CHAPTER 8

STATUS OF SELECTED CORAL RESOURCES

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Introduction

The purpose of this chapter is to present more detailed information on selected reef resources at Looe Key National Marine Sanctuary. The information provided here is intended to provide a better understanding on the status of selected coral species and potential sources of damage and mortality from natural and human causes. We provide maps of the distributions of two important corals, document sources of coral damage and mortality, and document the 1983 epidemic mortality of the long-spined urchin (*Diadema antillarum*).

Elkhorn coral (*Acropora palmata*) and pillar coral (*Dendrogyra cylindrus*) are two important coral species. Elkhorn coral is ecologically important as shelter and a major source of rubble. Shinn *et al.* (1981) found that elkhorn coral was the major historical source of material for spur formation and that living colonies were no longer abundant on the reef. Further decline of elkhorn coral may result in erosion and decline of the reef (See Chapter 4). Pillar coral on the other hand is a beautiful but relatively rare coral in the Caribbean. Its presence at Looe Key Reef was one of the reasons for nominating the Sanctuary (US Department of Commerce, 1980).

We also photographically documented sources of coral damage and mortality which are important management considerations. A better understanding of natural- and human-caused damage and mortality is important for developing effective management policies. Finally, we report data collected to document long-spined urchin densities during and after a major sea urchin disease epidemic at Looe Key Reef in 1983.

Methods

Detailed surveys were conducted to locate colonies of elkhorn coral and pillar coral in the forereef and shallow hard bottom areas of LKNMS. Divers recorded the location of all colonies of these two species on maps of the forereef and the backreef livebottom habitat. The location of patches of staghorn coral *A. cervicornis* were also noted in the forereef, although very small colonies may have been overlooked.

A series of photographs were assembled to document sources of coral damage and mortality. Most pictures were taken during this survey although some were taken over the past decade. Unless otherwise noted all photographs were taken by the author at Looe Key Reef or in the immediate surrounding area. Sources of coral damage and mortality were classified as primarily natural or human origin. No attempt was made to quantify the importance of any factor. Billy Causey, Sanctuary Manager for Looe Key National Marine Sanctuary, provided information used to map the general locations of recent vessel groundings.

During 1983 an epidemic disease of unknown origin caused mass moralities of the long-spined urchin over much the Caribbean region (Plate 8.8). The disease was first noticed at Looe Key Reef during the last week in August and was over by the middle of September. Sea urchin densities were measured along replicate 1 x 15 m (3 x 50 ft) transects conducted along the top shallow portion of the middle study spur (Chapter 3). Normally, sea urchin density was high in this area. Data were taken when the disease epidemic was first noted on 29 August and after active signs of the disease had disappeared on 16 September 1983 and in June 1984. Abundance values for four transects from the same location were transformed with $\log_{10}$ (n + 1) and analyzed by a one way analysis of variance.

Results

Mapping

Maps were constructed showing the distribution of colonies of elkhorn coral, pillar coral, and staghorn coral *A. cervicornis* (Figure 8.1). We found only four colonies of pillar coral in the entire Sanctuary. Photographs of the four colonies are provided so that any future changes in their condition could be detected (Plates 8.2, 8.3, 8.1, 8.3).

Natural sources of damage and mortality

Damage from wave action, especially during severe winter storms and hurricanes, has been considered the greatest source of physical damage to corals (Blumenstock, 1961; Stoddart, 1963; Vermeer, 1963; Bull *et al.*, 1967; Endean, 1976; Shinn, 1976; Randall and Eldredge, 1977; Ogg and Koslow, 1978; Highsmith, *et al.* 1980; Porter, *et al.* 1981; Tilmant and Schmahl, 1981; Woodley, *et al.* 1981). Branching corals such as elk-horn coral, are particularly vulnerable to wave damage (Plate 8.2). However, elkhorn coral depends on damage as a source vegetative reproduction and its rapid growth counteracts wave damage under normal end i ions .

Extreme water temperatures can stress and kill corals. The coldest temperatures are likely to occur during short winter cold spells and have caused of mortality in certain areas of the Keys (Plate 8.3) (Kinsman, 1964; Glynn, 1973; Endean, 1976; Jokiel and Coles, 1977; Shinn, 1976; Bohnsack, 1983). During this survey in 1983 some corals at Looe Key Reef showed stress by bleaching due to high water temperatures (32° C, Plate 8.3) (Jaap, 1979).

Natural predation and competition are sources of damage and mortality for corals (Plate 8.4). Documented Caribbean coralivores include bristle worms, other invertebrates, and, to a limited extent, fishes (Dart, 1972); Sammarco *et al.*, 1974; Bak and Van Eys, 1975; Bak *et al.*, 1976. Ogden and Lobel, 1978; Glynn *et al.*, 1979; Highsmith *et al.*, 1980; Sammarco, 1980). Sea urchins and some fishes can weaken coral colonies by scraping and eroding dead coral. Close contact between corals or corals and other sessile (non-motile) organisms results in direct competition for space (Lang, 1973; Endean, 1976; Maguire and Porter, 1977; Stern *et al.*, 1977; Buss and Jackson, 1979; Buss *et al.*, 1980; Porter *et al.*, 1982). Some corals compete directly by attempting to digest each other with mesentarial filaments. Usually a dominance hierarchy exists where certain species tend to win specific encounters. Indirect competition also occurs where corals with faster growth rates tend to shadow out slower growing corals. Branching corals, such as elkhorn and staghorn corals, are fast growing species that tend to overgrow and dominate slower growing rounded corals, such as brain coral (*Colcophyllia natans*). Periodic major storm damage may reverse the outcome of this competition by damaging more colonies of the fragile branching species than the stronger, storm resistant, rounded species. Thus, an equilibrium exists where species with both strategies are maintained. A final form of competition, not illustrated, occurs from erosion of dead coral by coral boring organisms such as sponges, polychaete worms, mollusks and tunicates.

Turbidity from natural or human disturbance can be an important source of injury and mortality to corals (Plate 8.5). Sediments can directly cover and kill coral tissue (Loya, 1972, 1976; Ray and Smith, 1971; Bak, 1974; Dodge *et al.,* 1974, 1977; Marszalek, 1981; Dallmeyer, *et al.*, 1982; Dodge, 1982). Suspended sediments can indirectly kill corals by reducing light levels for prolonged periods of time. Corals tend to exist in areas were normal sediment levels are low, however unusual events can temporarily increase turbidity to damaging or lethal levels.

Diseases affect corals (Garrett and Ducklow, 1975; Mitchell and Chet, 1975; Voss, 1973). Some have unknown origin (Plates 8.5, 8.6, 8.7) while others are better known like black ring disease (Plate 8.6). Black ring disease is caused by a bluegreen algae *Ocelletoria submembracea* (Sp. ??) which is believed to attack a coral colony more easily after it has been damaged. During the course of this survey several coral with disease symptoms were noted. Often disease epidemics occur over widespread reef areas.

Diseases also affect organisms besides corals. The long-spined sea urchin population declined drastically as the result of a disease epidemic at Looe Key Reef (Table 8.1). Analysis of variance shows a highly significant ($p < 0.001$) decline in population size, The initial decline from an average of 51 to 7 individuals per transect was highly significant ($p < 0.001$), The secondary decline from an average of 7 to 3 individuals per transect was not significant ($p = 0.18$).

Human sources of damage and mortality

Human activity can directly and indirectly cause injury and mortality for corals (Voss, 1973; Endean, 1976; Dahl, 1977, 1981; Davis, 1977; Tilmant and Schmahl, 1981). The forereef area receives especially heavy direct use and abuse (Plate 8.9). Careless navigating (Plate 8.9) and poor anchoring practices (Plate 8.10) are a major causes of direct coral damage. Anchors, anchor chain, and line can damage coral tissue and break fragile colonies. The ecological impacts of this damage have not been extensively documented, however, it is at least an aesthetic problem. Objects deposited on the reef accidentally or deliberately (Plate 8.11) can also damage coral or alter the aesthetic experience for divers. Another direct problem is from careless and inexperienced divers who touch live corals damaging their tissues (Plate 8.11). Whether this is an ecologically important factor or serious problem is not known.

Groundings and shipwrecks have had important impacts on the reef besides providing a name for Looe Key Reef (See Introduction, Chapter 1). In the recent past a number of shipwrecks and groundings have occurred at Looe Key Reef (Table 8.2). Carelessness, errors in judgment, and lack of local knowledge are causes for vessel run aground on the spur formations. Damage has been both temporary and long lasting from a variety of vessels and over a considerable portions of the reef (Fig 8.2, Plates 8.12, 8.13, 8.14, 8.15, 8.16, 8.17). The detrimental effects of groundings include physical damage to the reef and water column pollution from fuel, liquid waste, leaks, discarded narcotics, and lost cargo. In most cases the vessels were salvaged and removed. However, physical scars and wreckage are still visible for long periods of time. Despite new and improved aids to navigation the potential for a major future disasters still exists and presents a major management problem (Plate 8.18). Surprisingly, the wreckage of the Robby Dale, a wrecked narcotics smuggler, is an attraction for may divers because it is a convenient reference point, the extensive wreckage is dramatic and different from the natural habitat, and many fishes congregate around the wrecked superstructure.

Human activities can also indirectly affect the reef resources of LKNM. The Florida Keys are a region with much shipping activity and oil spills of various magnitudes are a frequent occurrence (Plate 8.19). Other sources of human pollution may impact the reef. Big Fine Key is the second largest Key in the Florida Keys and is immediately north of the Sanctuary. Most of Big Pine Key has yet to be extensively developed although activity is likely to increase in the near future as other Keys become saturated. Land clearing on Keys adjacent to the Sanctuary may have indirect effects on the Sanctuary by destroying mangrove forests (sources of food and habitat); increasing sediments from runoff; increasing pollutants from insecticide sprays and runoff; and increasing human use and subsequent damage to the Sanctuary (Plate 8.20).

Discussion and conclusions

Maps of coral distributions document the present location of important corals from which any changes can be ascertained. Although both *Acropora* species have a wide depth range, staghorn coral is more common in deeper water while elkhorn coral is more common in moderate depth water. Maps show that the east forereef, which has the poorest development of spur formation, also has no live *Acropora* colonies (Figure 8.1). Whether their absence is due to natural causes or harvesting activities is not known. However, both the east and west spurs show cracks that are signs of erosion (Figure 8.1, see Chapter 4). Finally, a disproportionate number of *A. palmata* colonies seem to occur on the west edges of spurs (Figure 8.1). This pattern is a possible consequence of prevailing seas from the southeast which would tend to wash broken coral fragments to the west and north side of spur formations.

The initial 86% population decline of the long-spined urchin can directly be attributed to the disease epidemic which was rapidly affected the population over a period of a two weeks. The secondary decline from 14% to 6% of the original population level, noted over the next 9 months was probably not due to disease. Two possibilities for the decline are that surviving urchins redistributed into other habitats and urchin predators (which were not directly impacted by disease) continued to reduce urchin population sizes. No data are available to substantiate these or other possible hypotheses. The continued decline) however, indicates that urchin recovery may not be rapid. The *Diadema* disease outbreak occurred during a period with the highest recorded water temperatures for the summer on the outer reef (30.9 °C). However, the inshore patch reef area just south of the Newfound Harbor Keys had higher temperatures (32.5 °C) and was not affected at this time. The disease was over on the forereef at Looe Key Reef by 14 September (the next visit after 31 August), but did not affect the inshore patch reef just south of the Newfound Harbor Keys until 16 October, over a month later. This information impunes the hypothesis that temperature was the sole source of the epidemic.

Natural and human impacts on the reef are complex and poorly understood. The photographs presented show a wide range of natural and human factors that effect corals and other reef resources. However, different factors can interact synergetically. A coral stressed by one detrimental factor is more vulnerable to stress from another factor. A better understanding of the causes, interactions, and consequences of stress is essential for wise resource management.

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Table 8.1. Changes in long-spined urchin densities as a result of the 1983 disease epidemic at Looe Key Reef. Transects were established in areas of high density urchin abundance on top of spurs in the shallow forereef zone. Paired transects were done contiguous to each other and each covered 1 x 15 m. Transect sites 1 and 2 were on the middle permanent study spur and sites 3 and 4 were on the first spur to the east, Healthy urchins showed no obvious visual signs of disease during survey. Urchins were considered diseased if they showed discoloration or loss of spines. No diseased urchins were observed after August 1983.

Site	DURING DISEASE OUTBREAK 30 August 1983			AFTER OUTBREAK 16 September 1983	A YEAR LATER 17 June 1984
	HEALTHY	DISEASED	TOTAL	TOTAL	TOTAL
1A	47	11	58	3	8
1B	53	10	63	3	2
2A	27	13	40	11	2
2B	28	14	42	11	0
3A	-	-	-	5	0
3B	-	-	-	4	0
4A	-	-	-	6	0
4B	-	-	-	5	0
Mean/transect			50.75	6.0	1.5
Standard Deviation			11.47	3.25	2.78
Density (No./m^2)			3.4	0.4	0.1

Table 8.2. Recent shipwrecks at Looe Key Reef. Information provided by John Halas, Billy Causey, Chet Alexander, and Florida Department of Natural Resource files.

Vessel	Size (ft.)	Date	Estimated Impacted Area (m^2)
Lola	110	5 March 1976	445
Robby Dale	70	18 May 1977	?
Miss Alissa	70	15 October 1982	3
Noah Smith	70	15 October 1982	10
Cleo	87	28 May 1983	12 - 15
Pacific Bell	49	17 June 1983	19
Marylin	27	10 July 1983	1.4
Papillion	41	12 March 1984	?

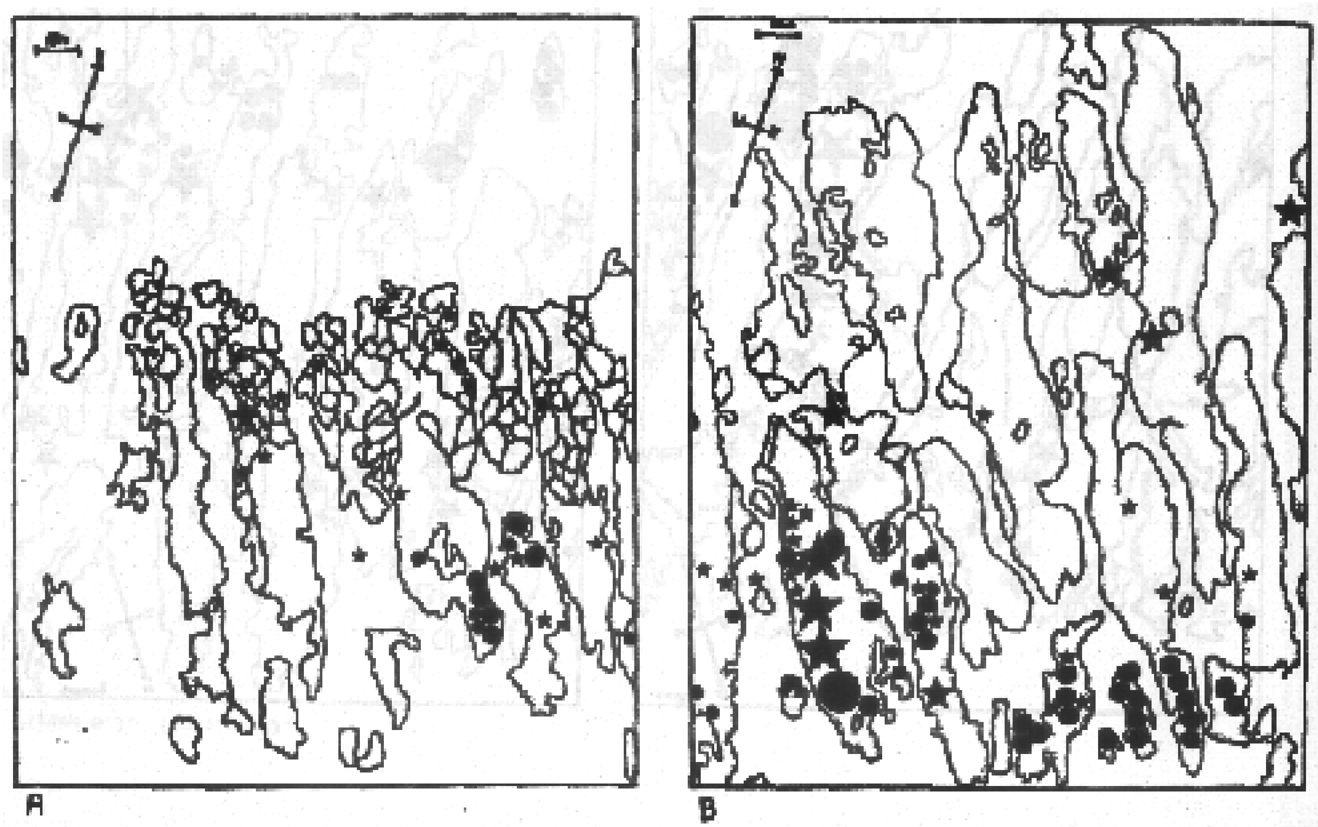
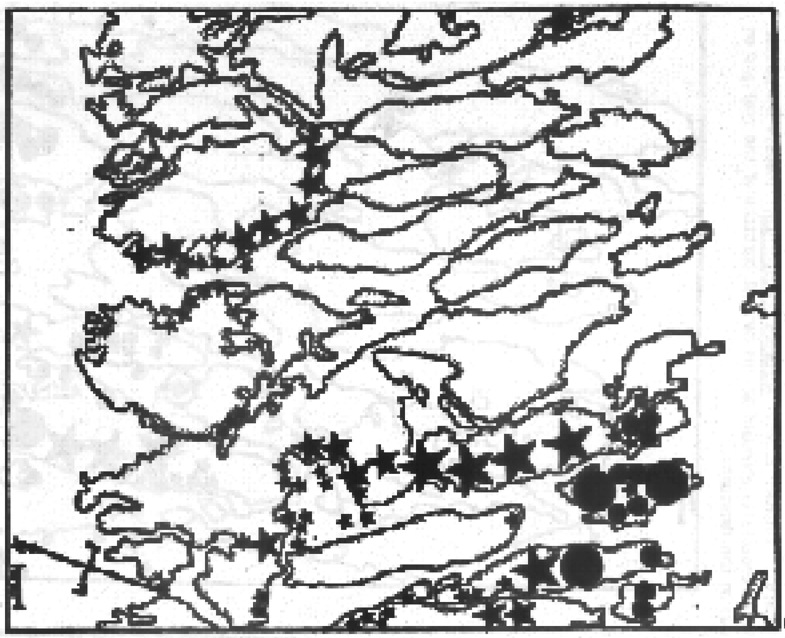
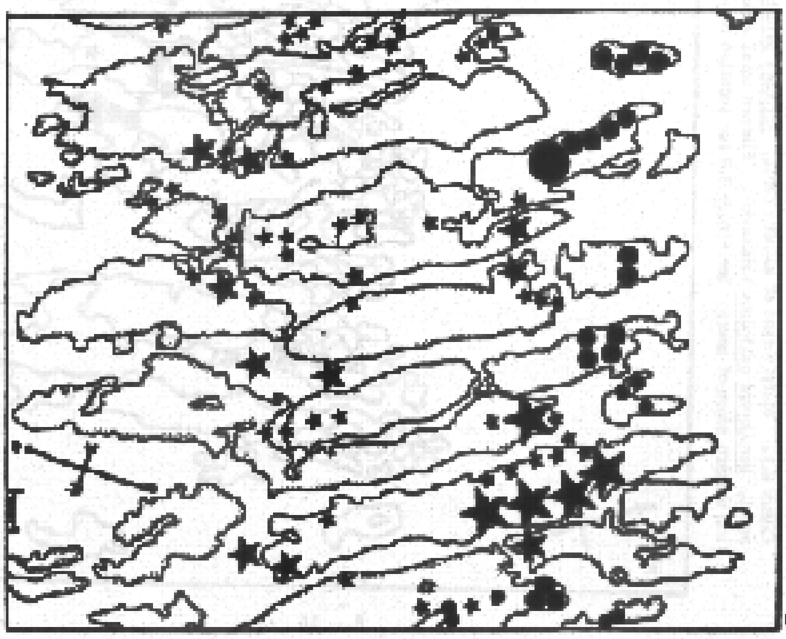
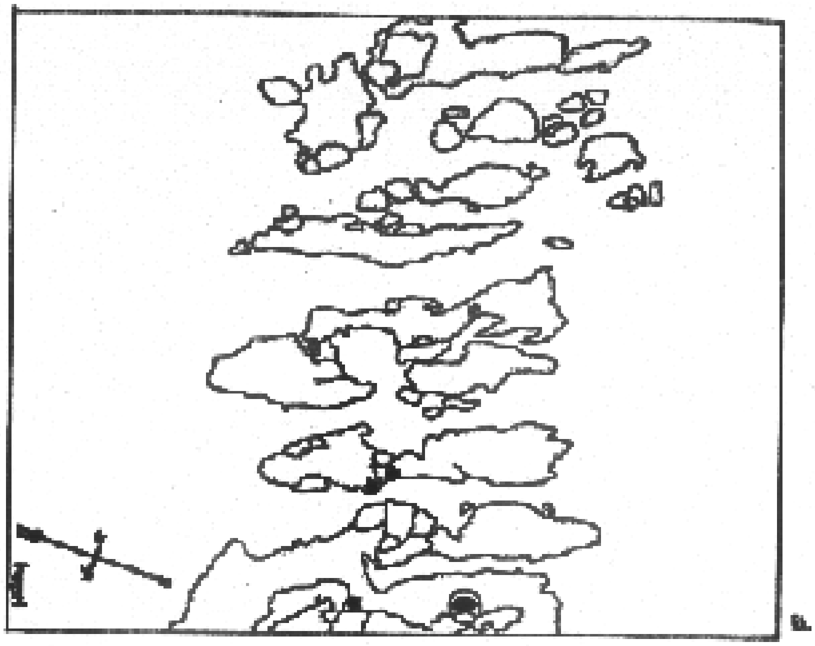
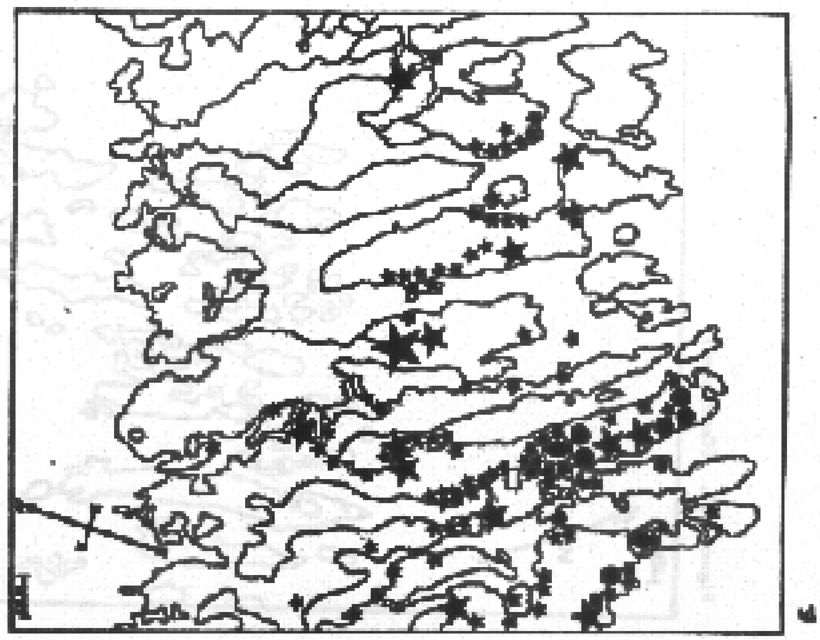


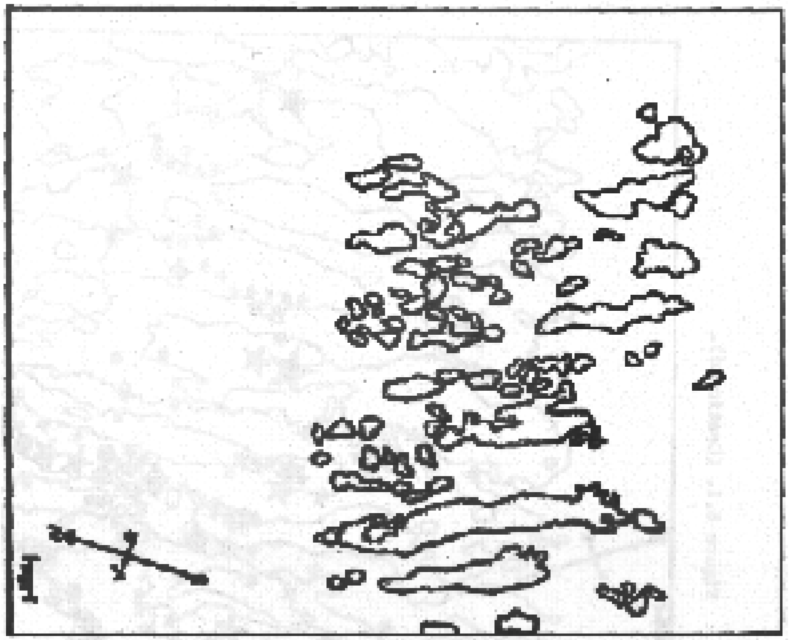
Figure 8.1. Distribution of elkhorn coral, *Acropora palmata*, (stars); staghorn coral, *Acropora cervicornis*, (dots); and pillar coral *Dendrogyra cylindricus* (diamonds). Elkhorn coral appears to be especially abundant in the central portions of the reef and on the western edges of spurs. See Figure 3.2 for location on each map on the forereef.











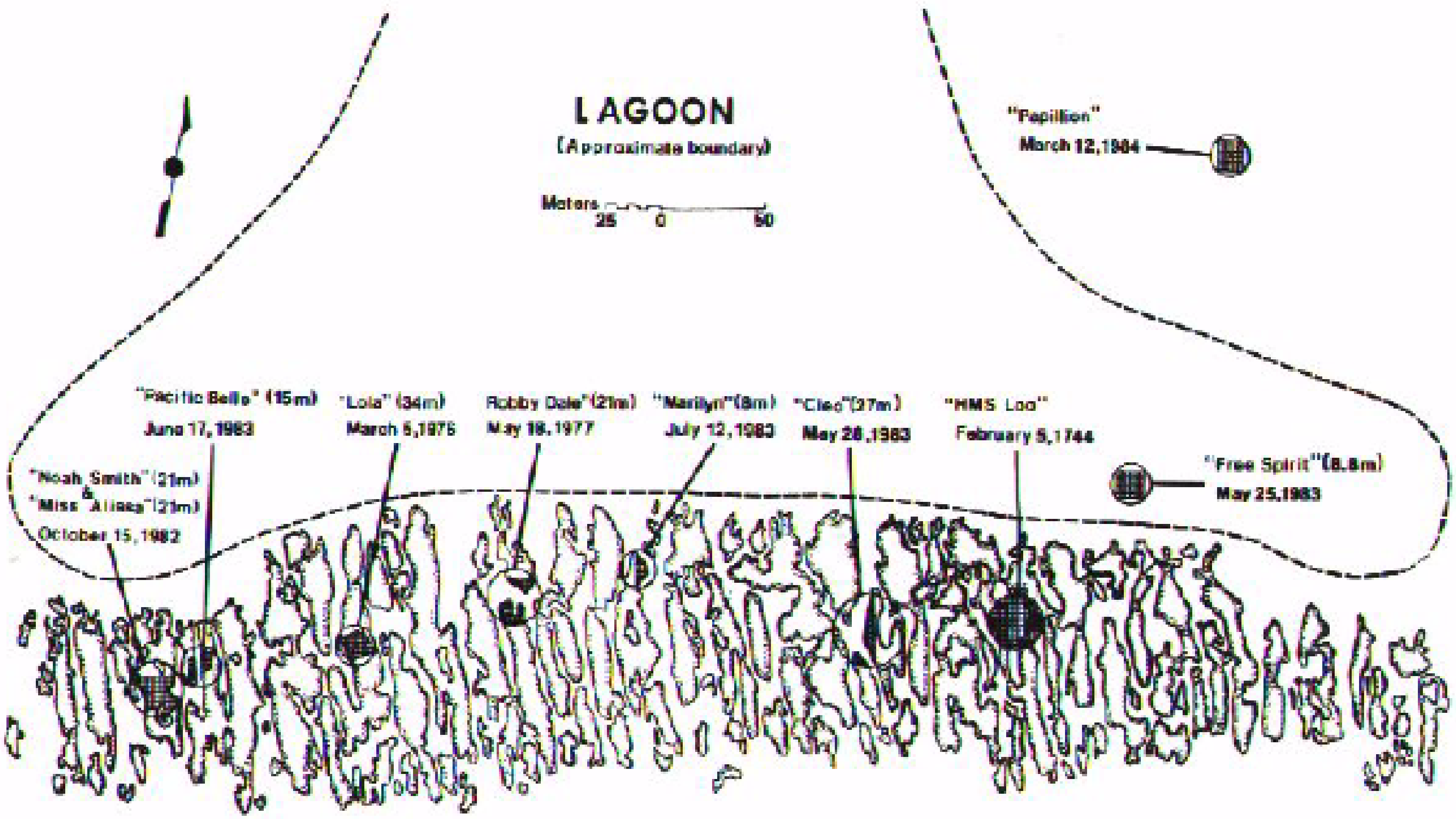


Figure 8.2. Map showing approximate locations of vessel groundings at Looe Key Reef.

Plate 8.1. Pillar coral, *Dendrogyra cylindrus*, colonies were found in only four places on the forereef. Locations of colonies are shown in Figure 8.1. Photographs of other colonies appearing Plates 8.2, 8.3 and 8.3.

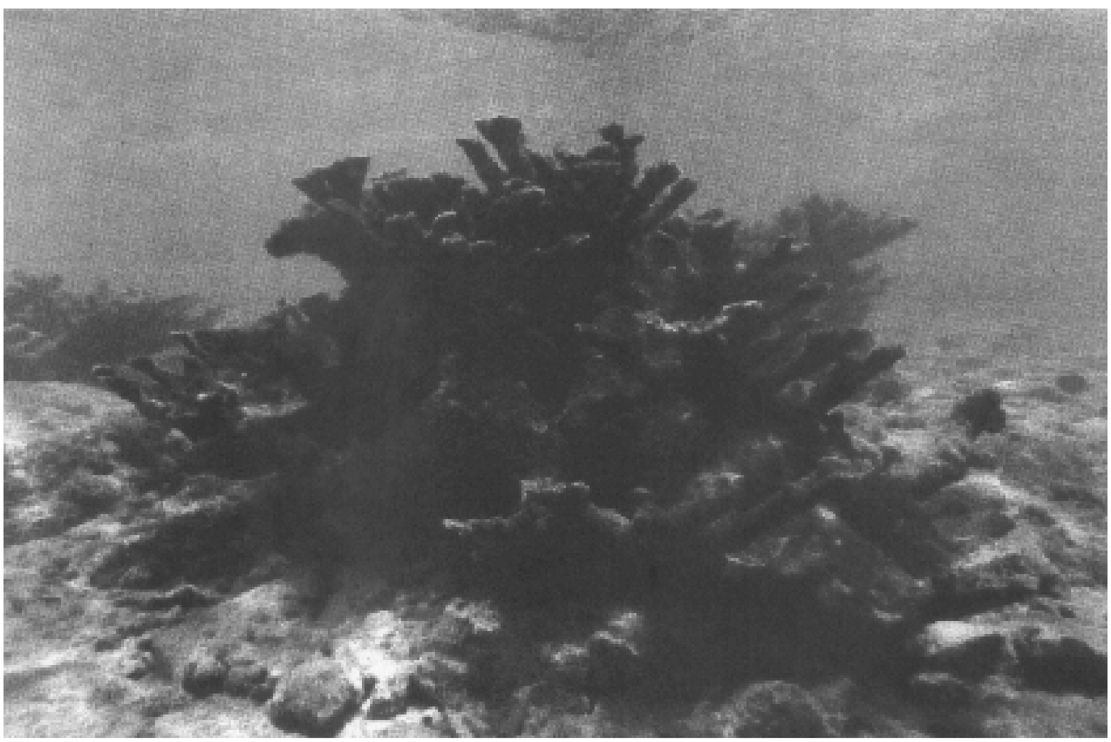


Plate 8.2. Natural storms are a major source of damage to corals. A colony of elkhorn coral (*Acropora palmata*) (top) was turned over after a severe winter storm. *A. palmata* is a rapidly growing branching coral and is a major contributor to reef rubble formation through wave damage. Despite being easily broken, the broken fragments are an important source of vegetative reproduction for the species. A colony (bottom) is beginning to spread and grow upward after being turned over.

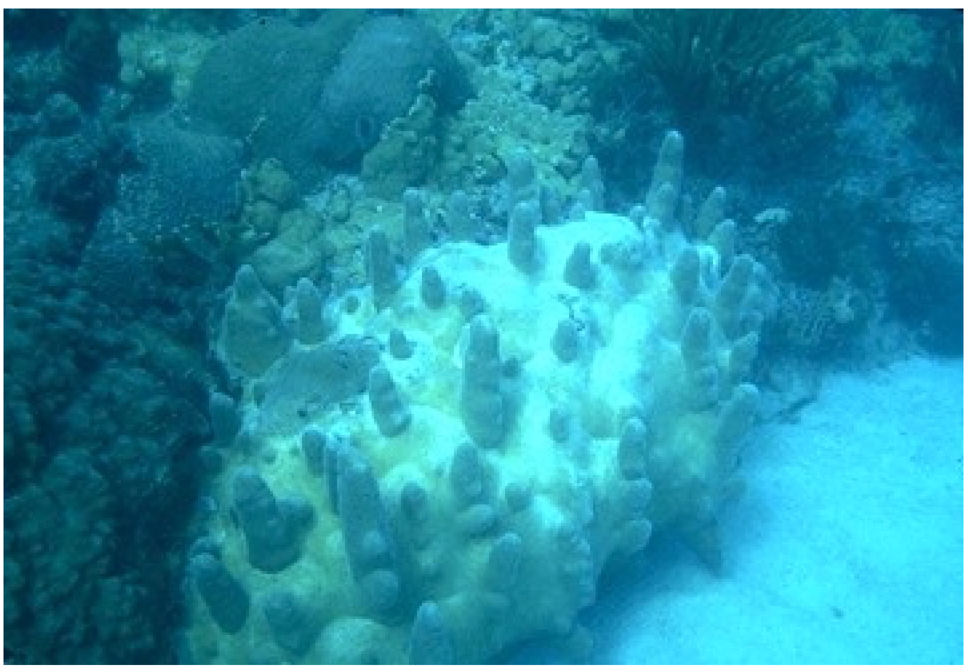


Plate 8.3. Severe heat and cold temperatures can kill coral. Staghorn coral (*A. cervicornis*) killed in the Dry Tortugas by the January 1977 cold spell (top). A large colony of pillar coral (*Dendrogyra cylindrus*) showing discoloration from warm water stress in 1983 (bottom). The arrow shows bleached areas where the stressed coral expelled its symbiotic algae.

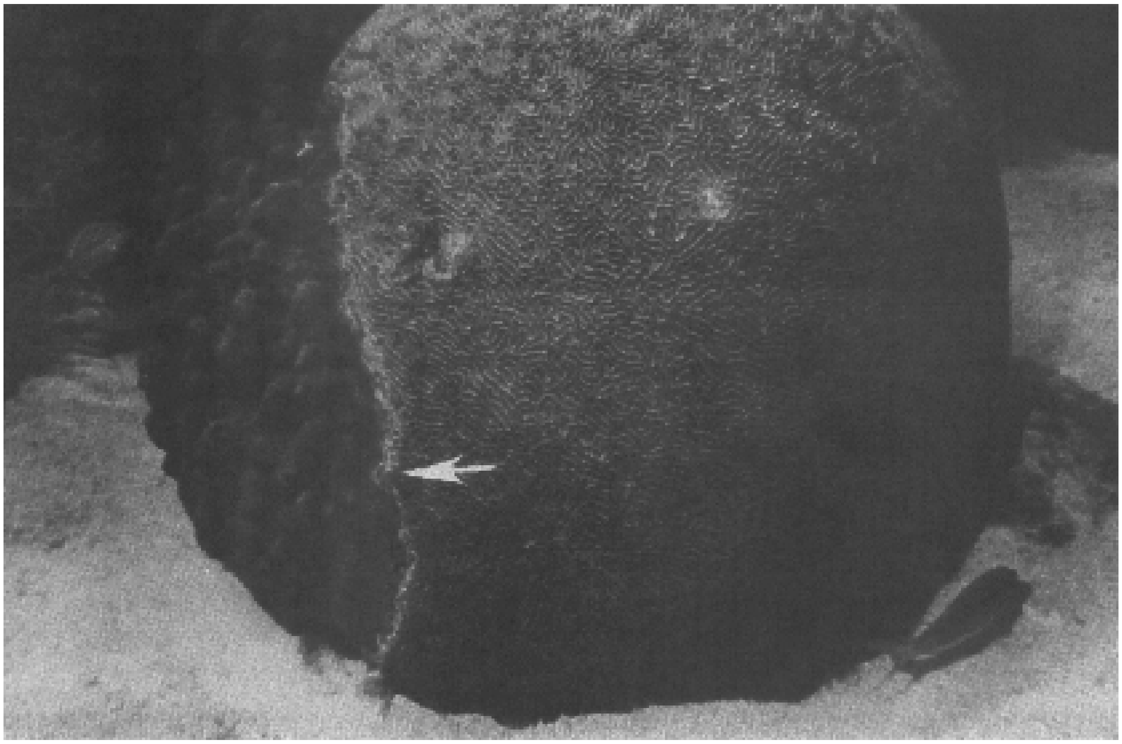


Plate 8.4. Some animals such as this bristle worm (*Hermodice* sp.) (top) feed on coral tissues. Direct and interference competition between corals (bottom) is a common occurrence. The arrow shows the site of direct interaction between two corals which are attempting to digest each other with mesentary filaments. A more common form of competition is indirect where corals shade each other from light.

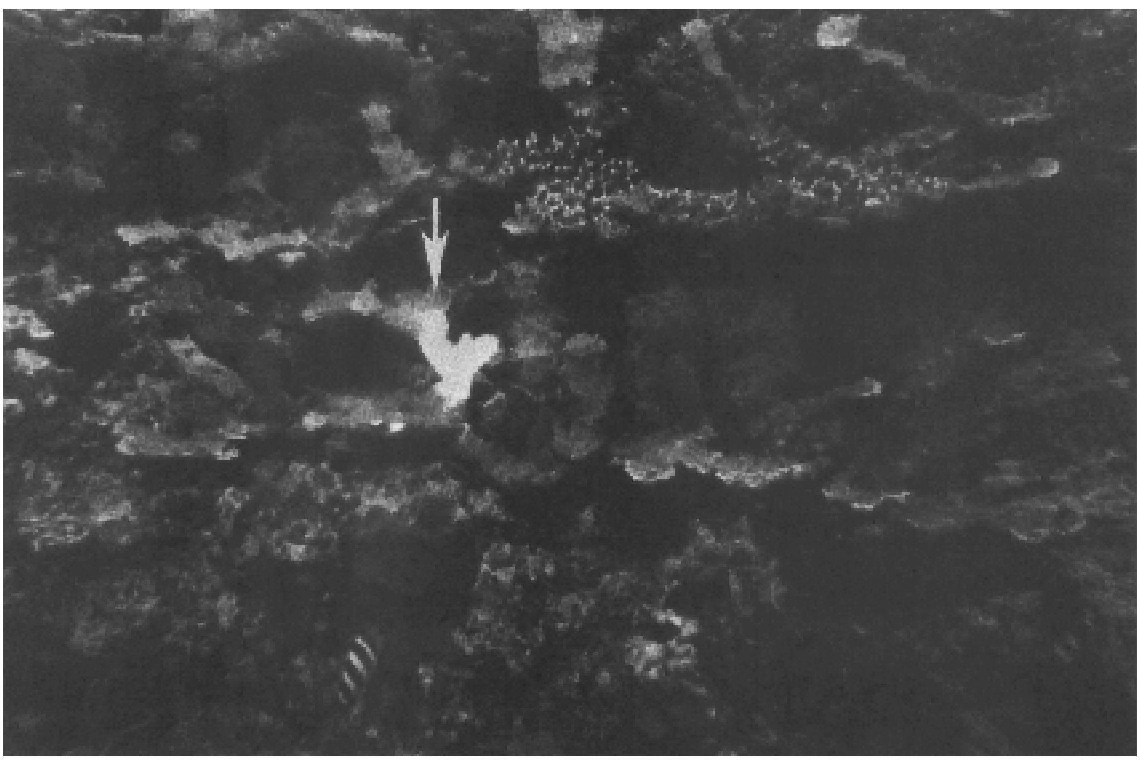


Plate 8.5. The lower white portion of the coral (top) has been killed recently by being temporarily buried by sediments. Lighter patches on the upper half of the colony show unhealthy tissue exposed to excessive sediment stress. The white area of the elkhorn coral (bottom) was recently killed by unknown causes.

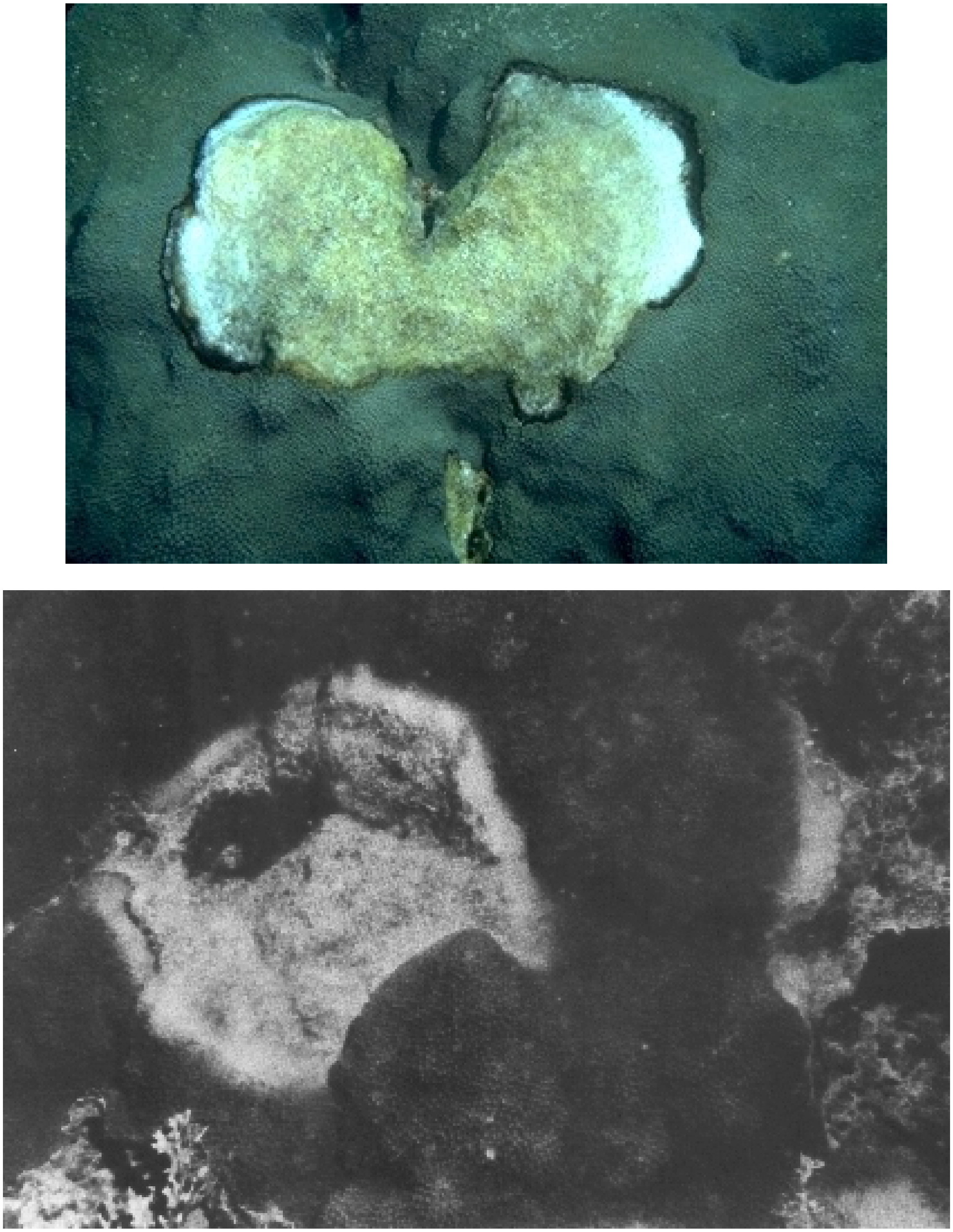


Plate 8.6. Two common coral diseases are black ring disease caused by a bluegreen algae (top) and white ring disease of unknown cause (bottom).

Plate 8.7. Periodic diseases of unknown origin affect several species of coral. Dead staghorn coral (*Acropora cervicornis*) (top) recently killed at Looe Key reef. *Montastrea annularis* (bottom) in the process of bleaching (arrow) and dying.

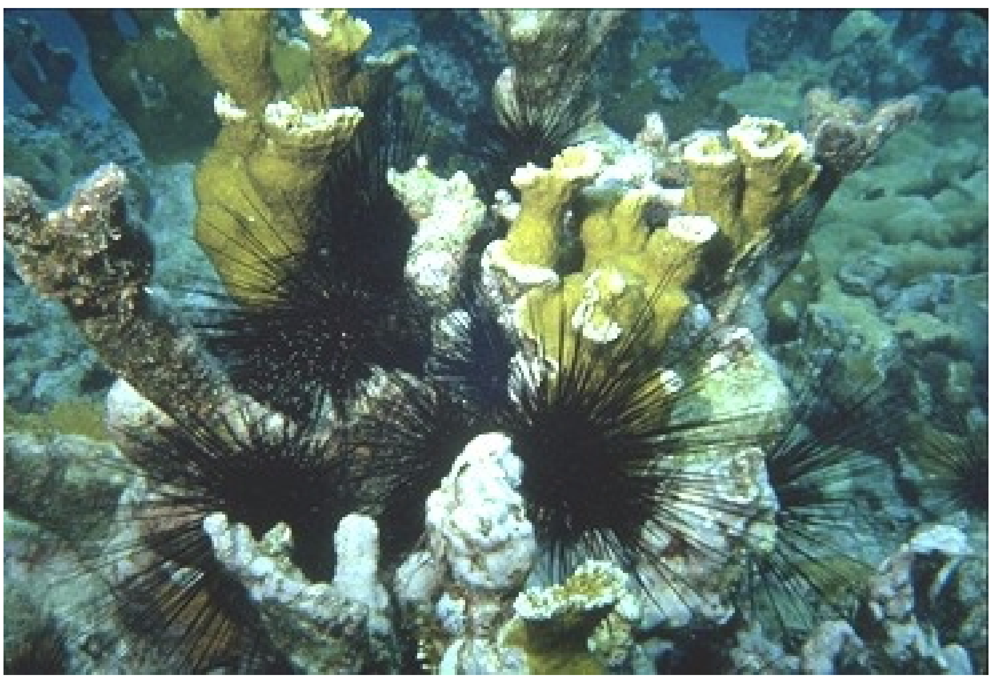


Plate 8.8. During late August 1983 a disease killed most of the long-spined urchins (*Diadema antillarum*) found within the Sanctuary. Although still alive, loss of spines and discoloration characterize the disease whose cause has not been identified (top). Normally, urchins are an abundant and conspicuous member of the herbivorous reef community (bottom).

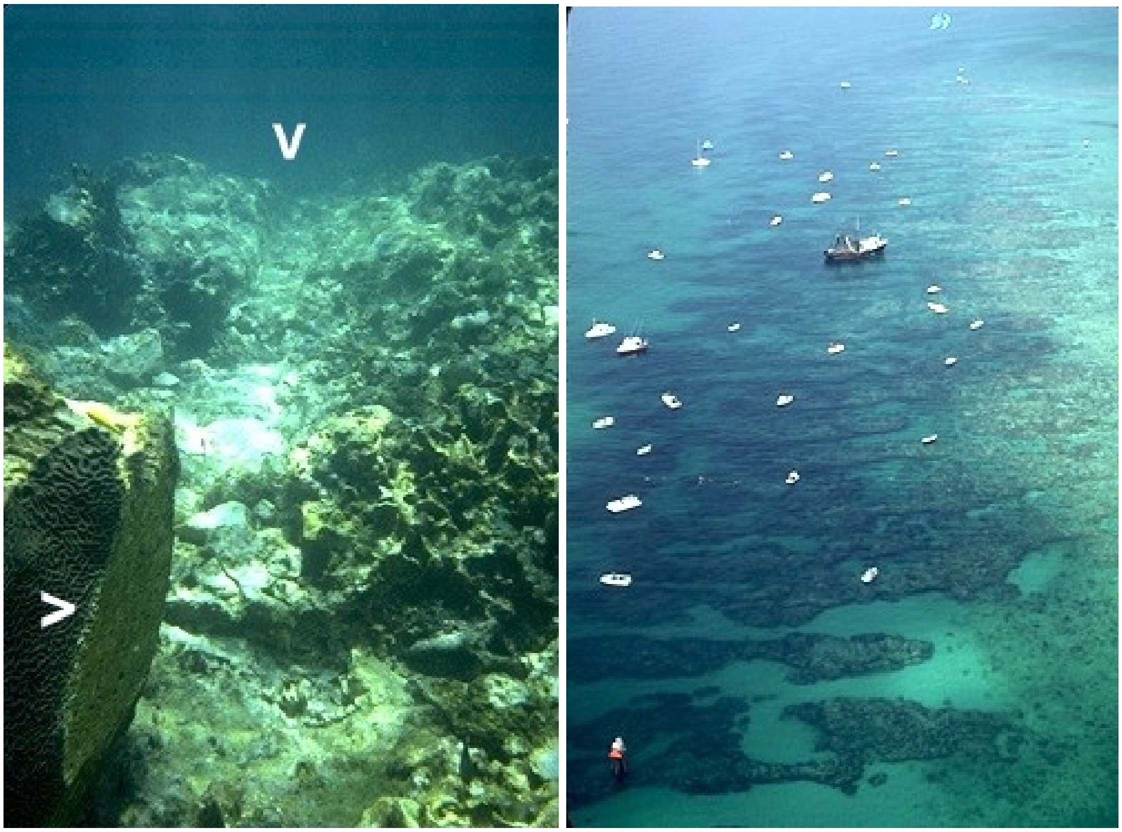


Plate 8.9. The forereef is the most intensively used area in the Sanctuary (left). The shrimp boat Cleo in the center had run aground on the reef and damaged the coral. The top arrow (right) shows a grove the Cleo's keel cut into the spur and bottom arrow shows a colony of brain coral (*Colpophyllia natans*) cut in half by the vessel.

Plate 8.10. Poor anchoring practices damage coral (left and right). Anchors should be placed only on sand or rubble bottoms. Broken coral from poor anchoring practices is certainly an aesthetic problem, however, its ecological consequences may be less important because many corals are adapted to (and may require) periodic physical damage.

Plate 8.11. A cross was deposited in the forereef as a monument (top). Excessive amounts of human materials may reduce the aesthetic experience of visiting a natural reef. Inexperienced divers may damage corals by deliberately or accidentally touching the tissues (bottom). The ecological impact of such treatment are unknown.

Plate 8.12. Wreckage and a groove cut into a coral spur from the Robby Dale. The engine (bottom) of the Robby Dale shortly after its sinking on 18 March 1977. The salvaging of the engine further damaged the reef.

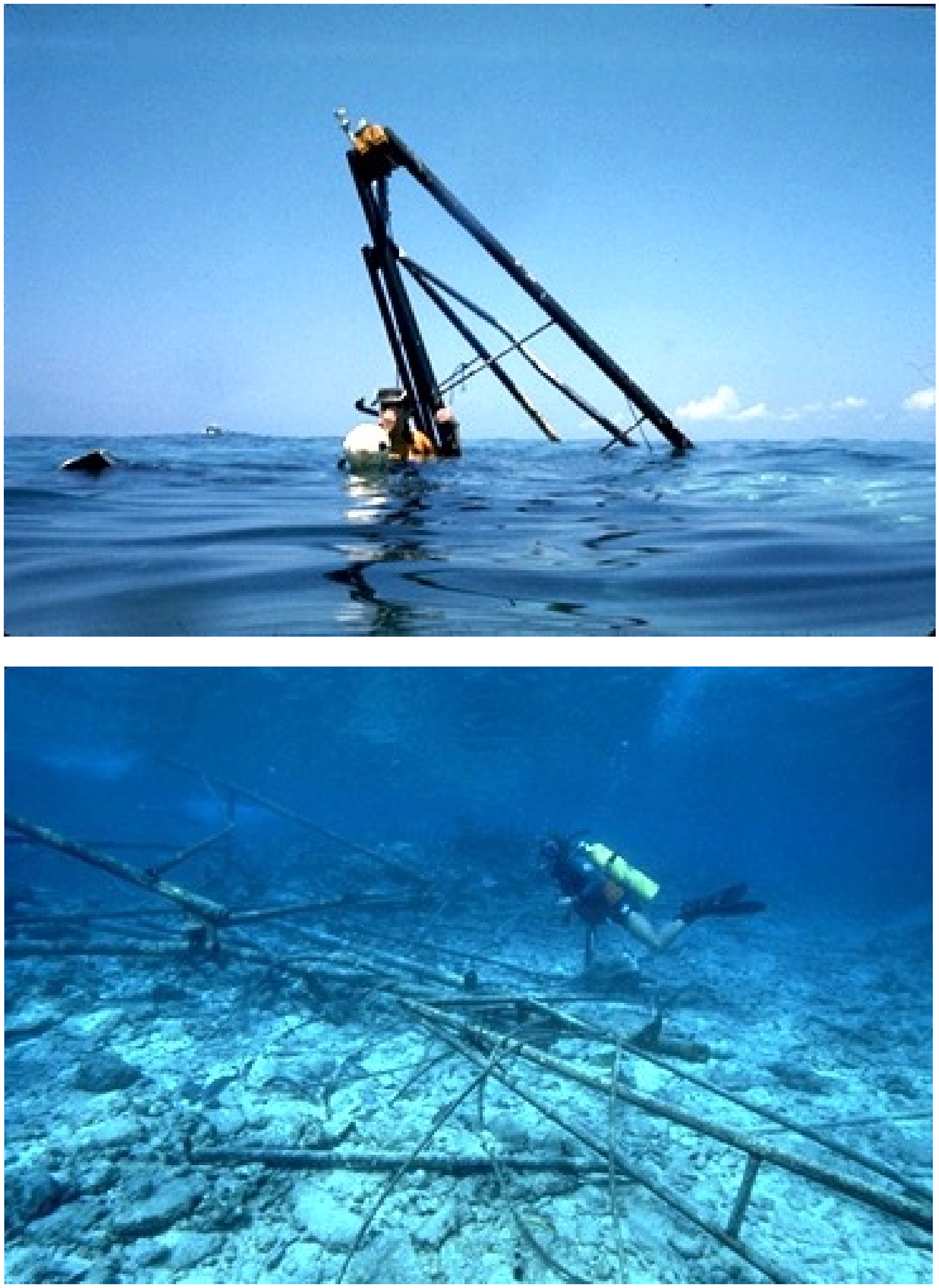


Plate 8.13. Wreckage of the Robby Dale seen extending above surface shortly after its sinking on 18 May 1977 (top) and as it appeared during the survey in 1963 (bottom).

Plate 8.14. Wreckage of the Robby Dale shortly after sinking in 1977 (top) and in 1983 (bottom).

Plate 8.15. Damage to the reef caused by groundings of the shrimp boat Noah Smith on 15 Oct 1982. View of the beginning of the impact area with a 3 ft groove (top). View of the core impact area showing crushed coral (bottom). Photos by John Halas.

Plate 8.16. Aerial view of Looe Key Reef showing damage from the grounding of the 110-ft Lola grounding of 5 March 1976 (top). Arrows show light areas on spur where surface coral was crushed and killed (Photo by Bill Becker). Closeup view (bottom) of groove cut into a spur by the keel of the Cleo, a 88 ft shrimper, grounded on 28 May 1983.

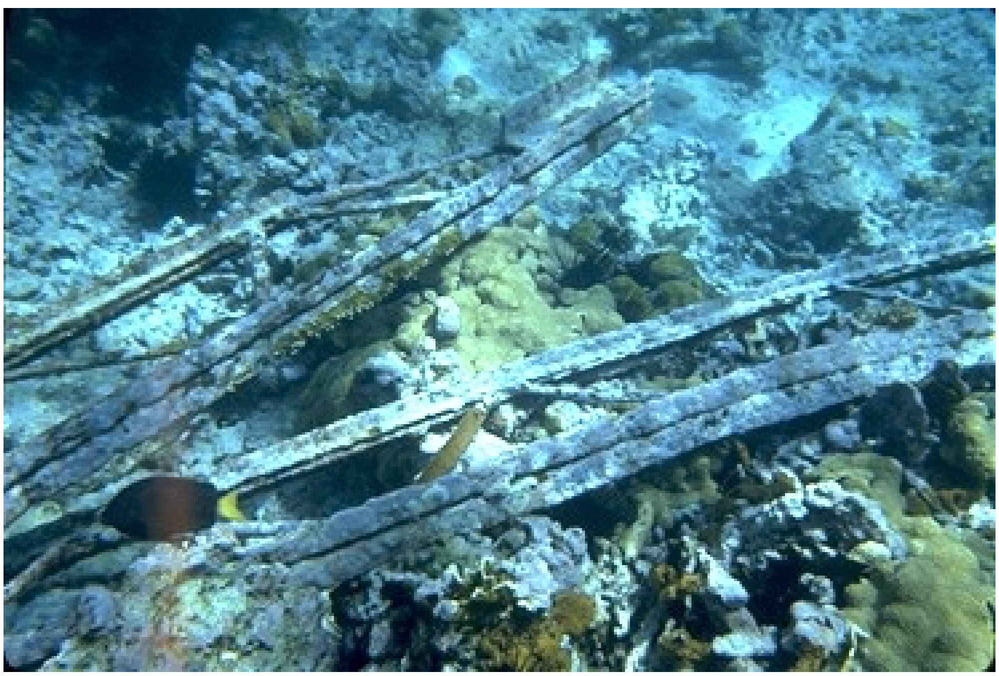


Plate 8.17. Wreckage materials left by the grounding of the 110-ft Lola, grounding of 5 March 1976 (top and bottom). Materials from previous wrecks are common on Looe Key forereef.

Plate 8.18. A potential exists for a major disaster caused by collision of a large ship with the reef. Ships traveling west frequently pass close to the forereef in order to avoid strong easterly currents in the Straights of Florida (top). Although a modern wreck of a large ship on a reef would be considered a major calamity, the wreckage of the warship H.M.S. Loo (bottom) and her prize are considered historical artifacts of great cultural value. Although much of the Loo has been removed, balast materials (below diver) can still be seen on the reef and are protected by the Sanctuary.

Plate 8.19. Oil spills have frequently occurred in the Florida Keys. An oil slick (top) can be seen with the Lower Florida Keys in the background (21 July 1975). Oil floating over shallow sea grass beds (bottom) north of the Sanctuary (21 July 1975).

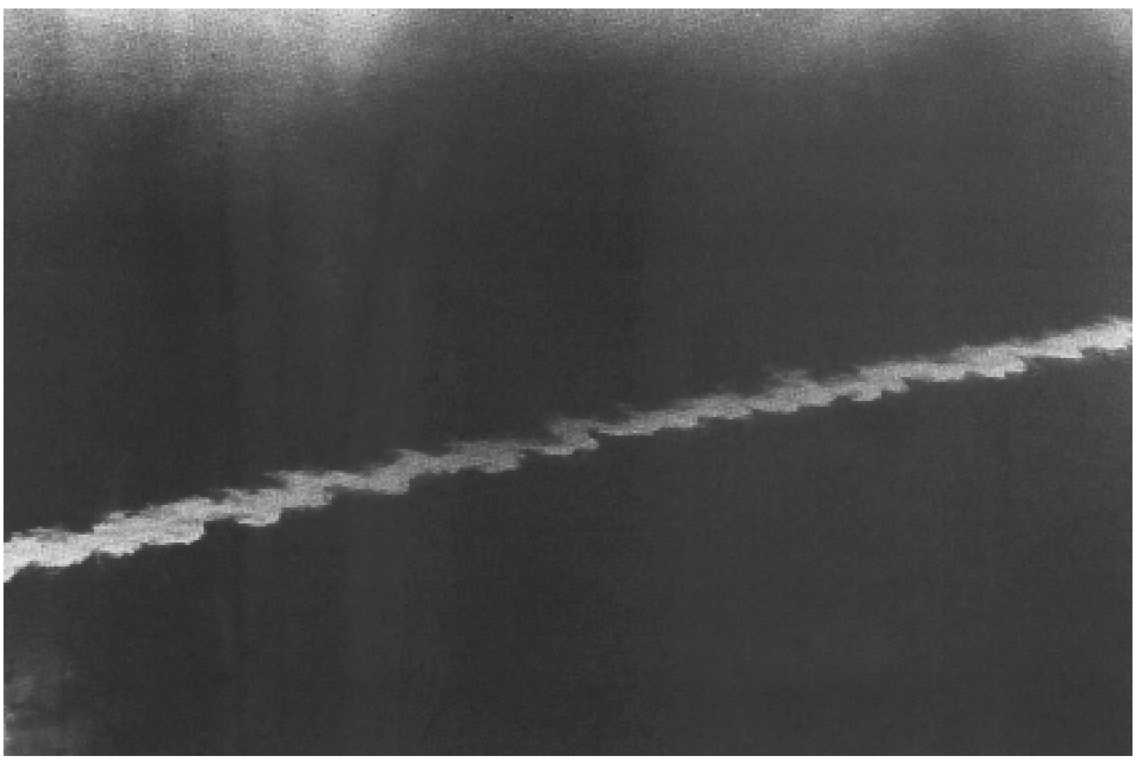


Plate 8.20. Land cleared for development on Big Pine Key north of the Sanctuary (top). Turbidity in Hawk's channel caused by a tugboat pushing a barge (bottom).

CHAPTER 9

MANAGEMENT CONSIDERATIONS

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The purpose of this chapter is to provide comments on implications of resource inventory for wise resource management. Results presented in previous chapters document resource features and abundance. In many cases, almost nothing is known about the population dynamics of most living coral reef resources. Many hypotheses have been suggested regarding the status and health of various resources and the environmental factors responsible for influencing resources. Many of the hypotheses presented need further testing or verification.

Results clearly indicate that Looe Key National Marine Sanctuary is an open ecological system and is therefore not self-sufficient. Water masses originating outside the sanctuary influence the health and perhaps the recruitment of corals (Chapters 4, 5 and 6), Most individuals of other species probably recruit to the Sanctuary from other areas. No juveniles were observed for many of the reef fishes censused, which suggests that they settle and grow in areas outside the Sanctuary. The importance of plankton as a food resource for the reef fish community was demonstrated (Chapter 7). The fact that many reef fishes migrate or feed away from the reef also shows that, the sanctuary is an open ecological system. Coastal mangrove forests, shallow flats, and seagrass beds are probably important sources of food and shelter for reef associated species. The fact that LKNMS is an open ecological system indicates that future research, monitoring, and management must consider factors outside the boundaries of the Sanctuary such as coastal development, reef resource utilization, and water quality.

The ability to distinguish between human induced changes and natural is a critical general requirement for management. In order to accomplish this, an understanding of natural and human processes involving the Sanctuary are necessary. In most cases this will involve considerably more fundamental and applied knowledge than is available at present. Monitoring the resources is important and the only way to detect changes in the sanctuary. However, determining the causes of observed changes is equally important and usually requires considerably more effort and the use of controlled experiments.

Although research funds are now and will continue to be limited, managers must be careful to emphasize fundamental as well as applied research in the Sanctuary. Only by understanding fundamental processes can applied actions have the desired effect. Obvious direct impacts on the Sanctuary tend to be the most noticed and get immediate attention. Managers should be aware, however, that subtle indirect factors may eventually have more impact on the health of the Sanctuary. For example, near shore pollution or loss of habitat may affect the survival and recruitment of species that depend on those habitats for part of their life cycle. Many reef fishes have home ranges that extend far beyond the sanctuary and may be vulnerable to excessive harvesting outside sanctuary boundaries.

Perhaps the major management decision will be to actively or passively manage the Sanctuary. Passive management minimizes intervention involving natural or human disturbances and is based on the premise that natural processes alone are sufficient to maintain the system in a healthy, natural state. Active management involves direct action with regard to natural or human perturbations and is based on the premise that human interference with the system is sufficiently great that, natural processes alone will not maintain a healthy natural system.

Usually human and natural events cannot be separated. For example, a severe cold spell may cause much greater devastation because current patterns have been altered by human activities, or low level pollution has weakened corals, making them more susceptible to cold mortality. As another example, human damage to corals may make them more susceptible to hurricane damage.

Evidence presented in this volume suggests that some potential impacts are of sufficient magnitude that active, creative management may be necessary. Creative management requires anticipating problems rather that merely reacting to situation as they occur. Evidence presented in this volume suggests several potential problems worth considering. Potential human impacts include intense direct exploitation of the sources, indirect damage from non-consumptive use of the resources, major collisions by ships, pollution, and other habitat deterioration. Natural disasters may also demand active management. Severe cold weather and hurricanes could potentially devastate the reef. Management should anticipate what preventive, corrective, or mitigative actions could be taken. For example, the loss of elkhorn coral has been identified as a detrimental impact on the reef in terms of geological time (Chapter 4 and 5). Sudden catastrophic loss from a natural or human created disaster could be devastating to the health and future of Looe Key Reef. A possibility exists that elkhorn coral could be artificially planted to mitigate, improve, or correct damage to the resource. Appropriate research would be to develop transplanting techniques and to demonstrate the feasibility of artificial coral propagation. Another possible example of creative active management is the construction and use of artificial reefs away from the reef proper in order to reduce or redistribute the impact of human use.

Several specific management problems have been identified in the resource inventory. Shinn *et al.* (Chapter 4) have noted the possible problem of reef areas being impacted by chilled Florida Bay water and being swallowed by sediment plumes. Hudson (Chapter 5) has suggested a decline in coral growth has occurred at Looe Key which may be a result of human activities. Jaap (Chapter 1 and 6) and Bohnsack *et al.* (Chapter 8) have emphasized the absence of elkhorn coral in much of its prime habitat at Looe Key Reef. Many direct and indirect impacts on coral and fishes resulting from human activities were documented in Chapters 2 and 7 including: vessel groundings, anchor damage, direct hook and line fishing, use of fish traps in surrounding waters, and others. Wise management of Looe Key National Marine Sanctuary will require monitoring, research, and an active role by creative managers.