FINAL REPORT

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INTRODUCTION

This report documents activities related to artificial reef work in the U.S. Virgin Islands from October 1, 1996 to September 30, 2000 in accordance with the F-10 Grant from the U.S. Fish & Wildlife Service on Artificial Reef Development, Nourishment, and Monitoring.

JOB 1 – ARTIFICIAL REEF LITERATURE REVIEW

General Artificial Reef Literature

Artificial reefs have been used for centuries. There is archeological evidence that Australian aborigines have been harvesting marine and freshwater food using artificial reef systems (Carstairs 1988).

Artificial reefs are commonly used as a tool for the management of fisheries and aquatic habitats (Christian et al 1998). They have been used for a diverse number of reasons. They have been used:

1. to promote of fishery catches (Jensen 1999);
2. for habitat protection such as for anti-trawling devices in the Mediterranean for protection of seagrass beds (Sanchez-Jerez and Ramos-Espla 2000);
3. for recreational fisheries (Jensen 1999);
4. to combat effects of eutrophication (Stachowitsch 1998);
5. to facilitate recovery of coastal fisheries resources and increase biological productivity (Abdul and Mohd 1990);
6. to physically protect the seabed and coast (Gardner et al 1997);
7. for erosion control (Bruno et al 1996); and
8. for enhancement of key stocks such as lobster (Jensen et al 1993).

Objectives of artificial reef programs are often stated (Christian et al 1998). However, information about the performance of artificial reefs in achieving these objectives is often limited. Monitoring artificial reefs needs to be an essential part of any artificial reef program.

A social and economic framework for analyzing artificial reefs was proposed by Willmann (1990). Whitmarsh (1996a) noted that the in order to maximize economic benefits of an artificial reef, property rights or harvesting rights need to be clearly defined. Whitmarsh (1996b) also noted that there were significant risks in developing artificial reefs due to the uncertainty regarding the benefits of artificial reef construction.

Artificial reefs have been constructed of a variety of materials including: oil platforms and rigs (Wiseman 2000), car bodies, concrete culverts, building rubble, quarry rock, prefabricated concrete fish houses (Stone 1974), various waste materials (Collins and Jensen 1996) such as fly ash and gypsum (Pickering 1996), ships (Eggen 1997), barges, boxcars, buses, dumpsters, concrete rubble, and concrete modules (Buchanan and Cirino 1994).

Studies in Florida indicate that "artificial reefs attracted juvenile and young adult fishes and had significantly more species, higher diversity, more individuals, and greater total biomass of fishes per area than did the nonreef controls" (Heise and Bortone 1999). Bortone et al (1998) noted that reef fish assemblages could impact available food resources adjacent to artificial reefs.

There has been a long standing debate on whether artificial reefs aggregate fish or increase biomass of fish. Polovina (1994) noted that artificial reefs could: 1) redistribute biomass, 2) aggregate unexploited biomass, or 3) increase total biomass. According to Polovina (1994), new production from artificial reefs can range from 0.02-0.5 kg/m^3, while catches from artificial reef can range from 5 to 20 kg/m^3. Therefore, artificial reef primarily serve to aggregate fishes.

Brock (1994) reported that artificial reefs used as part of dive "eco-tourism" packages provide greater economic return than when an artificial reef is used for commercial fisheries. If the objective of artificial reef development is economic gains and there is a viable tourist industry, artificial reefs for non-consumptive uses may provide the highest economic benefits.

Artificial reefs have been developed to mitigate loss of other marine habitat (Deysher et al 1998). Barnett et al (1994) suggested that the Biological Evaluation Standardized Technique (BEST) for habitat valuation be used to assess the mitigative value of an artificial reef.

According to Chou (1997), without proper planning and long-term management, artificial reefs become nothing more than pollutants that contribute to the further degradation of the marine environment. MacDonald (1994) noted that U.S. and international regulatory measures on artificial reefs are designed to prevent development of artificial reefs as a pretext for disguised ocean dumping. According to MacDonald (1994), inconsistent agency actions can often create opportunity for disguised ocean dumping.

To obtain community support for artificial reefs, Murray and Betz (1994) suggested that sport divers share in reef building expenditures and support an artificial reef stamp tax. In addition, they recommended improvements of artificial reef information programs. Halusky (1987) reported that volunteer sport divers have been trained and used to survey Florida's artificial reefs. Their tasks have included pre- and post-reef site and placement surveys, finding and verifying old artificial reef sites, and monitoring reefs. In addition, sport divers were essential for building community awareness of any artificial reef program.

Since the U.S.V.I. experiences periodic hurricanes, documented artificial reefs damage by hurricanes is of special interest. In 1989, Hurricane Hugo hit South Carolina, including its marine artificial reefs (Bell and Hall 1994). Detected damage to reef materials was slight and movement of materials was minimal. However, one small reef structure move in excess of 1.9

km, and one 140 m long ship in 33 m of water also moved. According to Bell and Hall (1994), effects on reef fish communities and epibenthic invertebrates were minimal and short-term in nature.

In 1992, Hurricane Andrew hit Florida (Blair et al 1994). Impacts to Florida artificial reefs varied from no impact to total structural modification. Blair et al (1994) reported that there was no correlation between damage and location, orientation or depth of reef material.

USVI Artificial Reef Reports

In 1960, a large artificial reef was constructed south of St. John, U.S.V.I. (Ogden and Ebersole 1981). This site was composed of 800 concrete blocks in a seagrass bed. According to Ogden and Ebersole (1981), results of fish population surveys completed between 1975 and 1979 at this artificial reef site and at a 1963 poison station were similar.

In 1975, the Virgin Islands Bureau of Fish and Wildlife conducted a fish trap survey of an artificial reef site in Pillsbury Sound between Coki Point and Thatch Cay (Mudre and Day 1981). This artificial reef was composed of scrapped automobiles, tires, and derelict vessels (see Table 1 below). Site depth was 22 m and the site measured 550 x 91 m.

Table 1. List of Materials Deployed at the Pillsbury Sound Artificial Reef Site, 1975-1979*

Date	Item	Notes
7/6/75	Mary King Barge	30.3 m x 12.1 m
7/30/75	930 tires	
8/20/75	M.V. Rogers	41.8 m x 9.4 m
7/25/76	1,000 tires	
7/30/77	1,000 tires	
7/31/78	1,692 tires	
8/15/78	768 tires	
2/7/79	Two steel containers	10.6 m x 2.4 m diameter
7/31/79	1,200 tires	
8/21/79	333 tires	

*source: Mudre and Day (1981)

Beets (1989) reported on combining FADs with benthic artificial reefs to assess fish enhancement. These experiments were located 2 km south of St. Thomas, USVI. The following treatments were investigated: (1) 2 artificial reefs constructed of equal quantities of conch shells; (2) 2 conch shell reefs surrounded with a cluster of 5 mid-water FADs, and (3) 2 clusters of FADS with no associated artificial reefs. According to Beets (1989), the FAD/artificial reef combinations (number 2 above) attracted more species and individuals than the other two treatments.

Existing USVI Artificial Reefs

In the U.S. Virgin Islands, artificial reefs have existed for many years. Table 2 below lists artificial reef material deployed around St. Thomas and St. John identified from U.S.V.I. Division of Fish and Wildlife files.

Table 2. List of Artificial Reef Materials Deployed prior to 1990*1

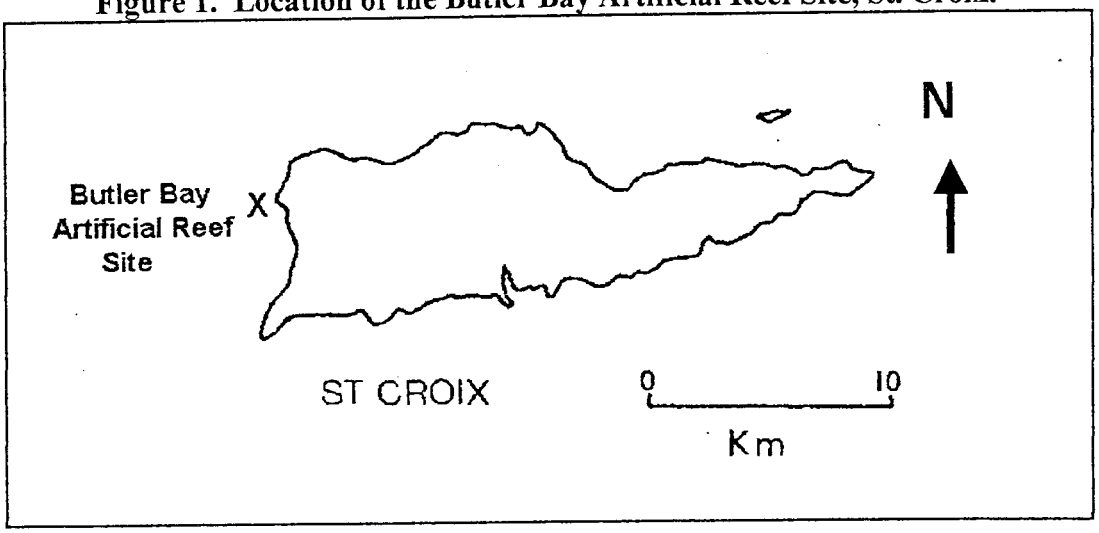
Location	Item	Length *2	Date	Depth *2	Condition
NW Carvel Rock	Cessna 170 airplane	12	1985	20-25	Partially intact
SW Lovango Cay	Mein Captain steel hull ferry	20	1989	20	Intact
SW Mingo Cay	Wooden ferry	14	1970's	15	Broken up
NW Water Bay	General Rogers/Mary Kay tug/barge/tires	50+	1970's	65	Intact
E. Little St. James Island	Wooden freighter	14	1988	18	Broken up
E. Great St. James Island	Caridad, steel hull	30	1970's	6-12	Broken up
S. Dog Rock	Steel barge	30		7-10	Broken up
S. Buck Island	Wye steel hull	70	1967	3-7	Broken up
W. Buck Island	Cartanser Sr. steel hull	43	1978	6-12	Partially intact
WNW Green Cay	Steel barges	Various	1940's	12	Partially intact
N. Water Island	Steel ships	30-40		13	Intact
S. Morningstar	Steel pontoons	40	1940's	15-20	Intact
S. Black Point	Apache airplane		1986	15	Broken up
S. Saba Island	Steel grain ship	75	1940's	18-37	Partially intact
N. Flat Cay	Steel hull	30	1960's	6	Broken up
Fortuna Bay	Constellation airplane		Late 1970's	10	Broken up
W. Airport	Miss Opportunity steel hull ferry	30	1985	25-30	Partially intact
SW Roads	Witshoal freighter	100+	1970s	90+	Intact

*notes:
1. source: DFW files
2. no unit of measure provided

On St. Croix, the Butler Bay artificial reef site was initially permitted in 1974 (Division of Fish and Wildlife 1996, and Beets 1992). This site is located at 17^0 45.1'N, 64^0 53.9'W at a depth of between 13.6 to 36.4 m. In 1994, this site was expanded to 242 x 197 m (14 September 1994 letter from Roy E. Adams, DPNR Commissioner to Mr. Osvaldo Collazao, Army Corps of Engineers). The new area was defined as within the following coordinates: (a) 17^0 45.267'N, 64^0 53.547'W; (b) 17^0 45.131'N, 64^0 53.603'W; (c) 17^0 45.147'N, 64^0 53.639'W; and (d) 17^0

45.234'N, 64^0 53.599'W. Figure 1 below illustrates the general location of the Butler Bay artificial reef site in relationship to the island of St. Croix.

Figure 1. Location of the Butler Bay Artificial Reef Site, St. Croix.



By 1996, there were three major artificial reef sites in St. Thomas and St. John (Beets 1992). These included:

(1) 1 nm SE of Saba Island, St. Thomas at 18^0 17.4'N, 64^0 59.0'W in about 30 m;

(2) 2.2 nm ESE of Buck Island St. Thomas at 18^0 16.2'N, 64^0 51.8'W in about 30 m; and

(3) south of St. John at 18^0 17.7'N, 64^0 44.9'W in about 30 m.

The relative location of these three sites in relationship to St. Thomas and St. John are presented in Figure 2 below.

Various materials have been deployed at the artificial reef sites in the U.S. Virgin Islands. Materials deployed prior to this grant period (October 1996) are listed in Tables 3 (Butler Bay, St. Croix), Table 4 (for the Saba Island site) and Table 5 (for the Buck Island, St. Thomas, and south St. John sites).

JOB 2 - SURVEYS OF FUTURE POSSIBLE ARTIFICIAL REEF SITES

St. Croix

In 1997, reconnaissance dives (Tobias 1998) were completed at the following locations: Lang Bank (east of St. Croix), Scotch Bank (north coast of St. Croix), and Sprat Hole (west coast of St. Croix). These locations are around the island of St. Croix (see Figure 3 below).

Figure 2. Locations of Artificial Reef Sites near St. Thomas and St. John.

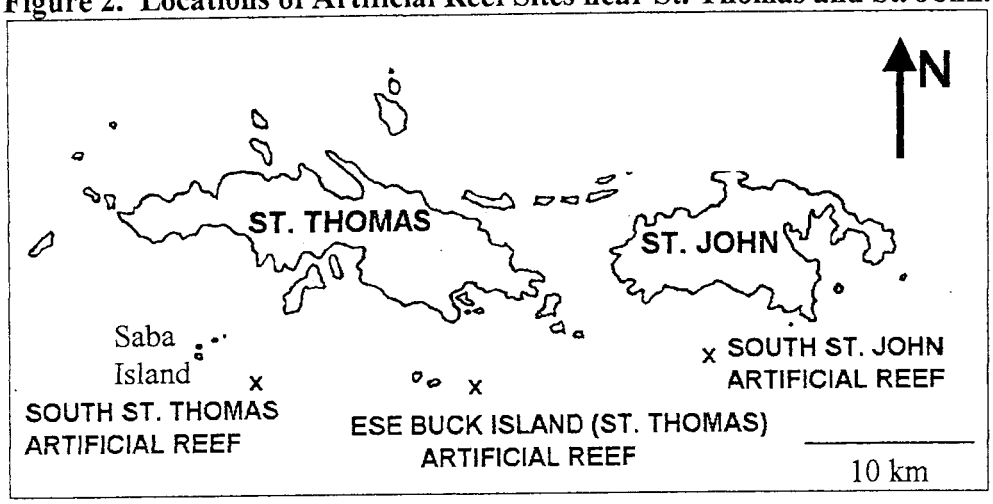


Table 3. List of Materials Deployed at Butler Bay, St. Croix prior to October 1996			
Date	**Location**	**Item**	**Notes**
1974-1976	17° 44.963'N, 64° 53.815'W	1000 banded/weighted auto tires, 200 flattened autos	40-70 ft depth
1975	Unknown	Small steel barge, dimensions unknown	Depth unknown
1985	17° 45.043'N, 64° 53.716'W	Steel tugboat	27.2 x 6.1 x 6.0 m (4,572 m^3); 45 ft depth
1986	17° 45.138'N, 64° 53.713'W	*Suffolk Maid*	Steel freighter (8,193.1 m^3); 40.8 x 7.6 x 6.3 m; 60-70 ft depth
1986	17° 45.066'N, 64° 53.073'W	Aquarius habitat	Two steel cylinders 2.7 x 6.1 m; 45 ft depth
1987	17° 45.131'N, 64° 53.731'W	*Rosa Maria*	Steel cargo vessel 51.5m; 80-100 ft depth
1990	17° 45.061'N, 64° 53.755'W	*Virgin Islander*	HESS fuel barge (15,060 m^3), 55.0 x 15.0 x 4.4 m steel; 50-70 ft depth
1994	17° 44.899'N, 64° 53.788'W	Frederiksted Pier debris	Concrete and steel; 60-100 ft depth
*source: DFW files; Adams et al 1996.			

Criteria used to assess each location included:

1. Accessibility (distance from shore and distance from public boat access facilities),
2. Potential environmental impact, and
3. Current use of the area.

Table 4. List of Materials Deployed at the Saba Island Artificial Reef Site Prior to October 1996.			
Date	**Location**	**Item**	**Notes**
6/1/92	18° 17.45'N, 64° 58.70'W	22 Yacht Haven dock slabs	Concrete, 2.4 x 8.8 m
12/29/95	18° 17.39'N, 64° 58.40'W	*WITIslander* waterbarge	Steel, 60.6 x 14.2 x 4.5 m
12/29/95	18° 17.39'N, 64° 58.40'W	Steel container with steel scrap inside	6.1 x 2.4 x 2.4 m
2/23/96	18 °18.28'N, 64° 58.13'W	*WITrollon* (WITBase) waterbarge	Steel, 45.5 x 12.1 x 3.6 m
3/21/96	18° 17.4'N, 64° 59.0'W	Bow rake of *WITrollon*	Steel, 12.1 x 6.1 m
3/25/96	18° 18.13'N, 64° 58.17'W	*WIT Waterhaul*	Steel, 50 x 9.7 x 3.6 m
8/5/96	18° 18.594'N, 64° 56.658'W	*Latina*	
9/17/96	18° 17.4'N, 64° 59.0 'W	*S/V Maverick*	Wood sailboat, ca 30.3 x 6.1 x 4.5 m
9/17/96	18° 17.1'N, 64° 59.21'W	Two sailboats	Fiberglass, 12.1 to 15.2 m each
*source: DFW files			

Table 5. List of Materials Deployed at the Buck Island (St. Thomas) and South St. John Artificial Reef Sites Prior to October 1996.			
Date	**Location**	**Item**	**Notes**
Buck Island (St. Thomas)			
12/22/93	18° 16.146'N, 64° 51.892'W	Aqua 1 barge	Site adjacent to coral structure, 27 m depth
South St. John			
4/9-11/94	18° 17.7'N, 64° 44.9'W	Ferry dock remains	Concrete pilings and deck slabs from Cruz Bay dock
4/9-11/94	18° 17.7'N, 64° 44.9'W	*SERACCA* sailboat	Steel, 8.4 x 2.4 x 2.4 m
*source: DFW files			

Tobias (1998) recommended that the Scotch Bank and Long Reef area should be investigated. In addition, he suggested that other sites on the south of St. Croix should also be surveyed. In 1998/1999 further site surveys were completed in St. Croix (Tobias 1999). Reconnaissance dives were completed on 2/12/99, 4/16/99, and 6/15-16/99 off Estate Northside (northwest St. Croix). During the 1999/2000 period (Tobias 2000), three additional areas were surveyed: (1) Turner Hole, (2) Robin Bay, and (3) Great Pond Bay. These locations are on the southeast side of St. Croix (see Figure 4 below).

Figure 3. Locations of Four St. Croix Sites Surveyed as Possible Artificial Reef Sites: Sprat Hole, Lang Bank, Scotch Bank, and Estate Northside

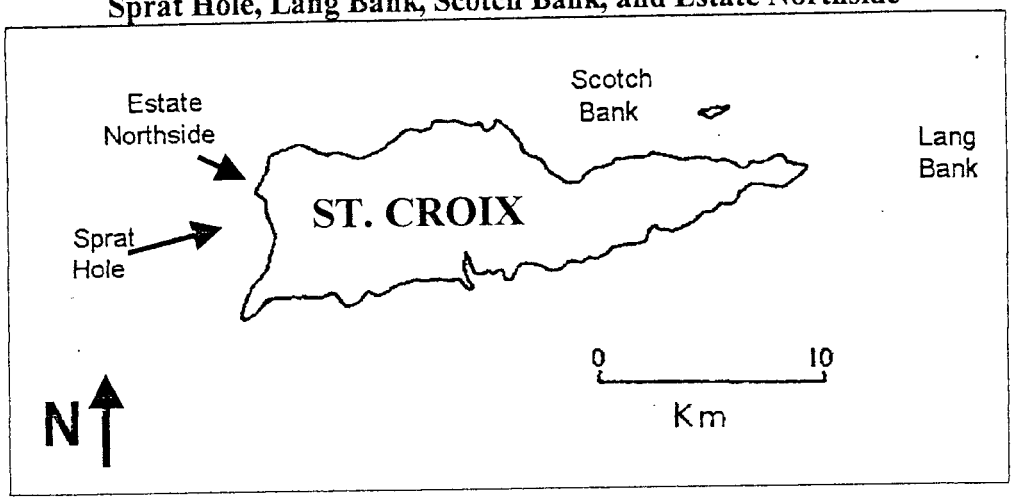
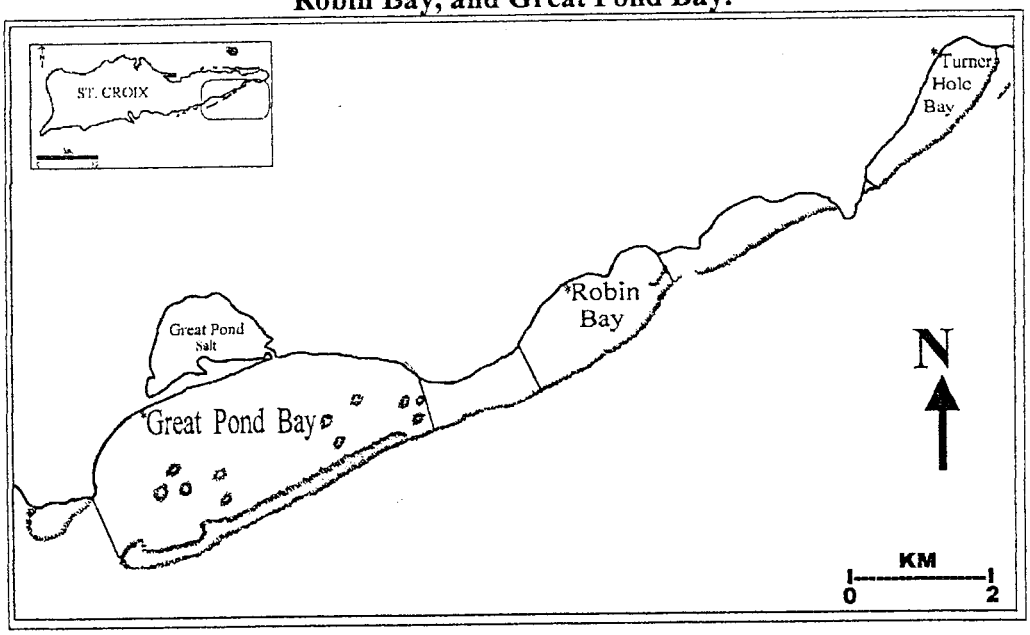


Figure 4. St. Croix Map Showing Possible Artificial Reef Sites of Turner Hole, Robin Bay, and Great Pond Bay.



Results of the southeast St. Croix surveys were as follows.

1. Lang Bank (17^0 48.5'N, 64^0 29.2'W) - The Lang Bank site was 9 km east of St. Croix and 12 km from the nearest public boat access facility at Altona Lagoon (Tobias 1998). It was the least accessible of the 3 sites investigated. The benthic community included a well-developed coral reef at a depth of 20-25 m. Heavy commercial and light recreational fishing activities occur in the area. This site was not suitable for artificial

reef development due to the distance from shore and well-developed deep reef community.

2. Scotch Bank (17^0 46.2'N, 64^0 41.4'W) - The Scotch Bank site was less than 1 km north of St. Croix, and 1.5 km from Altona Lagoon boat access facility in Christiansted (Tobias 1998). The site was a narrow shelf covered by calcium carbonate sand of biogenic origin. Some carbonate hard bottom communities of sponges, gorgonians and corals were also present. Depth was from 25 to 40 m. Both recreational and commercial fishing occur at this site. Site accessibility was good. Proper placement of artificial reef materials would minimize environmental impacts.

3. Sprat Hole (17^0 44.2'N, 64^0 53.6'W) - The Sprat Hole site was 2 km north of Frederiksted and 2.5 km from the nearest public boat access facility (Tobias 1998). The site included a well-developed reef community at 15 m depth. The reef community was dominated by colonies of *Montastrea annularis* coral (1.0-1.5 m in height) separated by patches of sand. There was commercial and recreational fishing in the area. This area is controlled by the Department of Defense and has numerous acoustical cables in the area. Artificial reef permitting and deployment would require approval from the U.S. Navy.

4. Estate Northside (17^0 44.7'N, 64^0 53.9'W) - The Estate Northside site was 6 km from the nearest public boat access facility in Frederiksted (Tobias 1999). There were coral reef communities on the shallow inshore shelf platform that extended offshore 50 to 100 m. Water depth over the inshore shelf platform was 10 m. Offshore substrate included carbonate sand interspersed with hard bottom communities (coral, sponge, gorgonians) to a depth of 30 m. The shelf edge was 200 to 300 m from the shore. There were several underwater cables (U.S. Navy and AT&T) in the area. There was also light recreational and commercial fishing in the area. This site was not suitable for artificial reef development due to the presence of numerous acoustic and communication cables on the bottom.

5. Turner Hole (17^0 44.6'N, 64^0 36.1'W), Robin Bay (17^0 43.6'N, 64^0 37.7'W), and Great Pond Bay (17^0 43.1'N, 64^0 39.3'W) – These sites were surveyed between 10/1999 and 9/2000 (Tobias 2000). For all of these areas, the distance from shore to the bank barrier reef was between 300-700 m. These areas were all protected from wave energy by the nearly continuous bank-barrier reef system. Water depth in the backreef areas was less than 6 m, except for the channel passages offshore where depth exceeded 10 m. Each of these areas had seagrass, algal plain, patch reef, sand and rubble habitats. The relative abundance of lutjanids and serranids in all bays was low. Except for the slab ramp in Alucroix Channel, 11 km west of Great Pond Bay, there is no public boat access in the south coast of St. Croix. Low-relief artificial reefs, may enhance recruitment of recreationally important reef fish species in these backreef embayments.

Based on surveys above, the Scotch Bank is an appropriate northside artificial reef site. There is still a need to identify an artificial reef site off the south coasts of St. Croix to accommodate the deployment of large artificial reef material such as decommissioned commercial vessels.

St. Thomas/St. John

During this period, there were no surveys of potential artificial reef sites near St. Thomas or St. John.

JOB 3. ADDITIONAL ARTIFICIAL REEF DEPLOYMENTS

St. Thomas

St. Thomas DFW staff inspected all vessels deployed on the artificial reef site south of Saba Island, south of St. Thomas (see Adams 1997, and Table 6 below). Deployments were coordinated with the Coast Guard and the Army Corps of Engineers (ACOE). ACOE took photos and video of the *Clairborne*, sailboats and barge sunk at this site.

In 1997, the *Wit Concrete II* (concrete Liberty Ship) was deployed at the artificial reef site south fo Saba Island (Tobias 1998). In 1998, 2 steel barges were also deployed at the Saba Island artificial reef site (Tobias 1998, see Table 6 below).

Table 6. Materials Deployed on the Artificial Reef Site South of Saba Island, St. Thomas between October 1996 and September 2000.

Date	Material	Location	Notes
4/12/97	*Sailboats from Krum Bay*	*1	
4/23/97	*Clairborne*	*1	
6/5/97	*Barge*	*1	
mid-July 1997	*WIT Concrete (*2)*	*1	
10/2/97	*WIT Concrete II (*2)*	18^0 17.4'N, 64^0 59.0'W	38 x 9 x 6 m concrete Liberty ship
6/16/98	*WIT Bridge (*2)*	18^0 17.753'N, 64^0 59.470'W	43 x 12 x 3 m steel barge
6/16/98	*WIT Barge II (*2)*	18^0 17.416'N, 64^0 59.570'W	37 x 9 x 2 m steel barge

*source:
1. Adams (1997) – no details provided in this report
2. Tobias (1998)

St. Croix

In December 1997, St. Croix DFW submitted a request letter to the Department of the Army Corps of Engineers (ACOE) and the Division of Coastal Zone Management to deploy the tugboat *Coakley Bay* at the Butler Bay artificial reefs site under Permit #74D-0641/CZX-76-83W

(Tobias 1998). DFW was informed by ACOE in March 1998 that a new permit application was required. A new joint application was submitted in March 1998 and the permit was approved in February 1999 (Tobias 1999).

On April 15, 1999, the *Coakely Bay* (HESS steel tugboat 28.0 x 7.0 x 3.0 m) was deployed at 17^0 45.181'N, 64^0 53.727'W in 16.7 to 22.7 m of water (DFW files). No other material was deployed at this site during the reporting period.

St. John

No artificial reef material was deployed off of St. John during the reporting period.

Deployment Technical Guidance

In addition to actual deployment of materials on approved artificial reef sites, DFW staff routinely responded to private and public sector requests for information about artificial reef development. For example, both 1999 and 2000, the Water and Power Authority (WAPA) approached DFW regarding hurricane damaged steel water tanks as artificial reefs. Despite several discussions, these materials were never deployed for artificial reefs.

JOB 4 - MONITORING ARTIFICIAL REEF SITE

Butler Bay, St. Croix

On November 5, 1998 and September 15, 2000, quantitative surveys were completed of fish at the Butler Bay artificial reef site including the Suffolk Maid, a barge and a tug (Tobias 1999 and 2000). During both surveys, a control site was also surveyed on an inshore natural reef edge and platform. Divers identified fish species, conducted fish counts, and estimated fish lengths. At artificial reef sites, divers separated and positioned themselves at opposite sides of each artificial reef (vessel). They then swam down the side of each artificial reef, meeting at the opposite end, and continued over the top of the artificial reef, recording fish observed in their respective areas. The Bohnsack-Bannerot (1986) stationary visual fish census method was used to survey fish at the control site.

A summary of observations of these monitoring surveys is provided in Table 7 below (from Tobias 1999 and 2000). Detailed summaries of fish observed are presented in Appendix Table 1 for the 1998 survey and Appendix Table 2 for the 2000 survey.

In general, artificial reef sites had more fish families and fish species observed than the natural reef (see Table 7 below). In addition, more fish were observed at artificial reef sites than at natural reef sites. Planktivores and herbivores were more numerous at artificial reefs than natural reefs. The increased height of the artificial reefs and the currents generated around them may have created favorable eddies for plankton to collect. The artificial reefs provided a good

substrate for filamentous algae, a primary food source for herbivorous fishes. It should be noted that the methodology for these surveys was different between artificial reef sites and natural reefs. Therefore the estimates provided here may not be directly comparable.

For November 1998 and September 2000 artificial reef monitoring surveys (Tobias 1999 and 2000), divers estimated mean fish sizes for each species and each location. A summary of these estimates is provided in Appendix Tables 3 and 4, respectively, below.

Table 7. Results of Monitoring Butler Bay Artificial Reef Site, November 5, 1998 (from Tobias 1999) and September 15, 2000 (from Tobias 2000).

	Artificial Reef			Natural Reef		
	Barge	**Suffolk Maid**	**Tug**	**Edge**	**Platform**	**Total**
11/5/98 Survey*1						
Fish Families Observed	17	17	16	13	6	22
Fish Species Observed	32	32	30	27	17	54
Total Fish Observed	420	595	348	231	169	1,763
9/15/00 Survey*2						
Fish Families Observed	14	11	10	11	10	15
Fish Species Observed	31	27	19	25	16	49
Total Fish Observed	388	259	296	180	144	1,267

*notes:
1. source: Tobias (1999)
2. source: Tobias (2000)

On April 15, 1999, a follow-up inspection was completed at the tugboat *Coakley Bay* that was deployed on that same day at the Butler Bay artificial reef site (Tobias 1999). On the tugboat, divers observed juvenile queen angelfish, *Holacanthus ciliaris* (2 fish); sergeant major, *Abudefduf saxatilis* (6 fish), doctor fish, *Acanthurus chirurgus* (8 fish), and blue tang, *Acanthurus coeruleus*. Divers noted that the inshore stern anchor had dragged about 15 m and had made a 0.25 m deep trench through the sand/algal plain. This was presumably caused when the vessel was sunk.

St. Thomas/St. John Artificial Reef Sites

During this grant period, there was no monitoring of the St. Thomas and St. John artificial reef sites.

JOB 5 – PREPARATION OF ANNUAL AND COMPLETION REPORT

Annual progress reports were completed for this grant. For 1996/1997, see Adams (1997). For 1997/1998, see Tobias (1998). For 1998/1999, see Tobias (1999), and for 1999/2000, see Tobias (2000).

This report constitutes the completion report.

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APPENDIX TABLE 1. Total Species Abundance for Reef Fish at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999)

Family / Species	Common Name	Artificial Reefs			Natural Reefs		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Acanthuridae							
Acanthurus bahianus	surgeonfish	11	18	2	3	3	37
Acanthurus chirurgus	doctorfish	2	0	4	0	0	6
Acanthurus coeruleus	blue tang	18	38	16	2	2	76
Aulostomidae							
Aulostomus maculatus	Trumpetfish	0	0	0	0	2	2
Carangidae							
Caranx latus	horseeye jack	0	2	0	0	0	2
Carangoides ruber	bar jack	2	3	16	3	0	24
Chaetodontidae							
Chaetodon capistratus	foureye butterfly	3	0	0	2	4	9
Chaetodon striatus	banded butterfly	0	1	0	1	0	2
Dasyatidae							
Dasyatis americana	southern stingray	0	1	1	0	0	2
Grammatidae							
Gramma loreto	fairy basslet	0	2	0	0	0	2
Haemulidae							
Haemulon album	Margate	1	9	1	0	0	11
Haemulon aurolineatum	Tomtate	2	6	0	0	0	8
Haemulon carbonarium	Caesar grunt	3	5	0	0	0	8
Haemulon chrysargyreum	smallmouth grunt	0	60	2	0	0	62
Haemulon flavolineatum	French grunt	4	3	2	1	3	13
Haemulon parra	sailor's choice	2	9	0	0	0	11
Haemulon sciurus	bluestriped grunt	0	3	0	0	0	3
Holocentridae							
Holocentrus ascensionis	Squirrelfish	4	4	0	3	3	14
Myripristis jacobus	blackbar soldierfish	23	36	14	18	0	91
Kyphosidae							
Kyphosus sectatrix	Bermuda chub	0	0	1	0	0	1
Labridae							
Bodianus rufus	Spanish hogfish	1	1	11	1	0	14
Clepticus parrae	creole wrasse	10	115	0	1	0	126

APPENDIX TABLE 1 (continued). Total Species Abundance for Reef Fish at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999)

Family / Species	Common Name	Artificial Reefs			Natural Reefs		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Halichoeres garnoti	yellowhead wrasse	0	0	1	3	1	5
Thalassoma bifasciatum	bluehead wrasse	44	56	45	106	79	330
Lutjanidae							
Lutjanus analis	mutton snapper	0	1	0	0	0	1
Lutjanus griseus	grey snapper	3	0	1	1	0	5
Lutjanus mahogoni	mahogany snapper	7	12	16	4	0	39
Ocyurus chrysurus	yellowtail snapper	5	0	10	0	0	15
Mullidae							
Mulloidichthys martinicus	yellow goatfish	21	93	30	0	1	145
Pseudupeneus maculatus	spotted goatfish	0	0	0	0	1	1
Ostraciidae							
Lactophrys triqueter	smooth trunkfish	1	0	0	0	0	1
Pomacanthidae							
Holacanthus ciliaris	queen anglefish	6	0	0	0	0	6
Pomacanthus paru	French anglefish	3	2	4	2	1	12
Pomacanthus arcuatus	gray anglefish	3	2	0	1	0	6
Pomacentridae							
Abudefduf saxatilis	sargent major	102	53	12	2	0	169
Chromis cyanea	blue chromis	0	0	0	2	0	2
Chromis multilineata	brown chromis	0	5	98	20	0	123
Microspathodon chrysurus	yellowtail damselfish	0	0	0	1	0	1
Stegastes dorsopunicans	Dusky damselfish	0	0	0	3	0	3
Stegastes leucosticus	Beau Gregory	0	0	1	0	0	1
Stegastes partitus	bicolor damselfish	4	17	23	28	23	95
Scaridae							
Sparisoma aurofrenatum	redband parrotfish	3	5	2	7	11	28
Sparisoma chrysopterum	redtail parrotfish	0	0	17	0	0	17
Sparisoma viride	stoplight parrotfish	3	0	3	0	1	4
Scarus taeniopterus	princess parrotfish	119	2	3	9	27	160
Scarus vetula	Queen parrotfish	0	0	1	0	0	1
Serranidae							
Cephalopholis cruentata	Grasby	0	0	0	1	0	1
Cephalopholis fulvus	Coney	5	22	6	5	4	42

APPENDIX TABLE 1 (continued). Total Species Abundance for Reef Fish at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999)

Family / Species	Common Name	Artificial Reefs			Natural Reefs		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Epinephelus guttatus	red hind	2	0	0	0	3	5
Paranthias furcifer	Creolefish	0	1	0	0	0	1
Serranus tigrinus	harlequin bass	0	0	2	0	0	2
Sparidae							
Calamus spp	Porgy	2	0	0	0	0	2
Synodontidae							
Synodus intermedius	sand diver	0	0	0	1	0	1
Tetraodontidae							
Canthigaster rostrata	sharpnose puffer	1	8	3	0	0	12
	Total	**420**	**595**	**348**	**231**	**169**	**1763**

APPENDIX TABLE 2. Total Species Abundance for Reef Fish at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 9/15/00 (N=2) from Tobias (2000)

Family / Species	Common Name	Artificial Reefs			Natural Reefs		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Acanthuridae							
Acanthurus bahianus	surgeonfish	7	7	4	0	10	28
Acanthurus chirurgus	doctorfish	2	1	0	1	0	4
Acanthurus coeruleus	blue tang	11	12	45	6	1	75
Carangidae							
Caranx latus	horseeye jack	0	0	1	0	0	1
Carangoides ruber	bar jack	3	6	5	3	0	17
Chaetodontidae							
Chaetodon capistratus	foureye butterfly	0	0	0	0	4	4
Chaetodon striatus	banded butterfly	3	0	0	0	1	4
Haemulidae							
Haemulon album	margate	1	6	0	0	0	7
Haemulon carbonarium	Caesar grunt	2	2	0	0	0	4
Haemulon chrysargyreum	smallmouth grunt	0	0	4	0	0	4
Haemulon flavolineatum	French grunt	5	5	1	7	2	20
Haemulon macrostomum	Spanish grunt	1	0	0	0	0	1
Haemulon parra	sailor's choice	2	0	0	0	0	2
Haemulon plumieri	White grunt	2	0	0	2	0	4
Haemulon sciurus	bluestriped grunt	0	1	0	0	0	1
Haemulon sp.	Grunt	0	0	50	0	0	50
Holocentridae							
Holocentrus ascensionis	squirrelfish	5	4	1	2	2	14
Myripristis jacobus	blackbar soldierfish	23	6	8	5	0	42
Labridae							
Bodianus rufus	Spanish hogfish	6	6	5	3	0	20
Clepticus parrae	Creole wrasse	0	5	0	2	0	7
Halichoeres bivittatus	slippery dick	0	0	0	5	0	5
Halichoeres garnoti	yellowhead wrasse	0	1	0	0	0	1
Thalassoma bifasciatum	bluehead wrasse	9	37	30	66	61	203
Lutjanidae							
Lutjanus mahogoni	mahogany snapper	22	8	30	0	0	60
Lutjanus synagris	lane snapper	2	1	0	0	0	3

APPENDIX TABLE 2 (continued). Total Species Abundance for Reef Fish at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 9/15/00 (N=2) from Tobias (2000)

Family / Species	Common Name	Artificial Reefs			Natural Reefs		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Ocyurus chrysurus	yellowtail snapper	1	0	4	1	0	6
Mullidae							
Mulloidichthys martinicus	yellow goatfish	60	51	46	5	0	162
Pseudupeneus maculatus	spotted goatfish	0	0	0	2	1	3
Muraenidae							
Gymnothorax funebris	Green moray	1	0	0	0	0	1
Ostraciidae							
Lactophrys bicaudalis	spotted trunkfish	0	0	0	0	1	1
Lactophrys triqueter	smooth trunkfish	2	2	0	0	0	4
Pomacanthidae							
Pomacanthus paru	French anglefish	2	0	0	0	0	2
Pomacanthus arcuatus	gray anglefish	1	0	0	0	0	1
Pomacentridae							
Abudefduf saxatilis	sargent major	59	37	4	2	0	102
Chromis cyanea	blue chromis	0	5	0	1	0	6
Chromis multilineata	brown chromis	6	1	40	18	0	65
Stegastes dorsopunicans	Dusky damselfish	0	0	0	1	0	1
Stegastes partitus	bicolor damselfish	1	23	9	25	21	79
Scaridae							
Sparisoma aurofrenatum	redband parrotfish	1	0	0	4	3	8
Sparisoma chrysopterum	redtail parrotfish	0	0	1	0	0	1
Sparisoma viride	stoplight parrotfish	0	1	0	1	0	2
Scarus iserti	striped parrotfish	11	0	0	12	5	28
Scarus taeniopterus	princess parrotfish	63	1	0	2	13	79
Serranidae							
Cephalopholis cruentata	grasby	0	1	0	0	0	1
Cephalopholis fulvus	Coney	11	28	8	3	17	67
Epinephelus guttatus	red hind	0	0	0	0	1	1
Paranthias furcifer	creolefish	63	1	0	0	0	64
Serranus tigrinus	harlequin bass	0	0	0	0	1	1
Synodontidae							
Synodus intermedius	sand diver	0	0	0	1	0	1
	Total	**388**	**259**	**296**	**180**	**144**	**1267**

APPENDIX TABLE 3. Mean Size (mm) of Fish (Fork Length) at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999).

Family / *Species*	Common Name	Artificial Reef			Natural Reef		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Acanthuridae							
Acanthurus bahianus	surgeonfish	14	14	15	10	11	37
Acanthurus chirurgus	doctorfish	14		17			6
Acanthurus coeruleus	blue tang	13	15	16	15	13	76
Aulostomidae							
Aulostomus maculatus	trumpetfish					38	2
Carangidae							
Caranx latus	Horse-eye jack		45				2
Carangoides ruber	bar jack	20	23	17	18		24
Chaetodontidae							
Chaetodon capistratus	foureye butterfly	7			7	7	9
Chaetodon striatus	banded butterfly		8		16		2
Dasyatidae							
Dasyatis americana	southern stingray		60	80			2
Grammidae							
Gramma loreto	fairy basslet		3				2
Haemulidae							
Haemulon album	Margate	17	21	20			11
Haemulon aurolineatum	Tomtate	15	12				8
Haemulon carbonarium	Caesar grunt	15	16				8
Haemulon chrysargyreum	smallmouth grunt		13	12			62
Haemulon flavolineatum	French grunt	15	13	15	15	14	13
Haemulon parra	sailor's choice	18	26				11
Haemulon sciurus	bluestriped grunt		25				3
Holocentridae							
Holocentrus ascensionis	squirrelfish	18	17		15	14	14
Myripristis jacobus	blackbar soldierfish	11	12	13	12		91
Kyphosidae							
Kyphosus sectatrix	Bermuda chub			30			1
Labridae							
Bodianus rufus	Spanish hogfish	17	10	11	9		14

APPENDIX TABLE 3 (continued). Mean Size (mm) of Fish (Fork Length) at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999).

Family / *Species*	Common Name	Artificial Reef			Natural Reef		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Clepticus parrae	creole wrasse	15	12		16		126
Halichoeres garnoti	yellowhead wrasse			5	7	8	5
Thalassoma bifasciatum	bluehead wrasse	5	5	5	5	4	330
Lutjanidae							
Lutjanus analis	Mutton snapper		25				1
Lutjanus griseus	Grey snapper	18		20	14		5
Lutjanus mahogoni	mahogany snapper	14	13	12	14		39
Ocyurus chrysurus	yellowtail snapper	24		21			15
Mullidae							
Mulloidichthys martinicus	yellow goatfish	16	16	16		14	145
Pseudupeneus maculatus	spotted goatfish					11	1
Ostraciidae							
Lactophrys triqueter	smooth trunkfish	13					1
Pomacanthidae							
Holoanthus cilaris	queen angelfish	14					6
Pomacanthus paru	French anglefish	27	27	18	12	10	12
Pomacanthus arcuatus	gray anglefish	25	30		25		6
Pomacentridae							
Abudefduf saxatilis	sargent major	10	9	10	10		169
Chromis cyanea	blue chromis				6		2
Chromis multilineata	brown chromis		9	7	5		123
Microspathodon chrysurus	yellowtail damselfish				10		1
Stegastes dorsopunicans	dusky damselfish				6		3
Stegastes leucostictus	Beau Gregory			4			1
Stegastes partitus	bicolor damselfish	3	4	4	4	4	95
Scaridae							
Sparisoma aurofrenatum	redband parrotfish	15	13	10	13	13	28
Sparisoma chrysopterum	redtail parrotfish			17			17
Sparisoma viride	stoplight parrotfish	25		3		15	7
Scarus taeniopterus	princess parrotfish	18	15	4	13	16	160
Scarus vetula	queen parrotfish			30			1

APPENDIX TABLE 3. Mean Size (mm) of Fish (Fork Length) at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 11/5/98 (N=2) from Tobias (1999).

Family / *Species*	Common Name	Artificial Reef			Natural Reef		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Serranidae							
Cephalopholis cruentata	Grasby				22		1
Cephalopholis fulvus	Coney	19	12	15	18	14	42
Epinephelus guttatus	red hind	25				14	5
Paranthias furcifer	Creolefish		22				1
Serranus tigrinus	harlequin bass			6			2
Sparidae							
Calamus pennatula	Pluma	24					2
Synodontidae							
Synodus intermedius	sand diver				9		1
Tetraodontidae							
Canthigaster rostrata	sharpnose puffer	6	6	6			12
	Total						**1,763**

APPENDIX TABLE 4. Mean Size (mm) of Fish (Fork Length) at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 9/15/00 (N=2) from Tobias (2000)

Family / *Species*	Common Name	Artificial Reef			Natural Reef		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Acanthuridae							
Acanthurus bahianus	surgeonfish	11	12	14		13	28
Acanthurus chirurgus	doctorfish	18	15		16		4
Acanthurus coeruleus	blue tang	15	12	14	14	14	75
Carangidae							
Caranx latus	horseeye jack			20			1
Carangoides ruber	bar jack	25	18	17	16		17
Chaetodontidae							
Chaetodon capistratus	foureye butterfly					7	4
Chaetodon striatus	banded butterfly	7				10	4
Haemulidae							
Haemulon album	margate	22	20				7
Haemulon carbonarium	Caesar grunt	20	13				4
Haemulon chrysargyreum	smallmouth grunt			14			4
Haemulon flavolineatum	French grunt	10	16	16	15	13	20
Haemulon macrostomum	Spanish grunt	20					1
Haemulon parra	Sailor's choice	20					2
Haemulon plumieri	White grunt	16			15		4
Haemulon sciurus	bluestriped grunt		20				1
Haemulon sp.	Grunt			1			50
Holocentridae							
Holocentrus ascensionis	squirrelfish	10	17	16	16	15	14
Myripristis jacobus	blackbar soldierfish	10	10	12	13		42
Labridae							
Bodianus rufus	Spanish hogfish	16	15	12	17		20
Clepticus parrae	creole wrasse		17		13		7
Halichoeres bivittatus	slippery dick				5		5
Halichoeres garnoti	yellowhead wrasse		4				1
Thalassoma bifasciatum	bluehead wrasse	8	10	5	7	6	203
Lutjanidae							
Lutjanus mahogoni	mahogany snapper	18	18	17			60
Lutjanus synagris	lane snapper	22	20				3

APPENDIX TABLE 4 (continued). Mean Size (mm) of Fish (Fork Length) at the Butler Bay Artificial Reef and Adjacent Natural Reef, St. Croix, U.S. Virgin Islands, 9/15/00 (N=2) from Tobias (2000)

Family / *Species*	Common Name	Artificial Reef			Natural Reef		Total No. of Fish
		Barge	Suffolk Maid	Tug	Edge	Platform	
Ocyurus chrysurus	yellowtail snapper	22		25	17		6
Mullidae							
Mulloidichthys martinicus	yellow goatfish	18	16	18	14		162
Pseudupeneus maculatus	spotted goatfish				14	15	3
Muraenidae							
Gymnothorax funebris	green moray	100					1
Ostraciidae							
Lactophrys bicaudalis	spotted trunkfish					14	1
Lactophrys triqueter	smooth trunkfish	10	15				4
Pomacanthidae							
Pomacanthus paru	French anglefish	30					2
Pomacanthus arcuatus	gray anglefish	25					1
Pomacentridae							
Abudefduf saxatilis	sargent major	11	12	7	9		102
Chromis cyanea	blue chromis		2		3		6
Chromis multilineata	brown chromis	5	7	7	5		65
Stegastes dorsopunicans	dusky damselfish				10		1
Stegastes partitus	bicolor damselfish	6	4	3	4	5	79
Scaridae							
Sparisoma aurofrenatum	redband parrotfish	8			14	14	8
Sparisoma chrysopterum	redtail parrotfish			17			1
Sparisoma viride	stoplight parrotfish		20		25		2
Scarus iserti	striped parrotfish	18			17	15	28
Scarus taeniopterus	princess parrotfish	19	15		17	17	79
Serranidae							
Cephalopholis cruentata	Grasby		15				1
Cephalopholis fulvus	Coney	18	15	21	13	14	67
Epinephelus guttatus	red hind					15	1
Paranthias furcifer	creolefish	18	15				64
Serranus tigrinus	harlequin bass					6	1
Synodontidae							
Synodus intermedius	sand diver				23		1
	Total						**1,267**