bay and inner bay sites, species richness was greater in the outer bay. This was true among transects as well as between transects and traps.

DISCUSSION

Many of the species present in Salt River are directly targeted in the St. Croix recreational fishery. Among the Gerreids, *E. jonesi* are caught with nets and used as bait for larger species (*e.g.*, *S. barracuda* and lutjanids), and large *G. cinereus* are caught with hook-and-line and spear in back reef areas. Most pomadasyids and lutjanids are recreationally targeted species and are caught with hook-and-line and spear. Larger members of the scarids are also often caught recreationally. Members of Pomadasyidae, Lutjanidae, and Scaridae are also caught commercially. *A. chirurgus* is an incidental recreational catch, but is an important part of the commercial fishery. The chaetodonts, primarily *C. capistratus*, were also an important part of the lagoon community but are not recreationally targeted. However, this family is represented by aesthetic species (including *C. capistratus*) important to the sport diving industry. Juveniles of many other species in low abundance support local recreational or commercial fisheries (Tables 1 and 4).

The fish community present in Salt River was similar to other mangrove lagoon communities (Baelde, 1990; Van der Velde *et al.*, 1992; Rooker and Dennis, 1991; Thayer *et al.*, 1987; Tzeng and Wang, 1992; Dennis, 1992). Gerreids, a highly abundant family in Salt River, are found in many estuarine systems throughout the world, including mangrove lagoons (Matthes and Kapetsky, 1988; Baelde, 1990; Rooker and Dennis, 1991; Thayer *et al.*, 1987). The other abundant families in Salt River, Lutjanidae, Pomadasyidae, Scaridae, and Chaetodontidae, are primarily reef-oriented as adults, but are common in mangrove lagoons as juveniles (Baelde, 1990; Van der Velde *et al.*, 1992; Rooker and Dennis, 1991). Carangidae and Sphyraenidae are often abundant in mangrove lagoons (Baelde, 1990; Rooker and Dennis, 1991), but were in low abundance in Salt River for unknown reasons. Potential prey (juveniles of all species) and shelter (prop-roots and seagrass) were abundant throughout the lagoon, and may have been able to support more carangid and sphyraenid individuals than were present. Although traps may have under-estimated carangid and sphyraenid abundance, visual censuses should have recorded greater abundances.

Species-specific resource requirements and resource allocation contributed to the relative abundance patterns shown in Figures 2 and 3 (De Vita, 1979). These patterns of relative abundance are common in tropical systems (*e.g.*, Bohnsack *et al.*, 1987). The most abundant species in Salt River were able to utilize the available resources to a greater extent than species in lower abundance that had more restrictive niche requirements. For example, *S. barracuda* were common but in low abundance, which is characteristic of many piscivorous species. In contrast, *H. flavolineatum* and *E. jonesi* have varied diets and are capable of utilizing various habitats and were more abundant. Thus, relative abundance was not an accurate indicator of the importance of mangrove nursery habitat for some species.

Species-specific habitat requirements were also important in determining species abundance between sites. *E. jonesi* are estuarine-associated and were ranked highest in abundance in the inner bay sites with extensive mangrove cover. *H. flavolineatum* and *C. capistratus* are able to utilize various habitats as nurseries (*e.g.*, seagrass and back-reef areas) (Shulman, 1985a), in addition to mangroves, and were able to exploit the areas with reduced mangrove cover. *L. apodus* and *L. griseus* are more dependent upon shelter, as reflected in higher abundance in transect sites with greatest mangrove cover. *A. chirurgus* are common in back-reef areas (Shulman, 1985b) and were most abundant in the outer bay sites. *G. cinereus*, *L. apodus*, and *O. chrysurus* utilize various habitats as adults and were able to use all mangrove sites equally.

Allocation of available shelter was partially responsible for the variation between sites in number of species and number of individuals as well. Among trap sites, mean number of species and individuals per trap was higher in the areas with less mangrove prop-root habitat, Sugar Bay West and Triton Bay West, than in the areas with more extensive coverage, Sugar Bay East and Triton Bay East. These differences were likely due to shelter limitation. In experiments with spiny lobsters, *Panulirus argus*, CPUE of traps was lower in areas with greater habitat (artificial shelters) than in areas with less habitat control sites) (D.B. Eggleston, pers. comm.). It is likely that the traps were competing with the artificial shelters as sources of habitat in the shelter enhanced sites and were not heavily utilized. In addition, use of artificial shelters by juvenile lobsters was greater in areas with less available habitat (*Laurencia* spp.) (Lipcius and Eggleston, in press), suggesting use of additional habitat only when natural habitat was limited. It is plausible that the juvenile fishes in Salt River reacted to the traps in the same way as *P. argus*, and utilized the traps more when habitat was reduced. Thus, trap catches were more a reflection of competition for available shelter than actual abundance. Between-transect variation supports this hypothesis; mean number of species and individuals were higher in transects with greater mangrove coverage (more available shelter), suggesting a relationship between shelter availability and abundance.

The proximity to larval supply was also an important factor in determining number of species and individuals at each site. Dominant currents in Salt River are wind and wave driven (Figure 6), and the outer bay is most directly in line with currents entering from outside Salt River. In contrast, Triton Bay, and to a lesser extent Sugar Bay, circulation is primarily tidally driven. Larvae entering Salt River will be more likely to encounter suitable habitat within the outer bays before reaching the inner bays. Larvae that do reach the inner bays are then more likely to encounter suitable habitat in Sugar Bay before reaching Triton Bay. Species in high abundance had sufficient larval input to settle in all parts of Salt River, while those with a smaller larval supply were less likely to reach the inner bay areas. This was the case in that more species in low abundance were present in the outer bay than in the inner bays, and in Sugar Bay than in Triton Bay.

The abundance of juveniles throughout the study indicates that the mangrove prop-root habitat is utilized primarily as a nursery, similar to other mangrove systems (Baelde, 1990; Van der Velde *et al.*, 1992; Rooker and Dennis, 1991; Thayer *et al.*, 1987; Tzeng and Wang, 1992; Dennis, 1992). Mean length of individuals and the juvenile/adult ratio remained relatively constant over time, and length-frequency histograms were highly skewed toward smaller fish. Although mortality among smaller fish may have partly reduced the number of individuals reaching larger sizes (*i.e.*, Type III survivorship curve), much of the reason for low abundance of larger individuals was migration to other habitats. In areas of intense predation pressure, such as back-reef areas, initial mortality of juveniles may be high, while mangroves may supply safer shelter. For example, survivorship for *H. flavolineatum* in some back-reef areas

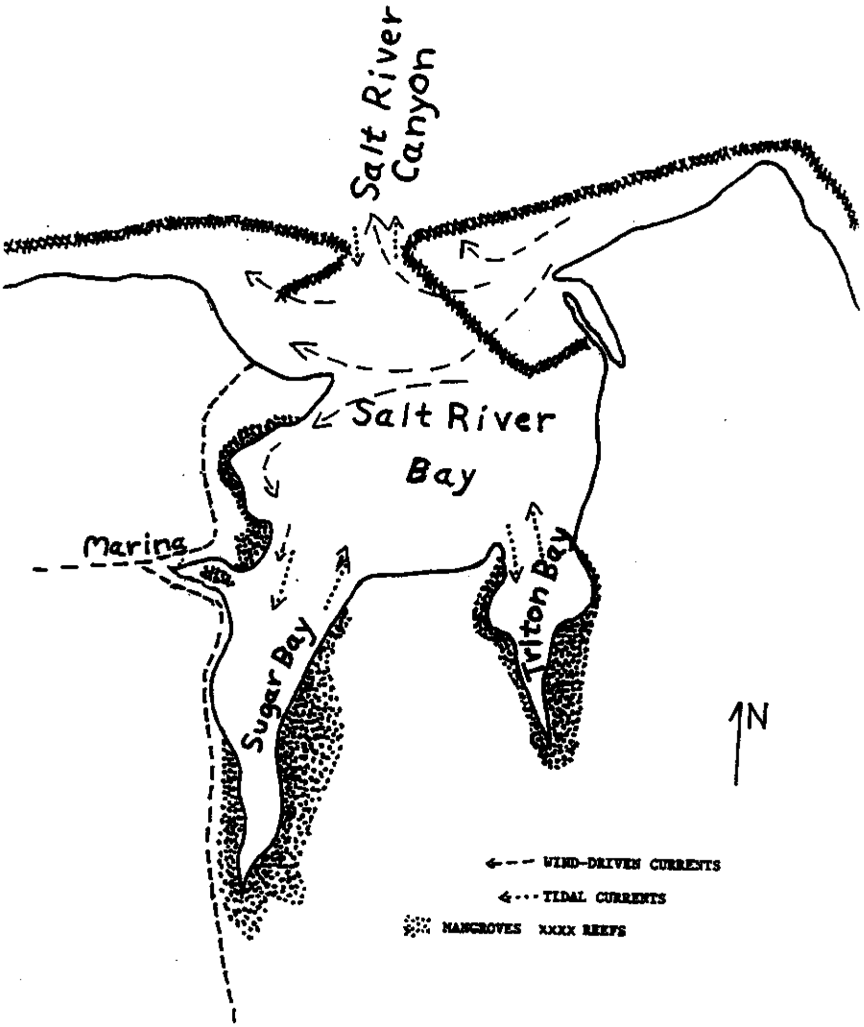

Figure 6. Diagram of major current flow in Salt River.

of St. Croix was only 20% after the first twenty-five days (Shulman and Ogden, 1987), but survivorship increased with distance from the reef due to increased shelter (Shulman, 1985b). Extensive, complex, heterogeneous habitats, such as mangrove prop-roots, reduce predation (Orth *et al.*, 1984; Sogard and Olla, 1993; Hixon, 1991), and increase the overall number of small fish (Hixon and Beets, 1995). Thus, survivorship within the prop-roots was likely relatively high. Many reef species also undergo ontogenetic niche shifts, resulting in emigration from the mangrove nursery habitat to the adult reef habitat. For example, *H. flavolineatum* migrate from back-reef lagoon grassbeds to the reef with increasing size. Finally, Pinto (1988) reported higher growth rates of juveniles within a mangrove lagoon than published species' K values. Further evidence that individuals recruit to the mangroves, grow rapidly in the nursery area, then emigrate to sub adult/adult habitats.

It is important to note that although there was only a single peak in abundance for most species, there was no evidence of a recruitment failure. Due to the transient nature of juveniles in the mangrove habitat, a recruitment failure would have been followed by a prolonged period of lower abundance. Thus, it appears that supply of new recruits occurs over a prolonged period as well as in larger, distinct events. Annual variability in recruitment is not uncommon (Shulman, 1985b), and likely added to the variability in overall abundance. For example, the juvenile population of *H. flavolineatum* was supplied primarily by recruitment over a prolonged period as there was no seasonal or annual trend. In this case, there were no apparent recruitment pulses, but the high abundance of juvenile *H. flavolineatum* precludes the possibility of recruitment failure. *A. chirurgus* was the only species with abundance peaks in both years; February - April. As with other species showing abundance maxima, the highs for *A. chirurgus* were followed by a rapid reduction toward pre-peak abundance levels, likely due to high mortality among the new recruits.

CONCLUSION

The Salt River mangrove lagoon system is an important nursery habitat for many fishes, some of which directly support recreational and commercial fisheries. In light of the interactive system of mangrove lagoon, seagrass, and coral reef, and the complex communities they support, it is important that the evaluation of mangrove lagoon nursery areas is not limited to fishery-important species. Direct recreational exploitation of species that utilize the mangrove nursery area is not the only gauge of the importance of the mangrove habitat to the fishery. Many of the species present in mangrove lagoons are potential prey for recreationally or commercially targeted species (Odum and Heald, 1975; Robertson and Duke, 1987; Thayer *et al.*, 1987). For example, *E. jonesi* are prey for *S. barracuda* (author, pers. obs.), juvenile *L. griseus* diet includes demersal fishes (Thayer *et al.*, 1987), and adult *L. griseus* diet includes a variety of fishes

(Starck, 1971). In addition, while the carbon derived from the mangrove detritus is primarily cycled within the lagoon (Fleming *et al.*, 1990), it directly (detritivores) or indirectly (carnivores) supports the nursery community. The juveniles that then migrate to the reef as adults are effectively exporting the energy of the mangrove lagoon to the reef system. This is a significant contribution, since fish density may be 35 times higher in mangrove prop-root habitat than in seagrass (Thayer *et al.*, 1987). Thus, even species that are not recreationally exploited likely play an important role in the health of the recreational fisheries.

Salt River provides nursery habitat for many fishes, similar to other mangrove lagoons (Baelde, 1990; Van der Velde *et al.*, 1992; Rooker and Dennis, 1991; Thayer *et al.*, 1987; Tzeng and Wang, 1992; Dennis, 1992), and is able to support a diverse community due to its geography. Located at the head of the Salt River Canyon and separated from the open ocean by a fringing reef, the lagoon is exposed to larvae that may otherwise settle in back-reef areas (*e.g.*, *H. flavolineatum*, and *A. chirurgus*), and is able to support nurseries for estuarine (*e.g.*, *E. jonesi*) and reef fishes (*e.g.*, *A. chirurgus*). This is unique for St. Croix, as the other remaining mangrove areas are partially enclosed and farther removed from the fringing reef area. As such they support different communities, primarily fewer reef species (Altona Lagoon, unpublished data).

This study provides information on the importance of mangrove lagoons to marine fishes, already documented in other regions. More importantly, this data emphasizes the importance of the Salt River estuary to the general health of the St. Croix marine fish community, especially the economically significant fisheries. Due to the limited number of mangrove lagoons on St. Croix, and uniqueness of Salt River among those lagoons, it is imperative that the nursery is monitored at regular intervals and appropriate steps taken to preserve the integrity of the habitat.

LITERATURE CITED

Baelde, P. 1990. Differences in the structures of fish assemblages in *Thalassia testudinum* beds in Guadeloupe, French West Indies, and their ecological significance. *Mar. Biol.* **105**: 163-173.

Bohnsack, J.A., D.E. Harper, D.B. McClellan, D.L. Sutherland and M.W. White. 1987. Resource survey of fishes within Looe Key national marine sanctuary. NOAA Tech. Mem. NOS MEMD 5. 108pp.

Boulon, R.H. 1992. Use of mangrove prop-root habitats by fish in the northern U.S. Virgin Islands. *Proc. Gulf Carib. Fish. Inst.* **41**: 189-204.

Cintron-Molero, G. 1987. Caribbean mangroves: a manager's guide. Government of the U.S. Virgin Islands, DPNR, Div. Fish Wild. 21pp.

De Vita, J. 1979. Niche separation and the broken-stick model. *Am. Nat.* **11**(2): 171-178.

Dennis, G.D. 1992. Island mangrove habitats as spawning and nursery areas for commercially important fishes in the Caribbean. *Proc. Gulf Carib. Fish. Inst.* **41**: 205-225.

Fleming, M., G. Lin and L. da Silveira Lobo Sternberg. 1990. Influence of mangrove detritus in an estuarine ecosystem. *Bull. Mar. Sci.* **47**(3): 663-669.

Hixon, M.A. 1991. Predation as a process structuring coral reef fish communities. In, P.F. Sale (ed.) *The Ecology of Fishes on Coral Reefs*. Academic Press, N.Y. 754pp.

Hixon, M.A. and J.P. Beets. 1992. Predation, prey refuges, and the structure of coral-reef fish assemblages. *Ecol. Monogr.* **63**(1): 77-101.

Lipcius, R. M. and D.B. Eggleston. In Press. Shelter limitation in Caribbean spiny lobster, *Panulirus argus*. *Mar. Ecol. Progr. Ser.*

Matthes, H. and J.M. Kapetsky. 1988. Worldwide compendium of mangrove-associated aquatic species of economic importance. FAO Fish. Circ. No. 814.

Odum, W.E. and E.J. Heald. 1975. The detritus-based food web of an estuarine mangrove community. *Estuarine Research*. Academic Pres, N.Y. p. 265-286.

Odum, W.E., C.C McIvor and T.J. Smith, III. 1982. The ecology of the mangroves of south Florida: a community profile. U.S. Fish Wildl. Serv. FWS/OBS-81/24. 144pp.

Orth, R.J., K.L. Heck and J. van Montfrans, Jr. 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships. *Estuaries*. **7**: 339-350.

Pinto, L. 1988. Population dynamics and community structure of fish in the mangroves of Pagbilao, Philippines. *J. Fish Biol.* **33**: 35-43.

Robertson, A.I. and N.C. Duke. 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. *Mar. Biol.* **96**: 193-205.

Rooker, J.R. and G.D. Dennis. 1991. Dieal, lunar and seasonal changes in a mangrove fish assemblage off southwestern Puerto Rico. *Bull. Mar. Sci.* **49**(3): 684-698.

Shulman, M.J. 1985a. Recruitment of coral reef fishes: effects of distribution of predators and shelter. *Ecology*. **66**(3): 1056-1066.

Shulman, M.J. 1985b. Variability in recruitment of coral reef fishes. *J. Exp. Mar. Biol. Ecol.* **89**: 205-219.

Shulman, M.J. and J.C. Ogden. 1987. What controls tropical reef fish populations: recruitment or benthic mortality? An example in the Caribbean reef fish *Haemulon flavolineatum*. *Mar. Ecol. Prog. Ser.* **39**: 233-242.

Sogard, S.M. and B.L. Olla. 1993. The influence of predator presence on utilization of artificial seagrass habitats by juvenile walleye pollack, *Theragra chalcogramma*. *Environ. Biol. Fish.* **37**: 57-65.

Sokal, R.R. and F.J. Rohlf. 1981. *Biometry*. W.H. Freeman & Co., San Francisco. 859pp.

Starck, W.A. II. 1971. Biology of the Gray Snapper, Lutjanus griseus (Linneaus), in the Florida Keys. In W.A. Starck, II and R.E. Schroeder (authors) *Investigations on the Gray Snapper, Lutjanus griseus*. Univ. Miami Press. 149pp.

Thayer, G.W., D.R. Colby and W.F. Hettler, Jr. 1987. Utilization of the red mangrove prop-root habitat by fishes in south Florida. *Mar. Ecol. Progr. Ser.* **35**: 25-38.

Tzeng, W-N and Y-T Wang. 1992. Structure, composition and seasonal dynamics of the larval and juvenile fish community in the mangrove estuary of Tanshui River, Taiwan. *Mar. Biol.* **113**: 481-490.

Van der Velde, G., M.W. Gorissen, C. den Hartog, T. van't Hoff and G.J. Meijer. 1992. Importance of the Lac-lagoon (Bonaire, Netherlands Antilles) for a selected nember of reef fish species. *Hydrobiol.* **247**: 139-140.

Zieman, J.C., S.A. Mack and A.L. Mills. 1984. Role of seagrasses and mangroves in estuarine food webs: temporal and spatial changes in stable isotope composition and amino acid content during decomposition. *Bull. Mar. Sci.* **35**: 380-392.