Use of Mangrove Prop Root Habitats by Fish in the Northern U.S. Virgin Islands

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ABSTRACT

Mangrove lagoon areas at St. Thomas and St. John, U.S. Virgin Islands, were sampled monthly to assess habitat use and nursery importance for fish and important invertebrates. Three study sites of varying degrees of degradation were chosen for study. Visual censuses and standardized trapping were conducted along the mangrove shoreline. All individuals of each species observed or trapped were counted and total and standard lengths of trapped fishes were recorded.

Results demonstrated differences in species diversity, species composition and abundance of fishes between degraded and natural sites. Principal differences between sites seemed to be related more to water quality than to structural complexity of the habitat. Both visual censuses and trapping provided indications of annual recruitment cycles into the nursery habitat by *Sphyraena barracuda*, and *Ocyurus chrysurus*.

INTRODUCTION

The tropical marine mangrove ecosystem has been suggested as an important nursery and juvenile habitat for many species of reef fish and invertebrates (Heald and Odum, 1970; Odum *et al.*, 1982; Thayer *et al.*, 1987). The nursery quality of the mangrove system is due possibly to the availability of shelter for juveniles in the prop roots and to an abundant supply of organic detrital food (Ogden and Gladfelter, 1983).

Coastal mangroves serve as a depository for runoff of sediment and particulate matter from uplands, thus indirectly protecting other nearshore communities from sedimentation and eutrophication. An additional important feature is the export of particulate organic carbon produced by the decomposition of leaf litter. Although food webs based on this mangrove carbon do exist, the value of this carbon input to secondary consumers in nearshore waters is not clear (Odum *et al.*, 1982).

In the Virgin Islands, as in most other tropical countries around the world, the coastal mangrove ecosystem is being destroyed at an alarming rate (Odum and Johannes, 1975; Towle, 1985). In less developed nations, mangroves are harvested for wood, bark and other products. In developed countries, mangroves are removed to make space for marinas or filled for residential development. Mangrove forests are the sites of most sewage treatment plants which discharge variously treated effluents into their waters, producing eutrophication of prop root communities. Landfills commonly occur behind them, altering the terrestrial conditions necessary for their existence and producing chemical pollutants which make their way into the water.

The destruction of mangrove systems allows terrigenous sediments to pass directly into the marine environment, seriously affecting nearshore seagrass beds and coral reefs (Ogden and Gladfelter, 1983). Over time, nutrients from natural mangrove decomposition processes are diminished which may lower the productivity of other nearshore marine communities. Additionally, the refuges and nursery habitat for many fishes and invertebrates are destroyed and recruitment into nearby communities is reduced (Ogden and Gladfelter, 1983). The destruction of estuaries in Florida and the Gulf of Mexico has been suggested as threatening fishery resources of adjacent waters (Lindall, 1973; Lindall and Saloman, 1977).

Although elevated nutrient loads that result from the discharge of partially treated sewage may be favorable for mangrove growth (Odum and Johannes, 1975), little has been done to document the effect this has on the nursery value for fish species utilizing the prop root habitat. Because dissolved oxygen levels are relatively low in most mangrove waters, the input of sewage might lead to mortality of the associated marine fauna (Austin and Austin, 1971).

Mangrove systems in the U.S. Virgin Islands can best be described as fringing forests along oceanic bays and lagoons. These can be characterized by generally having clear water, sand substrates and high, stable salinities (Odum *et al.*, 1982). In the northern Virgin Islands, the major stands of mangroves occur in Coral Bay, St. John; Mary's Creek, St. John; Benner Bay, St. Thomas and the Mangrove Lagoon, St. Thomas. Coral Bay and Mary's Creek are described in Boulon (1986). The Mangrove Lagoon is described in Towle (1985). Benner Bay is described in the present study. Of the four areas, the Mangrove Lagoon is the best studied. Water quality and environmental conditions of the Mangrove Lagoon were described by Grigg and van Eepoel (1971) but have changed considerably since then. Olsen *et al.* (1973) described the fish communities in the Mangrove Lagoon; however, because sampling was conducted primarily in sand and seagrass habitats, the results of that study may not reflect the species composition and abundances of fish that actually utilize the mangrove prop root habitat.

The present study was initiated to document the use of different mangrove systems in the northern U.S. Virgin Islands. Additionally, these observations on the fish communities can serve as a baseline data set, against which changes caused by stress or removal of stress on the system can be monitored.

METHODS

The three locations selected for this study represent the three major mangrove embayments in the northern U.S. Virgin Islands. They include Coral

Bay, St. John (Hurricane Hole), Vessup Bay (St. Thomas), and Benner Bay (the "Mangrove Lagoon") on St. Thomas (Figure 1). The Mangrove Lagoon was subdivided into three portions; inner, middle and outer (Figure 2), to stratify sampling by environmental quality. These five sites represent a spectrum of water and habitat quality, from the inner Mangrove Lagoon, with approximately 0.45 mgpd of "treated" sewage effluent, and the St. Thomas Municipal Landfill that produces an undetermined amount of leachate, to Hurricane Hole in the Virgin Islands National Park, which can still be considered pristine.

Varying degrees of environmental water quality required that different methodologies or combinations of methodologies be selected for the three study sites. Both the inner portion of the Mangrove Lagoon and Vessup Bay receive sewage discharge and are therefore not suitable areas for a diver to perform visual censuses. Consequently, traps were used in these areas. To be able to compare the inner Mangrove Lagoon to the middle and outer portions, it was necessary to use traps there as well. Visual censuses were conducted in the middle and outer portions of the Mangrove Lagoon as well as at Hurricane Hole. No trapping was conducted in Hurricane Hole due to the distance of the site and the logistics and time needed to transport and sample the traps.

Trapping was conducted in the Mangrove Lagoon and Vessup Bay monthly from December 1986 to October 1988 using 92 cm x 56 cm x 20 cm traps of 1.25 cm square vinyl-coated hardware cloth. Five traps were deployed at each site for one five-day period per month and were pulled, moved, rebaited and reset each day to obtain four samples per month. Traps were set within one meter of the seaward edge of the prop roots, with the trap funnel facing the mangroves. Traps were buoyed with hard foam floats. All traps were baited with blue fry (*Jenkinsia lamprotaenia*) in an 8 cm cubed bait basket of the same material as the traps. All fish caught were placed in a container of sea water, measured (standard and total lengths), enumerated and released at the same location where they were caught.

Visual censuses were conducted in the middle and outer portions of the Mangrove Lagoon and in the four finger bays of Hurricane Hole 12 times during the period of December 1986 to September 1988. Visual censuses were made by swimming pre-established, marked, 50 meter transects along the seaward edge of the mangroves. Eight transects were established among the mangrove cays that form the eastern side of the middle Mangrove Lagoon and eight transects were established in the channels that form the outer lagoon. The western side of the middle Mangrove Lagoon has poorer water quality and the decision was made that visual sampling there was unsafe. Four transects were established in each finger bay of Hurricane Hole except the innermost one (Borck Creek), where water depth on the north side is too shallow to produce significant habitat or to allow census. Only two transects were established there.

All individuals of all species of fish observed from within the prop root

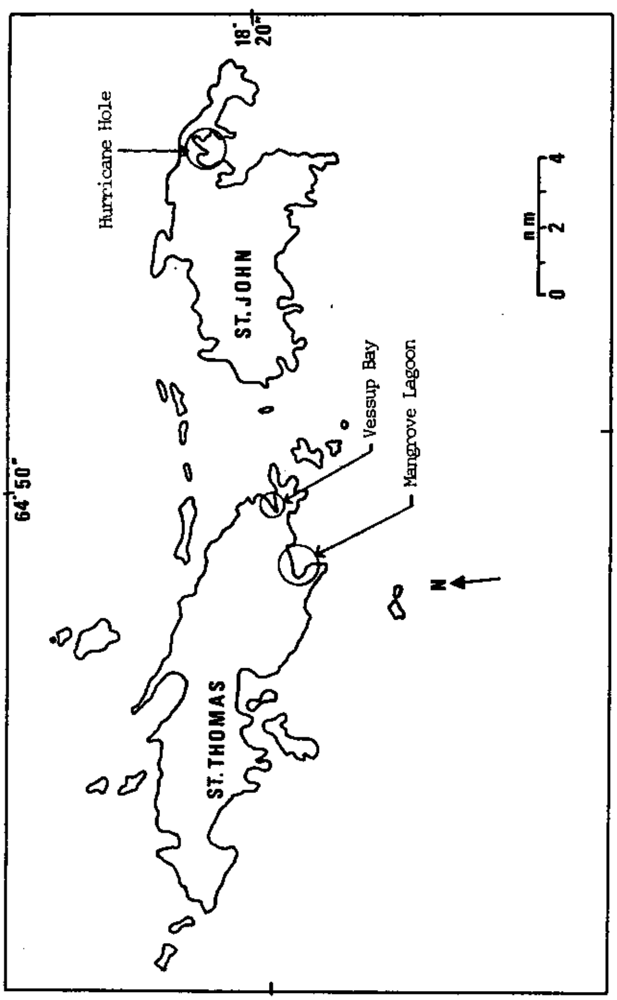

Figure 1. Mangrove study sites in the northern U.S. Virgin Islands.

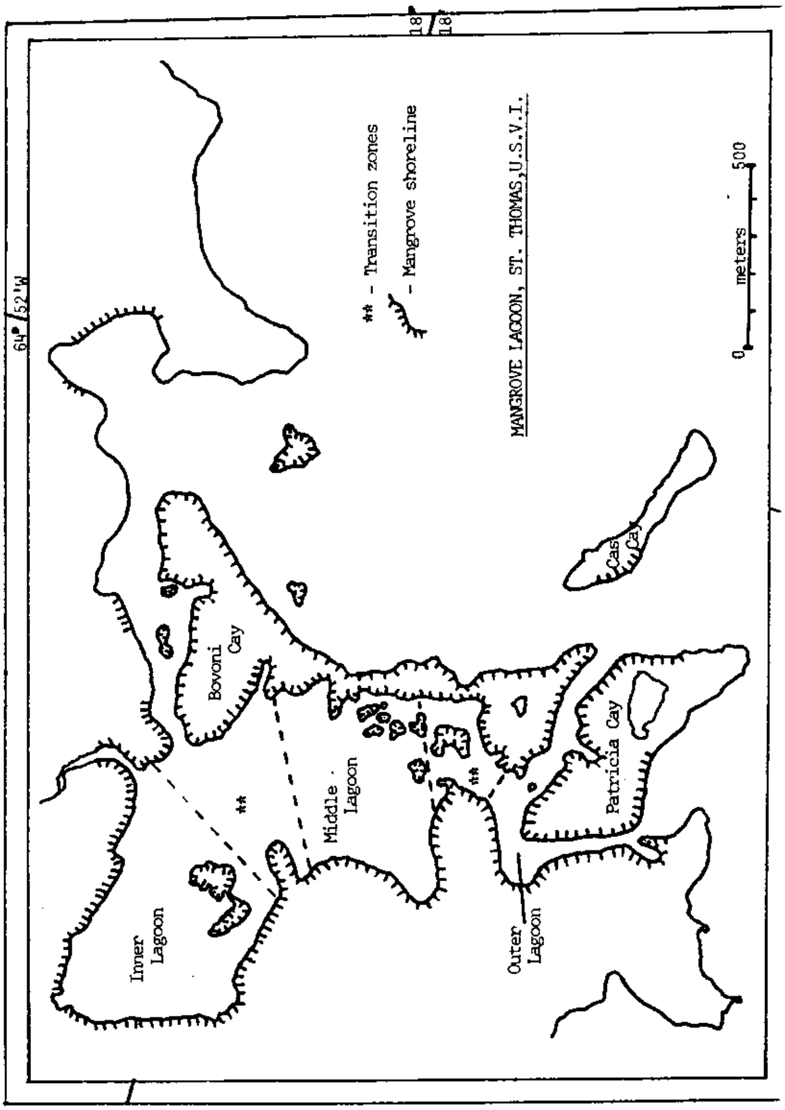

Figure 2. The Mangrove Lagoon, St. Thomas, U.S.V.I., showing subdivisions for sampling.

system to approximately two meters seaward of the root line were counted and sizes were estimated. All data was recorded on mylar sheets over pre-printed forms. The preprinted forms eliminated the need to write the species names for each transect and thus saved time. Each transect was swum in approximately 20 to 25 minutes. This period was slow enough to observe cryptic species and yet fast enough to keep track of fish that moved ahead of the diver and might be either not counted or double counted. Large schools of fish were estimated in the 10's, 100's or 1000's.

RESULTS

Species of fish recorded varied considerably between methods used and among locations sampled (Figure 3, Table 1). Although visual censuses generally yielded a greater number of species observed than did trapping, the results demonstrated differences among locations. The inner Mangrove Lagoon yielded the lowest number of species followed by Vessup Bay, middle Mangrove Lagoon, outer Mangrove Lagoon and Hurricane Hole. The principal species that were observed in visual censuses but rarely caught in traps were *Sphyraena barracuda*, *J. lamprotaemia*, *Atherinomorus stipes*, and very small species like blennies, gobies, and *Amblycirrhitus pinos*. Most of these species only occur in the areas having clean water.

Each trap was set in the same general area (± 100m) at each location, so trap data could be pooled to calculate differences in numbers of species and numbers of fish per area. Mean number of species varied considerably among areas (Figure 4). The Mangrove Lagoon was stratified into areas of different species richness; the inner lagoon had the lowest (average of all traps by area = .84; N = 340), the outer had the highest (4.23) and the middle fell between (2.11). The average species richness for Vessup Bay was intermediate between the inner and middle areas of Mangrove Lagoon with an average of 1.35 (N = 360). This is consistent with general observation on relative water quality.

Mean number of individual fishes per trap location demonstrated a pattern similar to that of species richness (Figure 5). The inner Mangrove Lagoon had the lowest number of individuals per trap (average of all traps by area -1.56) (N = 340), the outer lagoon had the highest (19.06), and the middle lagoon fell between (7.52). Abundance for Vessup Bay again fell between values for the inner and middle Mangrove Lagoon (2.59; N = 360).

All visual census transects were permanently established and marked, so data for each transect were pooled to calculate mean numbers of species and individuals per transect. The census data demonstrated a considerable amount of variation both within and among areas (Figure 6). In spite of this variation a significant difference was discerned in numbers of species per 50 m transect among areas. From 12 censuses per transect in the Mangrove Lagoon, the middle lagoon had a lower mean number of species per transect than did the

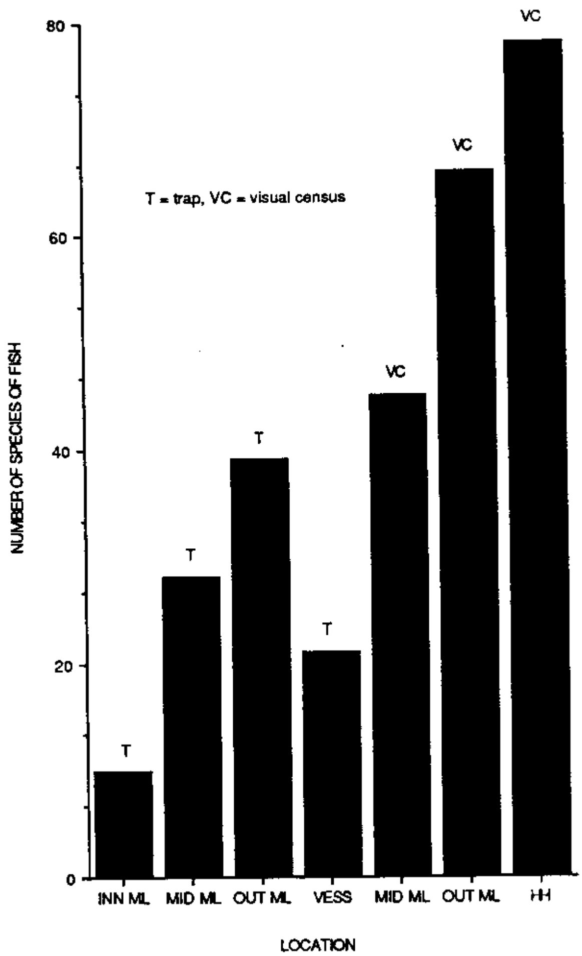

Figure 3. Total number of fish species observed at each location from trap and census data; ML = Mangrove Lagoon, Vess = Vessup Bay, HH = Hurricane Hole.

Table 1. Species observed at each study site, by method.

Fish species	Mangrove Lagoon					Vessup Bay	Hurricane Hole
	Traps			Visual Census			Visual Census
	Inner	Middle	Outer	Middle	Outer	Traps	
Gymnothorax funebris	X	X	X	X		X	
G. moringa			X				
Harengula humeralis				X			
Jenkinsia lamprotaenia				X	X		X
Atherinomorous stipes				X	X		X
Hyporamphus unifasciatus							X
Synodus intermedius							X
Holocentrus ascensionis		X	X		X		X
Adioryx coruscus						X	X
Aulostomus maculatus					X	X	X
Epinephelus guttatus							X
E. striatus			X		X		X
Serranus tabacarius					X		
Hypoplectrus spp.			X	X	X		X
Apogon binotatus			X				X
Caranx bartholomaei				X	X		X
C. crysos	X						
C. ruber	X				X		X
Trachiotus spp.							X
Lutjanus analis							X
L. apodus	X	X	X	X	X	X	X
L. griseus	X	X	X	X	X	X	X
L. jocu	X			X	X		X
L. mahogoni					X		X
L. synagris		X	X		X		X
L. buccanella							X
Ocyurus chrysurus		X	X	X	X	X	X
Eucinostomus argenteus	X	X	X	X	X	X	X
Anisotremus virginicus				X	X		X
Haemulon album		X			X		
H. macrostomum					X		X
H. melanurum					X		
H. aurolineatum		X	X	X	X	X	X
H. flavolineatum		X	X	X	X	X	X
H. parrai			X		X		
H. plumieri			X	X	X		X
H. sciurus		X	X	X	X	X	X
H. chrysargyreum							X
H. spp.		X	X	X	X		X
Archosargus rhomboidalis	X	X	X	X	X	X	X
Calamus bajonado				X	X		X
Lagodon rhomboides				X			
Mulloidichthys martinicus					X		X
Pseudupeneus maculatus			X		X		X
Chaetodon capistratus		X	X	X	X	X	X
C. sedentarius							X
Holacanthus ciliaris					X		X

Table 1. Ctd.

Fish species	Mangrove Lagoon Traps Inner	Mangrove Lagoon Traps Middle	Mangrove Lagoon Traps Outer	Mangrove Lagoon Visual Census Middle	Mangrove Lagoon Visual Census Outer	Vessup Bay Traps	Hurricane Hole Visual Census
Pomacanthus arcuatus			X		X		
P. paru				X	X		X
Abudefduf saxatilis			X	X	X	X	X
Microspathodon chrysurus		X	X		X		X
Stegastes partitus					X		X
S. dorsopunicans		X	X	X	X		X
S. leucostictus		X	X	X	X		X
S. planifrons			X		X		X
S. variabilis			X	X	X		X
Amblycirrhitus pinos				X	X		X
Halichoeres bivittatus		X	X	X	X	X	X
H. poeyi					X		
H. radiatus					X		X
H. garnoti					X		X
Lachnolaimus maximus		X		X	X		
Thalassoma bifasciatum			X	X	X		X
Scarus croicensis				X	X		X
S. taeniopterus		X	X	X	X		X
S. vetula					X		
S. guacamaia				X			
Nicholsina usta							X
Sparisoma atomarium				X	X		X
S. aurofrenatum			X	X			X
S. chrysopterum		X	X	X	X		X
S. radians		X	X	X	X		X
S. viride				X	X		X
Scaridae spp.		X	X	X	X		X
Sphyraena barracuda		X		X	X		X
Labrisomus nuchipinnis						X	
Malacoctenus macropus							X
M. triangulatus							X
Ophioblennius atlanticus						X	
Coryphopterus glaucofraenum				X	X		X
C. personatus							X
Bathygobius soporator	X	X				X	
Balistes vetula							X
Acanthurus bahianus			X	X	X		X
A. chirurgus		X	X	X	X		X
A. coeruleus			X	X	X		X
Cantherhinus pullus					X		X
Monacanthus ciliatus						X	
M. tuckeri							X
Lactophrys trigonus						X	X
L. triqueter							X
L. bicaudalis							X
Canthigaster rostrata		X	X		X	X	X

Table 1. Ctd.

Fish species	**Mangrove Lagoon**					**Vessup Bay**	**Hurricane Hole**
	Traps			**Visual Census**			**Visual Census**
	Inner	**Middle**	**Outer**	**Middle**	**Outer**	**Traps**	
Sphoeroides testudineus	X	X	X	X	X	X	
S. spengleri					X		X
Diodon hystrix					X		X
Chilomycterus spp.							X

outer lagoon. Hurricane Hole, with 13 censuses per transect, had the highest mean number of species per transect.

Mean numbers of individual fish per transect (Figure 7) demonstrated results similar to those based on species richness. In spite of considerable variation within the outer Mangrove Lagoon and Hurricane Hole transects, the three locations demonstrated significant difference in mean numbers per transect. As with species, the middle Mangrove Lagoon had the lowest, Hurricane Hole, the highest and the outer Mangrove Lagoon had an intermediate number of individual fish per transect.

Because the visual census transects yielded numbers of fish species and individuals per unit length of mangroves, the data could be reduced to numbers of species and individuals per linear meter of mangrove. This provides a quantitative measure of a particular mangrove habitat. The results of this analysis are shown in Figure 8.

As a preliminary analysis of fish sizes obtained using the traps, three species with fishery importance were selected. One hundred standard measurements were selected randomly from the entire Mangrove Lagoon data set for each species. The mean size of *Ocyurus chrysurus* in the Mangrove Lagoon was 95.83 mm (range: 55.00-152.00 mm, SD = 17.99). The mean size of *Haemulon flavolineatum* in the Mangrove Lagoon was 72.84 mm (range: 50.00-110.00 mm, SD = 12.76). The mean size of *Lutjanus apodus* was 93.34 mm (range: 45.00- 216.00 mm, SD = 31.22).

Future investigation and analysis should provide additional information. Seasonality of the abundance of certain species of fish was apparent. For example, during April and May of the two consecutive sampling years as many as two to three dozen *S. barracuda* in the 2 to 3 cm size range were counted in each 50 m visual transect. During the year, each cohort decreased in numbers and increased in body size until the next year class recruited into the system. Similar patterns of recruitment and growth were observed for *O. chrysurus* in the trap data.

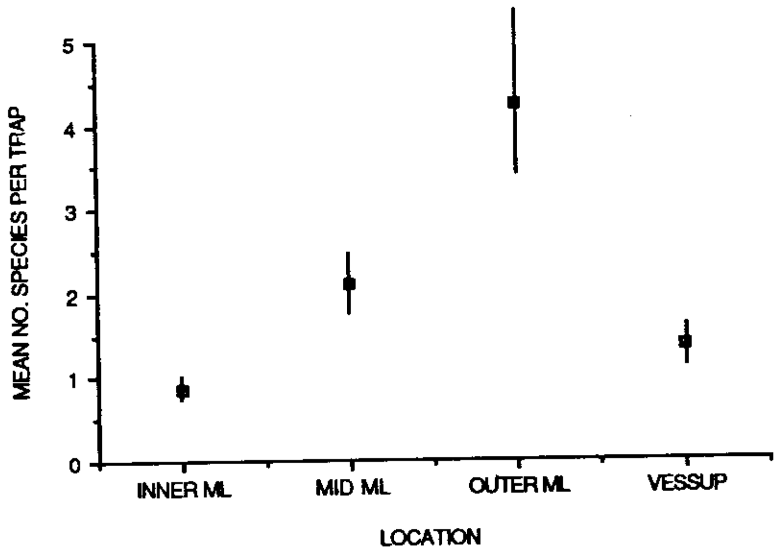

Figure 4. Mean number of species per trap by location. Vertical bar shows range. ML = Mangrove Lagoon.

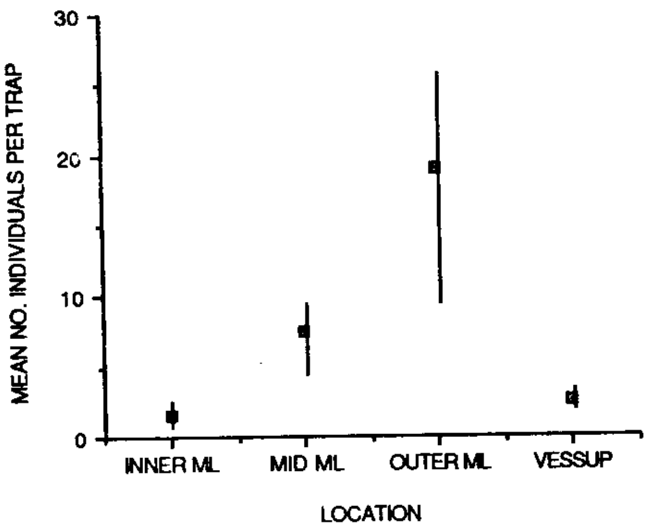

Figure 5. Mean number of individuals per trap by location. Vertical bar shows range. ML = Mangrove Lagoon.

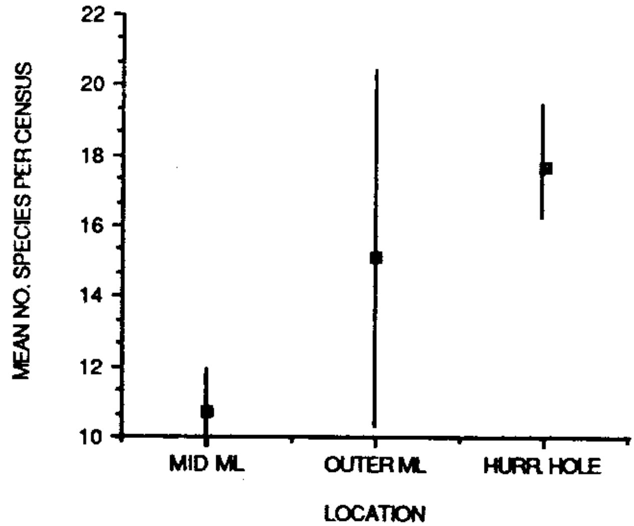

Figure 6. Mean number of species per census by location. Vertical bar shows range. ML = Mangrove lagoon.

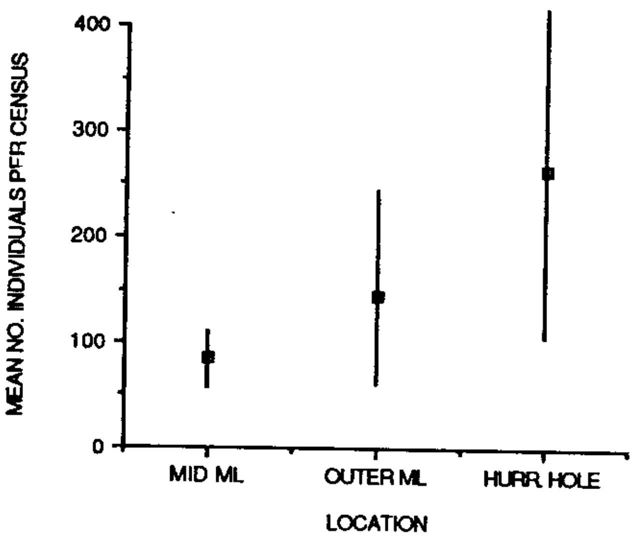

Figure 7. Mean number of individuals per census by location. Vertical bar shows range. ML = Mangrove Lagoon.

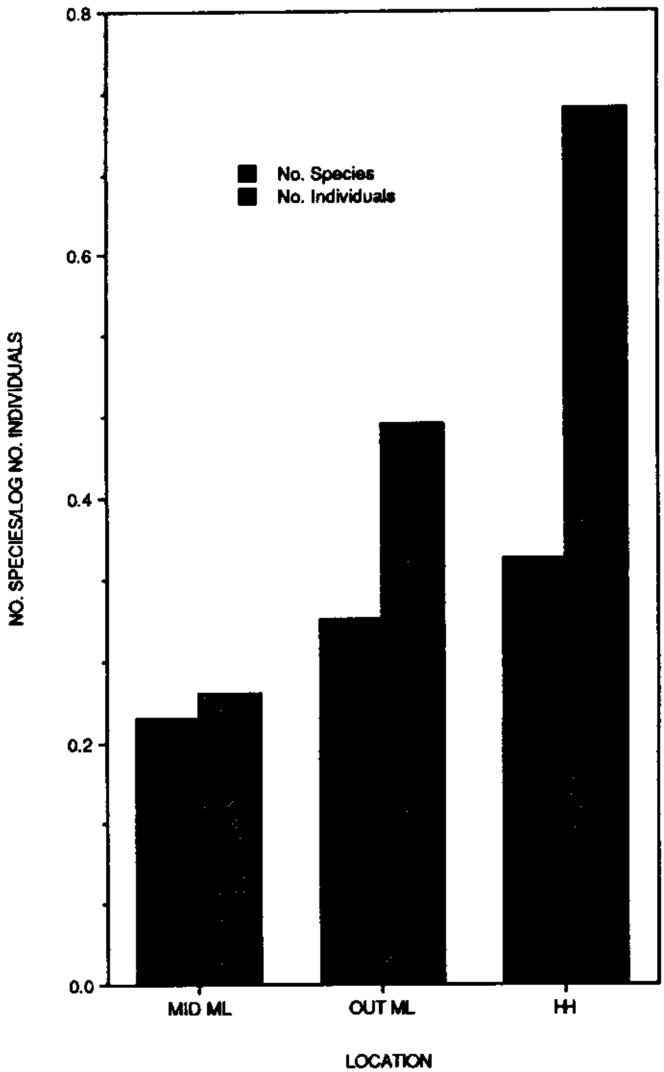

Figure 8. Number of species and log number of individuals per linear meter of mangrove shoreline. Visual census data from Mangrove Lagoon (ML) and Hurricane Hole (HH).

DISCUSSION

The value (or health) of marine mangrove ecosystems in the northern U.S. Virgin Islands is demonstrated to be quantifiable in terms of species richness and abundance by location and unit of mangroves. Based on this investigation it is clear that certain mangrove areas in the northern U.S. Virgin Islands (Hurricane Hole and the outer Mangrove Lagoon) are productive nursery habitat for many fish species. The relative importance of mangrove areas and seagrass beds as nursery habitat remains to be documented. However, it is indisputable that the destruction of mangrove nursery areas would have a serious impact on recruitment into other nearshore marine ecosystems, such as coral reefs.

The relationship between water quality and the numbers of species and individuals of fish present in the mangrove prop root habitat appears evident although no water quality parameters were measured to support this. Effluent from sewage treatment plants is probably the main factor leading to habitat degradation through eutrophication, decrease in dissolved oxygen and increase in suspended solids. Future work in this area will include monitoring water quality parameters, such as dissolved oxygen and turbidity, in an attempt to quantify this relationship. An Environmental Impact Statement has been approved by the U.S. Environmental Protection Agency and local authorities which proposes to remove the sewage treatment plant from the Mangrove Lagoon. A new plant is to be built and effluent discharged to an ocean outfall. The Vessup Bay plant may be connected to the new system. By removing this discharge into the bays, it is hoped that the present conditions will reverse and the prop root habitat will be restored to a healthier condition. If this happens, fish communities in these areas should increase in numbers of species and individuals. If sewage effluent is the primary factor leading to the degradation of these areas then monitoring after cessation of sewage discharge should demonstrate this.

From the preliminary analysis of sizes, it is obvious that the majority of the reef fish species caught in traps and observed in visual censuses were juveniles well below minimum sizes at maturity (CFMC, 1985). Mean size by species from visual census data were apparently slightly larger, perhaps because larger individuals do not enter the traps as readily. Adult *Lutjanus griseus* were observed in large numbers in the prop root habitat, but juveniles were rarely observed or caught in traps.

It was obvious during the study that certain species exhibit a strong seasonality in abundance. During the visual censuses, *S. barracuda* appeared in large numbers (up to 25 per 50m transect during April and May of each year in the 2 to 3 cm size range). During subsequent censuses the numbers gradually decreased and the sizes of individuals increased. Thus, year classes could be followed. *O. chrysurus* seemed to demonstrate a seasonal trend in abundance based on trap data. *Archosargus rhomboidalis* demonstrated seasonality both in trap and in visual census data.

The value of a mangrove system as a nursery area expressed in numbers of species or individuals per meter could be a valid means to compare locations. Additionally, by assigning a "real value" to a location, arguments can be made against development which might reduce that value or for a management action which might increase the value. The real values are numbers that resource planners, managers and users can relate to and use to justify protection or enhancement of a mangrove area (*e.g.*, numbers of fish which can recruit to reefs or algal plains to be caught by fishermen, thus increasing or maintaining money flow in the economy). When considering the numbers that are presented for value per linear meter of mangrove shoreline, it must be understood that this is essentially one moment in time, and the long-term value is only realized when time and other factors are calculated. By factoring in residence time by species, seasonal changes in abundance and other variables, the long-term value per linear meter of mangrove shoreline will be considerably more impressive than that which is presented here. At present, the information and techniques are not available to calculate such long-term value.

The two methods used to sample mangrove prop root habitat yielded somewhat different results, due to biases inherent in each method. Trapping tends to underrepresent species which avoid traps (*e.g.*, *S. barracuda*, *L. griseus*) or which are of such size to pass through the mesh and not be caught (*e.g.*, blennies, gobies, *A. pinos*). The method may also concentrate some species (*e.g.*, *O. chrysyrus*), which yields different results from the visual census method. Conversely, the wariness of certain species may yield a lower frequency of occurrence in the visual censuses. A combination of methods clearly presents a more complete picture of fish assemblages in this habitat than would a single method. Combining these with an unattended, continuous-recording method such as an underwater video system would certainly answer additional questions and allow assessment of the biases of the other methods.

ACKNOWLEDGEMENTS

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