INVESTIGATING REEF RECOVERY FOLLOWING A FREIGHTER GROUNDING IN THE KEY LARGO NATIONAL MARINE SANCTUARY.

(Florida Keys, USA)

ETUDE DU RETABLISSEMENT D'UN RECIF CORALLIEN APRES L'ECHOUAGE D'UN CARGO DANS LA RESERVE MARINE NATIONALE DE KEY LARGO (Etats-Unis)

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ABSTRACT

On August 4, 1984, a 400-foot Cypriot-registered freighter ran aground on Molasses Reef in the Key Largo National Marine Sanctuary, Florida, USA and remained aground for 12 days. While the ship sustained only minor physical damage and no hazardous wastes were spilled, the grounding and associated salvage efforts caused substantial damage to benthic marine populations on the forereef. Haystack-sized colonies of Montastrea annularis were abraded, fractured or overturned when struck by the ship as it approached the grounding site. Where the ship grounded, at the seaward end of the spur and groove track, the reef formation was crushed and now resembles a graded roadbed covered with a veneer of coraline debris. Additional damages were caused by cable drag, propwash scour and shading.

The recovery of Molasses Reef following the ship grounding is now the subject of a large scale, multidisciplinary research program sponsored by the National Oceanic and Atmospheric Administration which manages the Key Largo National Marine Sanctuary. A research plan has been developed in an effort to direct the multi-investigator program and inform the public of the research activities and results. An assessment of the immediate impact of the grounding on algal, coral and fish populations has been begun, and experimental studies are being conducted to identify factors that promote or inhibit reef recovery. Aerial photography has been obtained and a photomosaic is being produced for groundtruth mapping and monitoring purposes. The results of these investigations will be synthesized into a management document that describes the extent of damages associated with the ship grounding and identifies strategies, if any, that would be effective in enhancing or hastening reef recovery following such a disturbance.

RESUME

Le 4 août 1984, un cargo chypriote s’échoué sur le récif de Molasses dans la réserve marine nationale de Key Largo, aux Etats-Unis, et y resta pendant 12 jours. Alors que le navire ne subit que de dommages mineurs, et qu’aucun produit dangereux ne se répandit, l’échouage lui-même, ainsi que tous les efforts de sauvetage, causèrent des dégâts considérables aux populations benthiques de l’avant-récif. Des colonies de Montastrea annularis atteignant la hauteur d’une meule de foin furent abradas, brisées ou renversées lors de l’échouage du navire. Quant à l’endroit même de l’impact, au niveau des éperons-altères de la pente externe, le récif a été écrasé. Il ressemble aujourd’hui à une route passée au rouleau compresseur qui serait comme recouverte d’une couche de débris coralliens. Les espèces mobiles furent tues ou déplacées lors de la destruction du récif. D’autres dommages furent causés par le frôtement des câbles, le tourniblement des hélices, le décapage et l’ombre portée dûs à la présence du navire. La restauration du récif de Molasses consécutive à l’échouage du navire est maintenant le sujet d’un programme de recherche multidisciplinaire de grande envergure, subventionné par le "National Oceanic and Atmospheric Administration" qui assure la gestion de la Réserve Marine Nationale de Key Largo. Un projet de recherche a été développé dans le but de diriger ce programme multidisciplinaire et d’informer le public des activités et des résultats de ces recherches. L’évaluation de l’impact immédiat de l’échouage sur les populations d’algues, de coraux et de poissons est achevée et les colonies de coraux viables se sont rétablies. L’étude du rétablissement des peuplements du récif a commencé, et on cherche à identifier, à l’aide d’expériences, les facteurs qui favorisent ou inhibent ce rétablissement. Des photos aériennes et une carte photographique devront permettre de vérifier les données sur le terrain et de surveiller efficacement la recolonisation du récif. Les résultats de ces enquêtes seront synthétisés dans un document où l’étendue des dommages dus à l’échouage du navire sera examinée et les stratégies identifiées, afin de définir celles qui pourraient être favorables à l’accroissement du récif, ou à un rétablissement plus rapide de celui-ci après une telle perturbation.

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INTRODUCTION

Statistics on boat groundings on Florida reefs (i.e., frequency, vessel size and area of impact) have increased in recent years to the growing alarm of resource managers and the general public. Most groundings involve small pleasure and commercial boats of <12 m in length; however, since 1980, a disproportionate number of larger vessels (15-30 m in length) have run aground on Florida reefs. Groundings are attributed to several factors, including increased boating activities, inexperience, negligence and "Acts of God." In addition, the close proximity of Florida reefs to heavily trafficked ocean shipping lanes poses the threat of major shipgroundings. In 1984, this threat became a reality when a 122 m freighter, the M/V WELLWOOD, ran aground on Molasses Reef, a Caribbean-type bank reef on the margin of the Florida reef tract, resulting in extensive damage to the reef and complex law suits.

Molasses Reef is located in the southeasternmost corner of the Key Largo National Marine Sanctuary which was established by the United States Department of Commerce in 1975 to protect and preserve a 259 sq. km area of bank reef, patch reef, hardground, sand flat and seagrass habitats beyond the State of Florida's territorial boundary (Fig. 1). Molasses Reef is located approximately 8.4 km from shore (25°00.7'N, 80°22.4'W) and is comprised of several distinct biological zones, including an extensive reef-flat area with prominent rubble horns, a narrow Acropora palmata reef top, a spur-and-grove system dominated by alcyonarians (sea plumes, sea fans, sea rods) with low relief spur-and-grove formations, large abureseous gorgonians, barrel sponges, and star and brain corals.

Molasses Reef is by far the most popular reef in the Sanctuary. Its spectacular shallow-water coral formations, abundant fish life and excellent underwater visibility attract SCUBA and snorkel divers, a business zone with haystack-sized colonies of M. annularis, measuring 2-3 m in height and between 200-500 years in age (Hudson 1981) and a deep reef (15-20 m water depth) with low relief spur-and-grove formations, large abureseous gorgonians, barrel sponges, and star and brain corals.

Aerial Photography and Groundtruth Mapping

Aerial reconnaissance was conducted immediately after the grounding to document the ship's presence on the reef and, after the ship was removed, to accurately locate the grounding site in relation to the entire Molasses Reef complex. Low altitude color photography (1:2400 scale) was obtained for constructing a mosaic of the reef from which the major physiographic features of the coral reef will be scribed onto a clear acetate overlay. Biotic zonation will be interpreted from the photography based on textural and color contrasts and groundtruthing by reef ecologists. Photo enlargements of the grounding site will be made for use in monitoring large scale recovery processes.

Damage Assessment

Within hours of the grounding and over the course of 19 days, Sanctuary personnel using SCUBA surveyed Molasses Reef to measure and map areas of damage and to characterize resource conditions. Survey stakes were driven into bedrock along the inbound path of the ship and a grid system was set up at and adjacent to the grounding site. A combination of visual inspections, overlapping 35 mm photography, and video photography was utilized to document substrate type and condition. Direction was determined by shipboard and underwater compass and distance was measured using metered transit lines strong between permanent stakes. The grounding site was closed to visitors while surveys were in progress. Later, after the reef was reopened, additional area-intensive surveys were conducted using photographic transects after Littler (1980) and Bright et al. (1984) to quantitatively assess the effect of the grounding on the composition, distribution and abundance of algal and coral populations, and a reef-plate damage survey was conducted to document the location and extent of reef-plate fracturing and to ascertain a practical method for stabilizing damaged substrate and for the re-colonization of hard and soft corals (K. Hudson, pers. comm.).

Restoration and Monitoring of Surviving Coral Colonies

An immediate concern at the time of the grounding was the fate of large coral colonies, such as Montastrea annularis, that were fractured, detached, overturned, bleached or buried by the shipgrounding but were still alive, and a decision was made to rehabilitate these colonies that appeared to have a good chance of...
surviving. Consequently, shattered heads of stony corals were pieced back together, living fragments were rescued from the rubble and overturned colonies were righted using mechanical and air-bag devices. Detached alcyonarians were restored to an upright position by wedging holdfasts into crevices.

Reef Recovery Studies

Investigations are in progress to study the major processes of reef recovery that will be occurring at the M/V WELLWOOD grounding site (Fig. 3). To study recruitment and repair of surviving scleractinian and alcyonarian coral colonies and recruitment and establishment of corals and other colonizing organisms. The fate of surviving macrobenthos is being monitored through field observations, photography and systematic studies. Haystack colonies of M. annularis, which were variously injured when struck by the ship as it approached the grounding site, are being monitored using a quadrate grid method and macrophotography to document whole colony survivorship. To study tissue regeneration capacity in this coral species, stainless steel spikes have been driven into the surface of freshly exposed coral skeleton near the border of living tissue. Stations are monitored quarterly using close-up photography to measure tissue advance or retreat and the nature of colonizing organisms. Control colonies have been established for analyzing natural changes at living tissue borders. A limited photographic survey of the recovery of the vase sponge Xestospongia muta in deep reef areas is also being performed.

To quantitatively monitor successional algal and coral community reestablishment and development, permanent transects have been established so as to intercept both damaged and undamaged portions of the reef at the grounding site (Fig. 3) and the photogrammetric quadrate techniques of Bright et al. (1984) and Littler (1980) are being used to sample transects (weekly for the first two months and monthly thereafter for algae and epibenthic growth, permanent photostations were used to sample transects; monthly sampling trip is compiled using Jones & Thompson (1978) rapid visual technique, and time lapse photography is obtained in damaged and control areas to study aspects of reef fish behavior. Several fractured M. annularis heads are monitored visually to determine frequency and type of use (e.g., feeding, spawning or territory) by reef fish.

RESULTS

To analyze the species list for each monthly sampling trip is compiled using Jones & Thompson (1978) rapid visual technique, and time lapse photography is obtained in damaged and control areas to study aspects of reef fish behavior. Several fractured M. annularis heads are monitored visually to determine frequency and type of use (e.g., feeding, spawning or territory) by reef fish.
Dichocoenia stokesii, Meandrina meandrites and P. astrooides. In sand channels between the spur, beneath the ship, mortality was less than total, although marine life was distinctly affected by shading, prop wash scour and rubble fill.

The quantitative data from algal and coral transects indicate that the M/V WELLWOOD grounded in a transition zone between the shallow upper forereef, just seaward of the A. palmata reef top), which is dominated by the scleractinian Agaricia agaricites, Pseudopterogorgia spp. (sea fans) and long-lived perennial algal species, and a deeper forereef zone which is dominated by large head corals and alcyonarians other than Pseudopterogorgia spp. (i.e., sea rods and sea plumes). The data show substantially lower populations of scleractinian and alcyonarian corals and macro-algae in the grounding area (Area B in Fig. 4) than in adjacent areas extending to the east and west, and are expressed (by area greater number due to greater number of dead alcyonarian skeletons in the area beneath the ship than in the adjacent control areas. No scleractinians, few hydrocorals and only one alcyonarian were detected alive at the hull site immediately after the grounding. All but wary and stony forms of algae were sheared away by prop wash and scleractinarians were variably affected by shading and rubble scour.

Statistical evidence indicates that the impacts of the grounding on coral populations may have differed depending on the coral's growth form, size and systematic affiliation. Small scleractinian head corals suffered little mortality beneath the ship where the hull did not touch the bottom. However, populations of alcyonarians in general, and sea plumes in particular were significantly diminished in these areas. In addition, prop wash caused significant mortality of alcyonarians beneath the stern of the ship, and transported their skeletal remains out of the immediate area and into surrounding depressions. Colonies of M. annularis experienced substantial loss of zoanthellae where they were in the shade of the ship for 12 days; other scleractinian corals did not suffer as great a degree of zoanthellae loss.

Efforts to remove the M/V WELLWOOD caused damages to epiflora and fauna that could not be avoided. In the area adjacent to the hull grounding, populations of M. annularis, C. natans and Dendrogyra cylindrus were overturned, fractured or abraded, and in the deep reef area (Area C in Fig. 4), recovery of colonies of Xestospongia muta, M. annularis and other stony corals and alcyonarians were damaged or destroyed during salvage operations.

Motile invertebrates and reef fish inhabiting the grounding site were killed by the impact or fled the scene when the grounding occurred. While the ship was on the reef, opportunistic predatory fish (snook, bar jack, snappers and groupers) commonly occurred in search of displaced prey. Three weeks after the grounding, less than one half (63 of 122) species of fish previously reported for Molasses Reef had returned to the grounding site, and most of these were of a single size class, indicating recruitment from larvae or immigration from other parts of the reef. Exposed surfaces of M. annularis were observed to be used by algal gardens by three spot damselfish, spawning patches by sargent majors and feeding areas by blueheads and ocean surgeons.

At the time of this writing (i.e., 7 months after the grounding), there are very few results to report for those studies that are time dependent. Opportunistic successional species of microfilamentous yellow-turf algae have shown dramatic increases in disturbed areas. Recruitment of coralline and other algae and other epifauna to the surface of freshly exposed reef rock, coral skeletons and unconsolidated sediments is significant throughout the damaged areas. No change in the nature of random and permanent coral transects has been detected (i.e., a significant difference in scleractinian and alcyonarian populations between disturbed and undisturbed areas still exists), except for evidence of movement of unconsolidated sediments. No coral planulae have settled on M. annularis recruitment stations; however, one artificial settling plate out of 60 examined for the period between November 1984 and March 1985 yielded a single coral recruit. The results of recruiting growth studies are variable; in some instances, living tissue from groundings is destroyed due to coral tissue damage. In other cases, living tissue has made some advance across the fracture surface. For many of the coral colonies that suffered from zoanthellae loss, there was subsequent mortality of afflicted tissue, yet seven months after the grounding, surviving colonies had stabilized and the tissue that did not die had regained zoanthellae. The hull site continues to differ from control areas in the number of reef fish species and number of individuals and there is preliminary evidence that season affects these numbers, especially late winter when all areas exhibited a decrease in abundance. Xestospongia muta in deep reef areas appear to be regenerating lost tissue.

**DISCUSSION**

The damages caused by the grounding of the M/V WELLWOOD are significant, and preliminary results indicate that the processes involved in recovery are variable and the rates are slow. Recovery will depend upon a complex interaction of geological, biological and ecological processes, some of which may be aided by reef managers. Whether Molasses Reef recovers to pregrounding conditions remains to be seen. Unlike recovery from hurricanes in the Florida Keys which is rapid because of widespread scattering of live coral fragments, such as Acropora cervicornis and A. palmata (Shinn, 1976) and asexually propagated fragmentation is not likely to be significant at the M/V WELLWOOD grounding site because few fragments of reef-building corals and alcyonarians survived the grounding. The timing of recovery in this area is uncertain because the barren substrate is rendered suitable for colonization, the reef plate must be stabilized and rubble and debris must be consolidated and undergo a period of decomposition (Schumacher, 1977). For a description of the phases of colonization and recruitment of fish previously reported for Molasses Reef, see Schumacher (1977) for a description of the phases of colonization and recruitment of fish previously reported for Molasses Reef. The high mortality rate for coral larvae and juveniles and the low priority of sexual reproduction in many of the coral species implies by the grounding (e.g., M. annularis) (Righelotti, 1982) recruitment potential is uncertain. The recovery potential of injured corals is also variable. Whether colonies regenerate lesions completely or partly or are totally destroyed by continued retreat of living borders or invaded by disease will depend upon colony type, fragment size and regenerative capacity as well as the kind and degree of fouling.
Figure 1: Location map. Key Largo National Marine Sanctuary.

Figure 2: M/V WELLWOOD grounded on Molasses Reef Key Largo National Marine Sanctuary.

Figure 3: Algal transect in Area B. Note flattened reef platform which is reminiscent of a freshly graded road bed.

Figure 4: Grounding site of the freighter WELLWOOD. Showing is the path of the ship during the initial grounding (Area A), the major grounding site and environs (Area B), and the deep reef salvage-damaged areas (Area C).
of exposed skeleton at tissue borders and the competitive ability of surviving colonies, new recruits and other colonizing organisms. (Bak, Brouns & Heyes, 1977; Bak & Steward-Van Es, 1980). Interestingly, M. annularis which is the most severely affected coral species, is well-adapted to regenerating lesions, but produces very few juveniles, whereas A. agaricites, also impacted, has a high rate of recruitment, but the regeneration of lesions is poor (Bak & Engel, 1979). Organisms with minor injuries will probably survive, while those with extensive tissue necrosis, bleaching or major skeletal damage will be more prone to disease, overgrowth and death. Stochastic events may lead to alternate successful communities which inhibit the recruitment or regrowth of desirable species, and recovery may be prolonged or prevented altogether by chronic low-level disturbances, such as damages due to anchors, storms or additional groundings.

The grounding of the M/V WELLWOOD has re-focused attention on a problem that has persisted in the Florida Keys since the time of the Spanish explorers. Managers may not be able to stop all groundings but they may succeed in lowering the statistics through a variety of management strategies aimed at educating the boating public and protecting fragile resources (e.g., mooring buoys). And they may be able to mitigate damages by applying some of the lessons learned from the M/V WELLWOOD.

ACKNOWLEDGEMENTS

Hundreds of people assisted in reef damage assessment, coral rehabilitation and ship salvage efforts. I especially acknowledge the efforts by sanctuary personnel, B. Harrigan, J. Halas, and R. Causey. J. Fajtas and L. Van Hoog conducted damage assessment surveys and H. Hudson assisted in righting overturned coral heads and conducted reef plate damage surveys. B. Harrigan coordinated field research efforts and provided the summary of damages. N. Woronoff, D. Barre and N. Baldwin are in various ways responsible for aerial photography and the reef mosaic. M. Littler, D. Littler, J. Norris, K. Bucher, R. Sims and S. Blair initiated algal population surveys and D. Hanisack, S. Blair and J. Reed are carrying out long-term algal recruitment studies. T. Bright, D. Andrezyak, G. Dennis, S. Giddings are conducting coral population recovery surveys, and G. Dennis is responsible for reef fish survey work. Department of Commerce and Justice attorneys, L. Marks, D. Drake and I. Plamann are acknowledged for their guidance in developing the plan and B. Brown and R. Lopez are thanked for reviewing this paper.

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