

STATUS OF CORAL REEFS IN THE U.S. VIRGIN ISLANDS

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Introduction

The U.S. Virgin Islands (USVI) is a U.S. territory located approximately 1,000 nmi southeast of Miami and 45 nmi east of Puerto Rico. Coral reefs are found around the three main islands of St. Croix, St. John, and St. Thomas, as well as most offshore cays. Fringing reefs, deep reefs (wall and shelf-edge), patch reefs, and spur and groove formations are present on all three islands although only St. Croix has well developed barrier reefs. Bank reefs and scattered patch reefs with high coral

diversity occur on geological features offshore at greater depths.



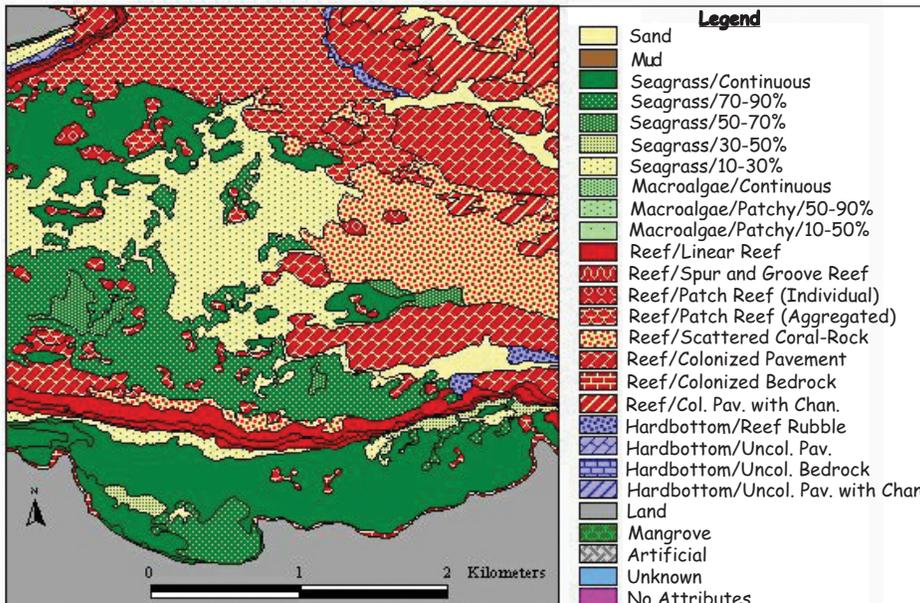
Figure 186. Shallow-water reef communities cover 61% of the region (Photo: William Harrigan).

Together the USVI total roughly 347 km² of land area. St. Croix is the largest of the three USVI islands at 207 km² (34 km by 10 km) with a relatively high western mountainous tip. This island has coral growth along much of the insular shelf with a well-developed barrier reef on the eastern end, and deep coral walls on the north shore. St. Croix is the only island with a permanent source of freshwater. St. Thomas is the second largest at 83 km² (22 km by 5 km) and St.

John is the smallest of the three USVI islands at 52 km² (14 by 5 km).

Recently NOAA mapped USVI coral reefs

Figure 187. Benthic habitats of Buck Island Channel, St. Croix, USVI were mapped from aerial photographs (Credit: John Christensen).



and associated ecosystems to approximately a depth of 20 m and delineated a total submerged area of 485 km² (Kendall 2001b, Monaco *et al.* 2001). Deeper water reef habitats off the USVI islands have yet to be mapped. Coral reef and colonized hard-bottom habitats comprised 297.9

km² and accounted for 61% of the mapped area; submerged aquatic vegetation covered 160 km² or 33% of the mapped total, and unconsolidated sediments and uncolonized hard-bottom habitat comprised 23 km² or the remaining 4%.

Condition of Coral Reefs

The long-term datasets for the USVI represent some of the best temporal data available for the Caribbean (Connell 1997). Although monitoring and research has occurred on all three USVI islands, consistent long-term datasets exist only for St. John and Buck Island, St. Croix (e.g. 1988 to present) and have been collected primarily by the Department of the Interior, National Park Service (NPS) and U.S. Geological Survey (USGS). Most of these studies are targeted in individual bays that might not be representative of conditions within the entire USVI (Table 1).

Corals and Other Invertebrates

– NPS has conducted and supported long-term monitoring on St. John (site of Virgin Islands National Park, VINP) and Buck Island, St. Croix (site of Buck Island Reef National Monument, BINM) since 1988. Over time, statistical rigor has significantly increased due to improvements in technology and sample design. For the last three years USGS and NPS scientists have collaborated on long-term monitoring of coral reefs using a comprehensive protocol based on use of a digital video camera along randomly chosen transects (Miller and Rogers 2001, Rogers *et al.* in press). This protocol is one of the most statistically rigorous methods to monitor coral reefs in the world. A total of 79 randomly located transects at four sites (three in St. John and one at Buck Island, St. Croix) have been repeatedly sampled for two or more years. An additional site at Buck Island, St. Croix (20 transects) has been sampled for one year and one

additional site on St. John has eight non-randomly located transects which have been sampled for three years.

Live scleractinian coral cover varies at these sites from a low of 5.8% (Buck Island, St. Croix) to a high of 22.8% (Mennebeck, St. John). —It should be noted that the site with non-randomly located transects has a live scleractinian coral cover of 45.3% (Tektite, St. John). Results of the repeated sampling are varied but overall, 76% of transects showed declines in the amount of live coral cover when the first year is compared to the third year. Percent of transects exhibiting declines at individual sites are as follows: 40% (Yawzi, St. John), 65% (Buck Island, St. Croix), 75% (Mennebeck, St. John), 95% (Newfound, St. John), and 62% (Tektite, St. John).



Figure 188. Monitoring in the USVI using videography (Photo: USGS).

NOAA monitoring funds were received by the USVI Territorial Government in 2001 and University of Virgin Islands conducted the study. The first year of this project supported six sites on St. Croix (six transects each) where coral, sea urchin (*Diadema antillarum*), and reef fish have been monitored. Live scleractinian coral cover varied from a low of 6% (Lang Bank) to 25% (Sprat Hole) (Nemeth *et al.* in press). Monitoring will be repeated in 2002.

White-band Disease – Branching acroporid species are most susceptible to White-band Disease. At BINM, elkhorn coral (*Acropora palmata*) cover fell from 85% in 1976 to 5% in 1988 because of mortality from the combination of storms and disease (Rogers *et al.* 1982, Gladfelter 1991). White-band Disease is still occasionally seen throughout the USVI and shallow reef areas are now graveyards of dead elkhorn coral, with branches and fragments interspersed among algal-



Figure 189. White-band disease on elkhorn coral (Photo: Caroline Rogers).

covered skeletons still upright in normal growth position.

There is current evidence that elkhorn coral is recovering in the USVI. Recruitment of elkhorn coral colonies may be increasing and biologists from NPS, USGS, and UVI are now monitoring and mapping this species at several USVI sites.

Plague – In July 1997, conspicuous white patches of necrotic tissue began to appear on scleractinian corals in several bays around St. John. Tissue samples have confirmed that Plague is affecting these corals. It has now been observed on 14 coral species. The disease can progress up to 0.5 cm/day but does not always result in total colony mortality, however diseased portions never recover. Monthly surveys on one St. John reef have documented new incidence of disease every month from 1997 to present (Miller *et al.* in press) making this the most destructive disease active on St. John.

Black-band Disease – This disease primarily infects major reef-building corals such as *Montastraea annularis* and *Diploria strigosa* (Edmunds 1991, Richardson *et al.* 1997). In 1988, Edmunds (1991) found very low incidence of Black-band Disease (0.2%) on corals in seven sites in the U.S. and British Virgin Islands. Nemeth reported 1.2% on St. John and

none on St. Thomas or St. Croix (Nemeth *et al.* in press). At Buck Island, Black-band Disease is seen on *Diploria* colonies but typically on fewer than 10 colonies a year (Zandy Hillis-Starr pers. comm).

A limited, recent assessment across the USVI found 3.4% (St. Thomas), 7.6% (St. John), and 2.0% (St. Croix) of coral colonies over 25 cm in diameter showing signs of disease (Nemeth *et al.* in press).

Other Diseases – Small USVI patch reefs of *Porites porites* have died from an unknown disease (Rogers 1999, J. Miller pers. comm., B. Kojis pers. comm.) and some of these reefs have been dead for over 12 years (see Beets *et al.* 1986). *Porites porites* is not known to be susceptible to either White-band or Black-band Disease.

Sea fan disease, caused by the fungus *Aspergillus sydowii*, occurs in sea fans on St. John reefs (G. Smith pers. comm.). This pathogenic strain has been isolated from air samples taken during African dust events, suggesting a possible link between air quality and sea fan condition.

Sea Urchins – According to Lessios *et al.* (1984), the condition of USVI coral reefs has been significantly impacted by a die-off of the long-spined sea urchin (*Diadema*

Figure 190. A. Long-spined sea urchin feeding on reef algae (Photo: NOAA Photo Gallery). B. Urchin dead from a Caribbean-wide disease. (Photo: Caroline Rogers).

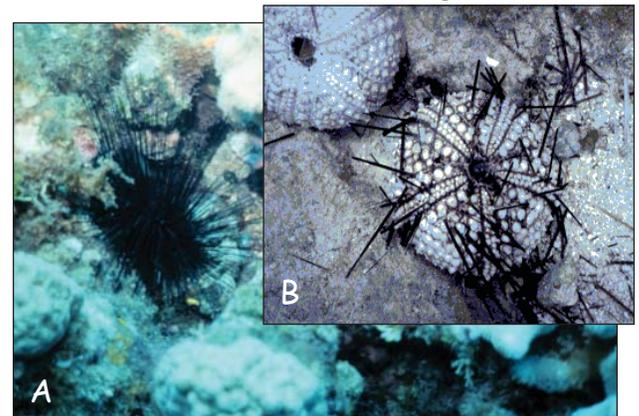




Figure 191. St. John's once extensive seagrass beds have significantly declined (Photo: Matt Kendall).

antillarum). While the extent of a possible recovery of the urchin population is unknown, recent surveys have noted increases in numbers (NPS and USGS records).

A major herbivore on Caribbean reefs, *D. antillarum* suffered losses of over 90% during an epizootic die off in 1983-1984 (Lessios *et al.* 1984). *Diadema* are recovering very slowly around the USVI. One estimate is that the current community is still at less than 10% of the level before the die-off (W. Tobias pers. comm.). Recent surveys of reefs 3-15 m deep in St. Thomas, St. John, and St. Croix found densities to be 0.02/m², 0.06/m², and 0.01/m², respectively and *Diadema* densities are higher along shallow (<3m) protected shorelines (Nemeth *et al.* in press.). Additional surveys at six St. Croix sites revealed a range of 0.005 to 0.15 of these urchins per m² (A. Adams pers. comm.).

Conchs – Queen conchs used to be very abundant around St. John (Randall 1964, Schroeder 1965). A recent study shows that conch populations in general appear to be decreasing and density of conchs inside VINP waters are not significantly higher than outside the park (Friedlander 1997). Conchs were surveyed along transects

around St. John and St. Thomas in 1981, 1985, 1990, 1996, and 2000 (Wood and Olsen 1983, Boulon 1987, Friedlander *et al.* 1994, Friedlander 1997). Because conchs have patchy distributions and move among several habitats and over a gradient of depths, it is difficult to document and interpret changes in their abundance. However, there is evidence of general declines in conch densities.

Lobsters – Limited data suggest decreases in the abundance of lobsters (Wolff 1998). Wolff (1998) noted that lobster densities for 4 sites around St. John in 1996 averaged only 5/ha compared to 19.4/ha at 89 sites around the island in 1970. Data suggest average size of lobsters declined within the park since 1970 (Olsen *et al.* 1975).

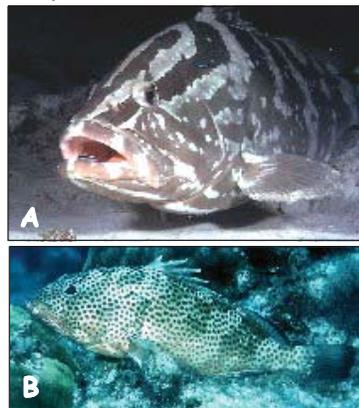
Marine algae and Other Plants – Long term data (e.g. 1990 to present) exists only for St. John.

St. John's previously large, dense seagrass beds are no longer present. Comparison of aerial photographs (1962 and 1983) showed a decline in areal extent and/or apparent density, especially within popular anchorages. Digital analysis of photographs of Great Lameshur Bay from 1971 to 1991 indicated a decrease in total seagrass area by 68,000 m² and the

seagrass bed in Little Lameshur Bay lost 22,000 m² of seagrass (L. Muehlstein unpub. data).

Williams (1988) reported densities of turtle grass (*Thalassia testudinum*) ranging from 80 to 200 shoots m⁻² in Maho and Francis Bays in 1986. In 1997, densities in these bays were much lower (L. Muehlstein unpub. data). Thousands of boats anchor in these bays each year,

Figure 192. Spawning aggregations of (A) Nassau grouper and (B) red hind have been depleted in the USVI (Photo: J.E. Randall, Fish-Base).



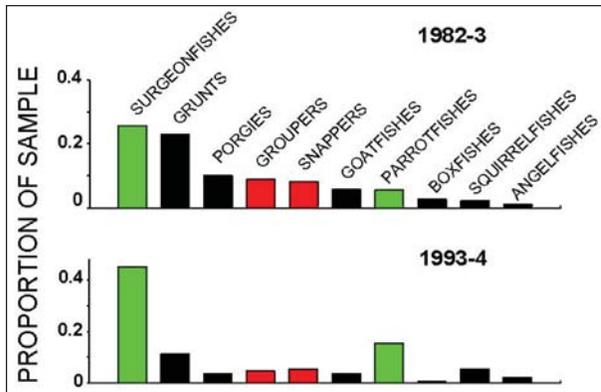


Figure 193. In only ten years, a 14% loss of desirable and a 19% increase in less desirable fish was documented within the Virgin Islands National Park (Source: Beets and Rogers in press).

leaving conspicuous scars (Williams 1988).

Seagrass communities in three other bays have been monitored annually from 1997 to 2001. In all these bays, seagrass have fluctuated but declined overall (L Muehlstein and NPS unpub. data).

Fish and Fisheries – Reef fish assemblages have changed markedly in the USVI (Rogers and Beets 2001), but it is difficult to separate out the causal factors. Over-fishing, deterioration of coral reefs, mangroves, and seagrass beds all have undoubtedly contributed to significant changes in reef fish assemblages. However, many of the characteristics of the USVI fishery provide clear evidence of heavy fishing pressure.

Up through the 1960s, groupers and snappers were abundant and dominated the landings in the USVI fishery. Following the tourism boom and technological changes in the fishery (larger boats, engines, improved gear), fishers began to set more traps and to target species like groupers and snappers, especially their spawning aggregations. By the 1970s, several spawning aggregations of Nassau grouper had been decimated and local abundance of this species crashed (Olsen and LaPlace 1978). The Nassau grouper is still particularly scarce today (Wolff 1996, Garrison *et al.* 1998, USGS and NPS,

unpub. data). After depleting the larger species of groupers, fishers began targeting smaller aggregating species such as the red hind. On St. Croix there is active targeting of the mutton snapper aggregations on the southwest side of the island. Herbivorous species have increased in relative abundance in the catch while groupers and snappers have decreased.

Several studies document the failure of existing territorial regulations to protect reef fishes or reverse the declines in abundance of preferred species such as the large groupers and snappers (Beets 1996, Garrison *et al.* 1998, Wolff 1996, Beets and Rogers in press). Lack of enforcement has no doubt played a role; in one study of traps set by fishers, over 50% had no functioning biodegradable panels to allow fish to escape if traps were lost (Garrison *et al.* 1998). However, it is unlikely that even full compliance with existing regulations would be adequate to reverse the alarming trends.

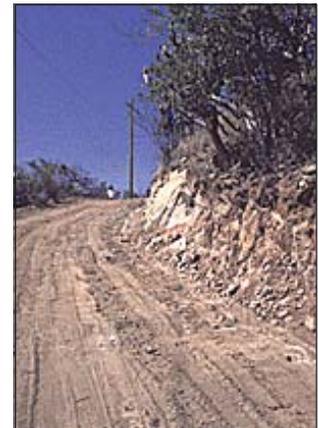


Figure 194. Erosion from unpaved roads are a major source of reef sediment

Water Quality

– In general, increases in point and non-point source discharges are causing declines in the water quality in the USVI.

Wastewater disposal has been a chronic problem in the USVI. There are eight sewage treatment facilities on St. Thomas, seven secondary plants, and an anaerobic pond at the airport. The plants do not always attain secondary treatment discharge requirements (OAI 1999). A new secondary treatment plant opened in 2000 serving the 2,000 residents of Cruz Bay and surrounding areas of St. John. This secondary treatment replaced an overloaded facility that did not meet interim effluent limits and discharged into

a salt pond. The 50,000 residents of St. Croix are served by one primary wastewater treatment facility. The sewage collection system consists of 87 miles of gravity and force mains, 3 major sewage lift stations, and 12 feeder pump stations. Because of long detention time for flows arriving at the wastewater treatment plant, hydrogen sulfide is sometimes generated and deteriorates concrete sewer mains. Sewer mains have frequently and repeatedly failed, requiring raw sewage bypass during repairs (OIA 1999). Raw sewage bypasses have lasted close to a year.

Untreated rum-effluent from a St. Croix distillery is discharged on St. Croix's south shore resulting in a 5-mile long benthic "dead zone" caused by the high toxin level, high Biological Oxygen Demand, and the high temperature of the effluent. Each year the VI Government requests and has been granted an exemption from the U.S. Clean Water Act for this discharge.

Poor land management practices associated with accelerating development on St. John pose an increasing threat. Over 80% of the island has slopes that exceed

Figure 195. Commercial fishing in the Virgin Islands National Park (Photo: J. Sneddon).



30% (CH²M Hill 1979) and rainfall often arrives in brief, intense showers that promote erosion. Runoff from 56 km of unpaved roads contributes the largest amount of sediment to the coastal waters



Figure 196. This bulk carrier, cruise ships, and other large ships regularly use St. Croix's piers (NOAA Photo Library).

(Anderson and MacDonald 1998). Water quality data from 30 sites around St. John show that bays with developed watersheds have higher turbidity and light extinction coefficients, and lower light transmission than bays inside the park associated with undeveloped or less disturbed watersheds (USGS and NPS unpub. data).

Recent studies suggest that excess sedimentation can exacerbate the effects of natural bleaching events. Nemeth and Nowlis (2001) found that bleaching of coral colonies during the peak of the 1998 bleaching event showed a strong positive relationship to sedimentation ($r=0.92$). At reef sites exposed to sedimentation rates between 10 to 14 mg/cm²/d, 38% of the coral colonies examined exhibited pigment loss compared to 23% of the corals observed at sites exposed to sedimentation rates between 4 to 8 mg/cm²/d.

Coastal Populations and Reef Economics

A total of 108.6 thousand residents inhabited the USVI in 2000, an increase of 6.7% from the 1990 census and 12.5% from 1980 (U.S. Bureau of Census 2002). In 1999, total number of visitors to USVI was close to 2 million (560,000 air visitors and 1.4 million cruise passengers) and in 2000 arrivals increased to 2.5 million (VI



Figure 197. Fish trap atop the Yawzi Reef in the Virgin Islands National Park (Photo: Virginia Garrison).

Dept. of Tourism 2002). I got new data from Dept. of Tourism.

Socioeconomics – Fishing is an important recreational and commercial aspect of the economy of the USVI. It is important to note that no fish are exported from the USVI; in fact, during peak demand fish are imported into the USVI (Downs and Petterson 1997).

USVI fisheries are small-scale, using several gear types to harvest over 180 species of reef fish (Caribbean Fisheries Management Council 1985, Beets 1997, Garrison *et al.* 1998). The primary fishing gear in the USVI fishery (traps, followed by hook and line, and nets) has not changed greatly since the 1930s (Fiedler and Jarvis 1932), although the fishing effort has greatly increased and catch composition has changed (Appeldoorn *et al.* 1992, Beets 1997). The level of fishing effort varies greatly, some fishers use little gear nearshore and others set long trap lines across the insular shelf (B. Smith unpub. rept., Garrison *et al.* 1998).

Reef fish harvesting equipment has become more sophisticated, allowing fishers to access more areas; set and retrieve more traps in a day; use longer lasting, less degradable traps; and subsequently severely impact many

species of reef fishes. Average number of traps fished per full-time fishermen has increased from 4 in 1930, to 8 in 1967, to >100 in 1997 (Fiedler and Jarvis 1932, Dammann 1969, W. Tobias pers. comm.). Maximum number of pots fished by a single fisherman in 1930 was 30 traps whereas in 1997 the maximum was 3000 traps (Fiedler and Jarvis 1932, Downs and Petterson 1997).

Larger scale net fishing has been recently reported occurring in the reef areas adjacent to and east of Buck Island, St. Croix. Large nylon fishing nets are set directly off the barrier reef in the evenings to catch species of fish during nocturnal migrations off the reef. Subsequent to these reports, NPS has had confirmation that local fisherman have more fish than

Figure 198. This vessel was subsequently removed from the St. Croix reef it grounded on, but others still litter USVI harbor and reef areas (Photo: NOAA Photo Library).



they can sell in a day and would rather throw the fish out than sell the fish for a bargain price (J. Tutein, NPS Superintendent, pers. comm.).

Environmental Pressures on Coral Reefs

A diverse array of stresses has caused degradation of USVI coral reefs, associated marine ecosystems, and the fishery resources dependent on them. Some natural stresses such as hurricanes have had dramatic and acute effects, while



Figure 199. Prior to 1979, extensive thickets of elkhorn coral were dominant elements of USVI shallow-water reefs (Photo: Andy Bruckner).

other stresses are considered chronic conditions such as strong swells, sea temperature fluctuation, sedimentation, and pollution.

Human activities are superimposed on these natural stresses. Anchoring and ship groundings on coral reefs and seagrass beds are examples of acute stresses with immediate, obvious, and sometimes long-term effects (Rogers and Garrison 2001). Other acute human caused stresses affecting reefs, especially in St. Thomas and St. Croix, are dredging, sand extraction, groin construction, and sewage effluent (Goenaga and Boulon 1992).

Human Stresses – Chronic stresses like over-fishing (commercial, hand-line, pot fishing, spear fishing, net, long-line, trolling, driftnet), point and non-point source water pollution, and sedimentation

Figure 200. This diver is surveying off Buck Island, St. Croix the extent of elkhorn coral rubble left after Hurricane Hugo (Photo: Caroline Rogers).



generally cause changes that are difficult to quantify and track but are particularly damaging. Moreover, stressors can act synergistically with natural disturbances to accelerate damage to reefs or slow their rate of recovery (Rogers and Beets 2001, Nemeth and Nowlis 2001).

Fishing Pressure – Over-fishing throughout the USVI has had profound effects on the resources, including those within federally protected areas such as VINP and BINM. Reports and observations from more than 20 years ago suggested that fishing was already changing the reef-associated fishes (J. Randall's field notes 1958-1961, Olsen and LaPlace 1978). Fisheries are close to collapse, and even those ecosystems within the boundaries of "marine protected areas" are deteriorating (e.g., Beets 1996, Beets and Rogers in press). Existing zoning, erosion control, and fishing regulations are not providing sufficient protection. The present combination of natural and human stresses and the magnitude of their effects may be unprecedented.

Recreational Uses – Destruction from boats running aground on reefs has been severe. Large vessels (greater than 65 ft) run aground with surprising regularity on USVI reefs (more than twice a year) and vessels abandoned after recent hurricanes still litter several harbor and reef areas.

Small boats run aground on shallow reefs, destroying corals, particularly elkhorn coral. For example, within VINP, an average of four boats per week ran aground on Windswept Reef (R. Boulon pers. comm). After the installation of resource protection buoys in 1985, groundings to this reef have decreased to an average of one a year (NPS records).

Surveys off St. John make it clear that benthic resources have been damaged by anchoring (Link 1997). A dramatic case of anchor damage involved the cruise ship "Windsprite" which destroyed a 283-m²

section of reef within VINP in 1988. Ten years later, no significant recovery of coral had occurred (Rogers and Garrison 2001). VINP has installed 211 moorings and over 111 resource protection buoys around St. John to help prevent anchor damage to benthic habitats and the entire southern section of VINP is a no-anchor zone. NPS has been monitoring benthic recovery surrounding moorings in several bays for the last three years.

All three USVI islands have popular snorkel and dive sites experiencing heavy visitor use (>200 visitors/site/day) (St. Croix Cane Bay Dive Shop instructors pers. comm., NPS records) that may be damaging coral reefs. BINM remains the number one tourist destination for St. Croix. Over 150 people per day visit the underwater interpretive snorkel trail and visits can peak over 200. BINM has a mooring system at the underwater trail that limits boats and snorkelers, but intensive use has resulted in some coral damage (Z Hillis-Starr pers. comm).

Natural Stresses

Hurricanes – Since 1979, eight hurricanes have affected USVI reefs. Damage varied with storm path, strength and velocity, wave height and direction, the dominant coral species, and reef depth (e.g., Rogers *et al.* 1997, Bythell *et al.* 2000). Hurricanes David (1979) and Hugo (1989) were the most destructive and it appears that these acute incidents have pushed percent live coral cover to a relatively stable, albeit lower, equilibrium.

In some shallow zones at BINM, *A. palmata* cover, already reduced from 85 to 5% by White-band Disease, fell to 0.8% after Hurricane Hugo (Gladfelter 1991). Structural recovery from Hugo has been very slow due to several subsequent hurricanes in 1995, 1998, and most recently in late 1999.



Figure 201. In 2001, Buck Island National Marine Monument off the island of St. Croix became the USVI's first substantial no-take area (Photo: NOAA Ocean Service).

Bythell *et al.* (1993) recorded partial and total mortality of coral colonies of three common species at 15 BINM sites over a 26-month period (1989-1991) that included Hurricane Hugo. The dominant species, *M. annularis*, suffered greater mortality from chronic factors such as predation and tissue necrosis than from the hurricane. *D. strigosa* suffered more tissue loss from the storm than from chronic factors, while *P. astreoides* had substantial mortality from all factors.

Hurricane Hugo also caused a 40% decline in the living coral in transects surveyed on a reef in Lameshur Bay, St. John which has failed to show any significant recovery in terms of an increase in live coral cover (Rogers *et al.* 1997, NPS and USGS and NPS, unpub. data). Macroscopic algae,

Table 17. Authorities with jurisdiction over USVI waters and submerged lands with coral reefs.

Government Agency	Marine Jurisdiction
U.S. Department of Interior * Minerals Management Service * National Park Service	* Submerged lands and waters adjacent to federal property, seaward to 3 nmi; submerged lands withheld (1974) * Leasing responsibility for: Submerged from 3 nmi out to extent of U.S. jurisdiction; Federal submerged lands within 3 nmi of shore. * Buck Island Reef National Monument, Virgin Islands National Park, Salt River Bay National Historical Park and Ecological Preserve
U.S. Department of Commerce * National Oceanic and Atmospheric Administration	* From the outer extent of the USVI jurisdiction (3 nmi) to the outer extent of the EEZ (200 nmi from the shoreline)
Virgin Islands Territorial Government	* Non-U.S. government waters and submerged lands from the shoreline to 3 nmi

Type	Agency	Location/Frequency	Results/Products
St. Croix			
Water quality	NPS (temperature BUIS)	Every 2 hours	Temp. graphs from 1991 to present
	VI DPNR DEP (various parameters)	Variable (quarterly to yearly)	Coastal water quality is degraded in developed bays, BUIS and East End water quality remains very good
Fisheries	VI DPNR DFW (commercial reef fish, conch, lobster, landing reports)	Monthly catch reports from fishermen	Declining, especially adults and diversity of reef fish
	NPS (visual census and trap counts at BUIS)	Bi-annually, 1988-1994; trap counts 1992-1993	Fishy is degraded due to over-fishing surrounding the park
Biological (benthic)	LVI-VIMAS* (photo-quadrats, 4 sites)	Quarterly	None to date
	LVI-CMES** (AGRRA, 4 sites)	Single survey in 1999	Coral cover 19%; macroalgae 16%; coral recruits 9.5/m ²
	NPS (chain transects, colony monitoring, video transects, and cross-reef depth profiles at BUIS)	Sem-annual to annually and after severe storm or bleaching events depending on type of monitoring	Increased hard coral recruitment; survivorship of recruits of boulder and branching corals, specifically <i>A. palmata</i>
St. John			
Water quality	NPS	15 sites/quarterly	Quality generally high except in bays with developed watersheds
	LVI	Lameshur/Fish Bay (turbidity, TSS)	Turbidity significantly greater in Fish Bay
Water temperature	USGS	4 sites/every 2 hours; thermistor at 8-12 m depth	Maximum temperature over 30° C associated with coral bleaching
Reef fishes	USGS/NPS/visiting scientists (adult fishes)	Annually for at least 4 reefs	Temporal and spatial trends
	USGS/visiting scientists (juvenile fishes)	Monthly at Lameshur Reef	Peaks in recruitment in summer/early fall
Biological (benthic)	USGS	Lameshur and Newfound Reefs surveyed at least once a year; done with video method	Decrease in coral cover from storms and probably disease; high macroalgal levels at Lameshur
	LVI	Great Cruz Baoy, Fish Bay/Lameshur Bay; monitored quarterly with AGRRA method and video	Coral cover is 25 and coral recruit density is 33/m ² at Lameshur; Coral cover is 12% and coral recruit density is 25/m ² at Fish Bay. Macroalgae is about 8% at both sites
	NPS	Biannual monitoring of cover around newly installed moorings in several bays	Study just beginning
Coral diseases	USGS	Tektite Reef (monthly); Haulover Reef (every 2 months)	16 different coral species affected; disease present in almost every month surveyed
Coral growth	USGS	4 sites; transplanted and naturally occurring colonies of 3 species measured	Naturally occurring and transplanted coral fragments/colonies showing similar survivorship
Sedimentation	LVI	Fish Bay/Lameshur Bay	3 times more sediment entering sea at Fish Bay
Air quality	NPS/EPA/USGS	Lind Point; rainfall and nutrients in wet deposition	Pathogens in dust, high particulates <1 μ m
St. Thomas			
Water quality	DPNR, DEP	Quarterly; sites around St. Thomas	Not available
	LVI	Caret Bay; TSS and turbidity monitored monthly	Avg. TSS 8 mg/l Avg. turbidity 0.4 NTU
Biological (benthic)	LVI	8 sites; monthly to quarterly with photoquadrats, AGRRA, and video	Coral cover 17%, macroalgae 42%, coral recruits 17/m ²
	DPNR, DFW	Permanent transects; Annual to biennial with sites in St. James and Mangrove Lagoon Marine Reserves	Data being analyzed
Reef fishes	LVI (adult fishes)	Southdrop (Red Hind Reserve); quarterly	Increase in size of spawning groupers since last survey. Groupers migrate 7-15 miles to spawning site.
	LVI (juvenile fish)	5 sites with belt transects	Peak recruitment of snappers and other spp. in spring and late summer/fall. Snapper and grunts most abundant in grass beds.
	LVI (larval fishes)	3 sites with light traps	Peak recruitment of snappers and other spp. Spring and late summer/fall
	DPNR, DFW (larval fishes)	Fish census at permanent transect sites at St. James and Mangrove Lagoon Marine Reserves	Data being analyzed
Sedimentation		6 sites (traps)	Avg. sediment load 12.6 mg/cm ² /d nearshore and 6.0 mg/cm ² /d offshore cays

Table 18. Monitoring related to coral reefs in the USVI.

* VMAS – Virgin Islands Marine Advisory Service
 ** CMES – Center for Marine and Environmental Service

covering about 5% of the bottom before Hurricane Hugo, are now periodically very abundant and can reach averages of over 30%. It appears that the level of herbivory by sea urchins and fishes has been too low to keep the macroalgae in check, and algae are inhibiting coral settlement and recruitment (Rogers *et al.* 1997).

Climate Change and Coral Bleaching – Global warming is thought to contribute to an increased frequency and strength of hurricanes in the Caribbean and coral bleaching is often associated with higher water temperatures. The worst episode of coral bleaching to date occurred worldwide in 1998 (Pomerance 1999).

Extensive coral colony mortality was not associated with 1987, 1998, and 1990 USVI bleaching episodes. At two St. John sites, bleaching of coral tissues was estimated in the fall of 1998 at 43% and 47% (Rogers and Miller 2001). The 1998 bleaching episode coincided with the hottest seawater temperatures on record (four sites, NPS records). At Caret Bay reef, St. Thomas, maximum bleaching recorded was 41% but most colonies had recovered within six months (Nemeth and Nowlis 2001). Extensive bleaching (but not mortality) was observed at BINM in the fall of 1998 where an estimated 20% of *D. strigosa* at one site and 53% at a second site exhibited bleaching. During the fall of 1999, when sea temperatures reached 28.8f C,

mild bleaching was observed on 16%, 26%, and 48% of the coral colonies greater than 25 cm in diameter on St. Thomas, St. John, and St. Croix, respectively (Nemeth *et al.* in press).

Current Conservation Management

The U.S. Department of the Interior (DoI), U.S. Department of Commerce (DoC), and the Virgin Islands Territorial Government all have jurisdiction over submerged lands within the USVI (Table 2).

Mapping – Benthic habitat types found throughout the USVI have been digitally mapped to a depth of 20 m (Kendall *et al.* 2001). These habitat maps will be the basis for establishing a number of permanent sites as part of a new USVI-wide long-term monitoring program.

Assessments, Research, and Monitoring

– The NPS and USGS in the USVI have collected some of the longest time-series data sets on coral reefs in the Caribbean, some dating back decades (Table 2).

Several innovative marine research and monitoring projects have been conducted in the USVI. The Tektite I and II underwater habitat projects took place on the south side of St. John from 1969-1971 (Collette and Earle 1972, Earle and Lavenberg 1975), and approximately 80

Figure 202. Long-term monitoring is needed to track trends and predict change in the USVI reef ecosystem (Photo: Matt Kendall).



Figure 203. Little is known about the roles that deeper reef (A) and mangrove (B) habitats play in the life histories of shallow-water reef species, particularly those that have been overfished (Photo Matt Kendall).

Hydrolab (1977-1985) and 13 Aquarius (1987-1989) underwater habitat missions were conducted in St. Croix.

Much of the baseline information for the VINP comes from a series of reports produced by the Virgin Islands Resource Management Cooperative from 1983-1988. Fairleigh Dickinson University's West Indies Laboratory, located on St. Croix, conducted nearly 20 years of ecological studies that established a baseline for BINM (Hubbard 1991, Bythell *et al.* 1992, Gladfelter 1992).

BINM and VINP have formal monitoring programs dating to the early 1980s focusing on coral reef condition, reef fish, sea turtle populations, and seagrass beds (only VINP). USGS and NPS scientists have collaborated on long-term monitoring of coral reefs using a comprehensive protocol based on use of a digital video camera along randomly chosen transects (Miller and Rogers 2001, Rogers *et al.* in press). Each year three coral reef sites (20 transects each) at VINP and two at BINM are monitored using this protocol. For the past 14 years, reef fish in VINP have been monitored at between 4 and 16 reef sites (15-18 censuses are conducted at each site) and fish censuses were recently re-established at BINM (130 censuses). Research and monitoring on

both nesting and juvenile sea turtles at BINM has been summarized in Hillis-Starr and Phillips (1997).

In 2001, the USVI Territorial government initiated a long-term monitoring program with financial support from NOAA.

MPAs and No-Take Reserves – The USVI Territorial Government has designated Marine Reserves and Wildlife Sanctuaries (Salt River, Cas Cay and St. James) where fishing is allowed only with hand lines or for baitfish with a permit. Federal MPAs provide varying levels of protection and enforcement for USVI coral reef ecosystems.

St. Croix – A total of six federal MPAs protect aspects of coral reef ecosystems off this island.

Buck Island Reef National Monument – The NPS manages the BINM, established on St. Croix, USVI in 1962 (Presidential Proclamation No. 3443) to protect one of the finest coral reef ecosystems in the Caribbean. Additional marine portions were added in 1975 (Presidential Proclamation No 4346) and 2001 (Presidential Proclamation 7392). Current size of BINM is 71 ha of land and 77.7 km² of submerged lands.

This park and preserve includes approximately 1.6 km² of land and 2.5 km² of water that extends seaward to about 91 m depth. Fishing is allowed in this MPA.

This includes the water surface and marine resources of the Salt River Bay, Triton and Sugar Bays. An area seasonally closed to fishing off this island now has been designated a Federal Marine Reserve.

Hind Bank Marine Conservation District – Mutton Snapper Spawning Aggregation Area – From March 1 to June 30 each year, all fishing is prohibited by NOAA within this federally protected 3.75 km² MPA at the red hind spawning site off St. Thomas south of St. Croix (50 CFR 622.23) in 1990. In November 1999 this 41 km²

MPA area south of St. Thomas was designated a marine reserve with all



Figure 204. Beautiful reefs can still be found in shallow-waters of the USVI. However, additional regulations and enhanced enforcement are needed to reverse the serious decline in harvested species and general degradation of the reef ecosystem (Photos: Matt Kendall).

Presidential Proclamation 7392 declared the entire Monument a no-fishing and no-anchoring zone, ending 40 years of legal extractive use. This monument is the first substantial “no-take area” established for the island of St Croix and will require consistent and enhanced law enforcement to protect the area and effect the recovery of St. Croix’s depleted reef fisheries. Up until 2001, only a small eastern section (49.7 ha) was designated a no-take zone, thus most of BINM was open to extractive uses including setting of fish traps, cast net, hook and line, and hand collection of conch and lobster. NPS has had limited success in controlling illegal fishing due to a lack of law enforcement staff.

Salt River Bay National Historical Park and Ecological Preserve (SRBNHP) – The NPS manages this park, established on St. Croix, USVI in 1992 to preserve, protect, and interpret for the benefit of present and future generations certain nationally significant historical, cultural, and natural sites and resources in the Virgin Islands (16 USC 410tt). From December 1 through February 28 each year, all fishing is prohibited by NOAA within this federally protected 3.9 km² MPA located on Lang Bank, east of St. Croix (50 CFR 622.23).

St. Croix Restricted Areas – Anchoring in the two restricted areas (0.01 km² and .4 km²) is prohibited with the exception of U.S. Government owned vessels and private vessels that have been specifically authorized to do so by the Commanding