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ASSESSMENT OF VESSEL GROUNDING INJURY TO CORAL REEF AND SEAGRASS HABITATS IN THE FLORIDA KEYS NATIONAL MARINE SANCTUARY, FLORIDA: PROTOCOL AND METHODS

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In recent years, small boat and large vessel groundings in southern Florida and the Florida Keys have been recognized as a major impact to coral reef and seagrass habitats (Zieman, 1976; Jaap, 1984; Tilmant, 1987; Causey, 1990; Sargent et al., 1995). As a result of these insults, an in-house grounding assessment program has become a vital component of natural resource management in the Florida Keys National Marine Sanctuary (FKNMS). Information derived from these investigations is used to determine extent and severity of injury, potential for restoration and, when appropriate, to recover costs related to the incident. This report presents procedures and equipment developed by FKNMS over the last decade for responding to and conducting natural resource injury assessments in coral reef and seagrass environments.

Response to all groundings in FKNMS waters is coordinated by Sanctuary personnel through the Florida Fish and Wildlife Conservation Commission (FWC) and United States Coast Guard. After receiving notification that a grounding has occurred, FWC will dispatch an officer to investigate. Upon arrival, the officer will caution the vessel operator not to attempt using power to free the stranded vessel. Experience has shown that attempting to 'power off' is rarely successful and can result in significant additional injury to natural resources. On-scene evaluation by the responding officer regarding stability of the grounded vessel, condition of those onboard, severity of the grounding, weather conditions, and other factors, will dictate if need for assistance from a commercial salvor, the Coast Guard, or other government agency is required. If the vessel remains aground and commercial assistance is required, FKNMS biologists who specialize in grounding assessments may be called upon to assist the salvor in locating a suitable exit path for the stranded vessel. This service is provided solely in an advisory capacity to help prevent further injury to natural resources. The investigating officer will remain on scene to observe salvage efforts and complete an Offense Investigation Report (OIR) of the incident. Once the vessel has been removed, the injury site is marked by the officer with an anchored surface float and its position fixed with differentially corrected global positioning system (DGPS) coordinates. The above scenario assumes no bodily injury as a result of the incident, no release of hazardous materials into the water, a cooperative responsible party, and a simple pull by tow rope at high tide in calm seas to free the vessel. It is beyond the scope of this report to address complicating factors that can arise in grounding incidents.

Injury Assessment Protocol

It is extremely important that an assessment be conducted as soon after the incident as possible so that injury to biota and the substrate can be easily identified, measured and documented with still and video cameras. Biofouling of a grounding site in tropical waters can quickly camouflage broken coral and abraded substrate, making it difficult to differentiate between natural and man-induced injury. Strong currents can alter seagrass injury sites by displacing sediment berms, deepening or infilling excavation craters, and undercutting exposed rhizome mats. In the event that the grounding location is not known by injury assessment personnel, it is preferred that the officer who investigated the grounding direct them to the site. This is done to insure quick relocation of the site and to maintain a clear ‘chain of evidence’ should legal action be required. Sanctuary personnel provide FWC officers with tethered floats and PVC stakes to mark the end points of an injury site to facilitate return assessment visits. In the event that the responding officer is unavailable to guide assessment staff back to the injury, the combination of DGPS coordinates and markers should put the investigators on scene. However, there is no substitute for an orientation to the grounding site by the responding officer. It is also helpful to obtain a copy of the OIR report before visiting the site. This report contains information that will provide assessment personnel with data about the vessel and circumstances surrounding the grounding. It also contains vital statistics on the vessel and the owner/operator that are required for the final injury assessment report. Once on scene the assessment vessel should be positioned as close to the grounding site as conditions permit so that diver time and energy are expended efficiently. From this vantage point it is often possible for assessment personnel to identify major elements and orientation of the grounding injury before entering the water.

INJURY ASSESSMENT STEP 1. (ESTABLISH MASTER TRANSECT LINE).—Locate and mark with a surface buoy the beginning (inbound path) and end (final resting place) of vessel injury to natural resources (Fig. 1). For coral reef and hardground areas, securely anchor a master 1.25 to 1.5 cm (1/2 to 5/8 in. dia.) stainless steel or fiberglass stake into the substrate at either end of the grounding track. Proper anchoring of master stakes in reef rock requires drilling a 15 to 30 cm (6 to 12 in.) deep, slightly oversize hole, filling it with fast-set epoxy or quick-setting portland cement and inserting the stake with a twisting motion. Stakes should project a minimum of 30 cm (12 in.) above the substrate so that they are easy to relocate. Placing master stake markers in seagrass or in unstable substrates such reef rubble requires a special Manta type anchor to prevent withdrawal. Information on Manta anchor systems can be found in Halas (1997). To complete the master transect line, attach a metric fiberglass measuring tape to the inbound path zero-meter stake and carefully lay out and securely fasten the tape along an approximate centerline down the entire length of the grounding track (Fig. 1). It may be necessary to affix temporary attachment points for the tape in order to hold it in place and to negotiate curves or sharp turns in the grounding track. For limestone reef rock, a hardened steel masonry nail makes an ideal temporary fastener. In seagrass areas underlain by soft sediment, temporary attachment stakes can be cut from lengths of plastic PVC pipe. Coarse gravel and rubble substrates will require a pointed steel rod and hammer for adequate penetration. All attachment points should be marked with high visibility plastic surveyors flagging tape. Coordinates of the two master stakes should then be determined with a Differential Global Positioning System (DGPS) unit capable of sub-meter (within 3 ft) accuracy.

INJURY ASSESSMENT STEP 2. (VIDEO-STILL CAMERA DOCUMENTATION).—Beginning at the surface buoy (0-m mark on the tape), record on HI-8 (or digital) video tape the significant features of the injury as they are encountered along the entire length of the master transect line. Camera should be panned very slowly and held as steadily as possible at all times. Objects or areas that exhibit major injury should be referenced by close-up video of the meter tape to pinpoint their location along the grounding track. It will sometimes be necessary to make lateral excursions away from the transect tape to capture all areas of

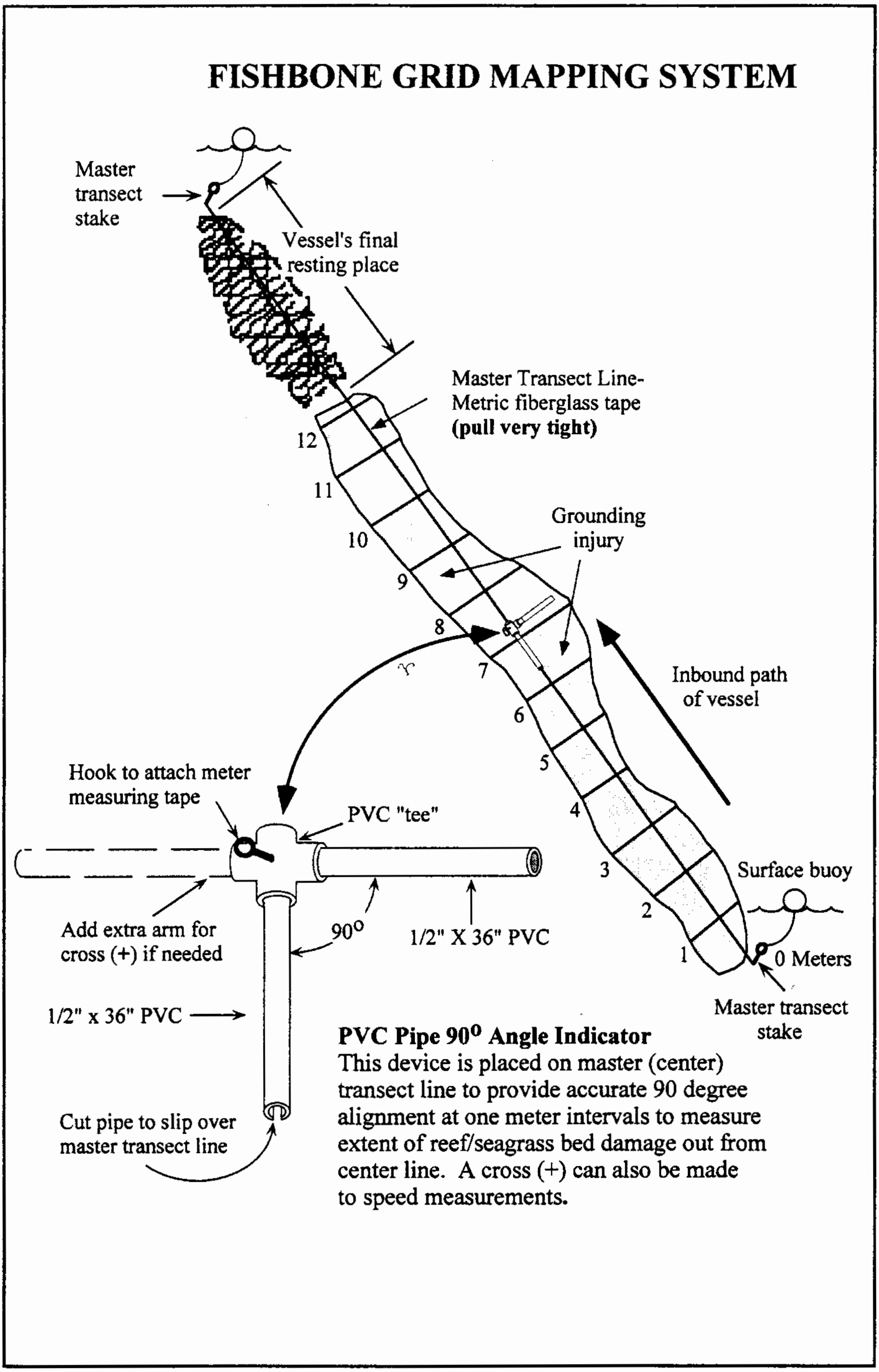

Figure 1. FISHBONE mapping system

the injury. To maintain continuity, a similar procedure of meter tape registration should be done at the start and end of each lateral traverse. The full extent of injury to natural resources will not always be apparent, even on video tape. Corals, reef framework, mats of seagrass and other biota will often appear only superficially injured. Upon closer inspection, however, it is often discovered that they have been dislodged from the substrate. For this reason it is prudent to document a representative number of unstable objects as evidence of injury severity. This can be accomplished by moving the dislodged item slightly while recording it on video. Any manmade materials found at the grounding site, such as paint flakes, propeller fragments, boat equipment, or other items that could link a vessel to a grounding site should be collected and held as evidence. Before removal, location and orientation of these items relative to the master transect line should be recorded on video tape, and if necessary, drawn and labeled on an underwater sketch pad. This procedure can be especially useful if a vessel has grounded, freed itself and fled the scene before FWC personnel arrive. In instances where a vessel remains aground for an extended period of time, it is sometimes possible to obtain underwater video footage of its hull and the adjacent seabed. This type of documentation is relatively inexpensive to obtain and can be very instructive to the Coast Guard and designated salvor in planning vessel removal. It is the diver-videographers' responsibility to insure conditions on and around the vessel are safe before entering the water. Underwater still-camera photographs should be taken of key areas and objects throughout the grounding site as supplemental documentation. Ability to correctly interpret size relationships in video and still-camera images is extremely important. Divers make an excellent scale for both still and video camera and should be used whenever possible. Meter sticks, stadia rods, quadrats, and small weighted centimeter scale bars should also be used as appropriate to indicate size of objects and natural features.

INJURY ASSESSMENT STEP 3. (M^2 QUANTIFICATION OF INJURY).—Depending upon extent and severity of injury, it may be necessary to use a combination of assessment techniques to adequately determine loss of biota and substrate. Our experience has shown that, depending upon circumstances, power and sailing vessels up to 9 m (30 ft) in length usually cause injury to natural resources that can range from minor to significant. As a rule they do not have sufficient weight, draft, or horsepower to cause catastrophic injury and groundings in this category can usually be assessed in 1 d with a minimum of equipment and personnel. Conversely, larger vessels, due to their greatly increased weight, draft and horsepower, are capable of inflicting severe and widespread injury to biota and substrate. These catastrophic groundings may require several teams of divers, specialized equipment, and up to a week or more to assess (Hudson and Diaz, 1988). For purposes of this report, a minor to significant grounding injury can be described as one which, at some point in time, is likely to recover without human intervention. Catastrophic injury on the other hand implies that in addition to being severe and widespread, natural recovery is not likely and site conditions may worsen without human intervention. Procedures described herein can be applied as appropriate to any observable level of grounding injury to coral reef or seagrass environments.

Coral Reef Injury Assessment

Area of a grounding injury up to 10 m^2 can usually be quickly determined with a hand-held m^2 quadrat or by simple length-width measurements with a fiberglass meter tape. Due to increase in size and complexity, non-catastrophic coral reef grounding sites greater than 10 m^2 in area may require the FISHBONE grid mapping system for an accurate and efficient assessment (Fig. 1). This technique, developed by the senior author, utilizes the master transect line meter tape already installed on the grounding site in Step 1 as the focal point for measurements. Beginning at the '0' m mark of the tape, a right-angle (90°) measurement is made out to the injury boundary. These measurements (to the nearest cm) are repeated at 1 m intervals along both sides of the transect line and recorded in proper sequence on waterproof paper mounted on a clipboard. From these data, a m^2 grid of the injured area can be plotted on graph paper or by computer to determine total area of injury. Compass bearings should be taken at known points along the master transect line to establish direction of the grounding track for later use in constructing a map of the grounding site. Water depth(s) at strategic points within the grounding site and time of observation should also be recorded. Determining percent cover and species within the grounding site is facilitated by an injury assessment data sheet printed on waterproof paper that provides a check-off list of coral species and other biota likely to be encountered during the survey. In coral environments, displacement and crushing of specimens within a grounding site can be so severe that percent cover cannot be determined. In these instances, percent cover is determined by sampling uninjured areas adjacent to the grounding site. A m^2 quadrat constructed of plastic PVC pipe is placed on the seabed and a full-frame vertical photograph is taken of the quadrat at random locations on both sides of the injury area. Adequate quadrat coverage can usually be obtained with two photo frames (one each side) per 3 m of grounding track. This number may be adjusted up depending upon diversity and zonation of biota. If photographic equipment is unavailable, biota can be sketched in situ on a gridded waterproof data sheet. The data sheet is scaled to match a m^2 PVC quadrat frame that has been subdivided into sixteen 25 cm^2 compartments with tightly stretched nylon string or rubber bungee cord. After placing the PVC quadrat, the diver hovers directly over it and carefully sketches on the data sheet all relevant biota contained within the m^2 outlined by the frame. Although time consuming, this method is accurate because all objects are being drawn to scale. Data collected by either method are then reduced to obtain m^2 percent cover and species within the injured area.

Seagrass Injury Assessment

Procedures for assessing injury to seagrass with minor exceptions are the same as those outlined above for coral reef areas. Assessment of groundings in seagrass caused by a 9 m (30 ft) or less vessel is in most instances considerably less complicated than those in coral. Injury is typically from propellers that cut and excavate a narrow trench of uniform width through the seagrass blades, underlying rhizome mat and sediment. These well defined scars are usually about the same width as the propeller that created them and are devoid of living seagrass. Trench depth is a function of vessel draft and water depth. Measuring the propeller grounding track length, plus width and depth of trench at 5 m intervals with a fiberglass metric tape will usually provide adequate quantitative assessment data. If an excavation crater (blowhole) is present, its depth should be measured and area mapped using the FISHBONE method. Volume of craters and trenches should be calculated to determine sediment loss. Any sediment ejecta berms caused by the grounding that have completely buried seagrass blades should also be included. All seagrass species and associated biota impacted by the grounding should be listed and their percent cover determined by visual inspection of 25 cm^2 PVC quadrats placed in adjacent uninjured seagrass beds. Two sampling quadrats (one each side of track) per 2 m of grounding track is usually sufficient to census bottom cover. A rigid meter-long ruler divided into centimeters makes an ideal tool for measuring narrow propeller scars, shallow trenches and excavation craters. As in reef injury assessments, aerial photography and DGPS can also be useful tools for mapping seagrass groundings.

Aerial Photography Mapping

Although not usually employed in non-catastrophic grounding surveys, high-resolution aerial photography and the differential global positioning system (DGPS) can be used to map both coral reef and seagrass injury sites. Some guidelines on when and how to use these techniques to map a grounding site are outlined here. As a general rule, aerial photography should be considered if the area of injury is 100 m^2 or more, is in clear water less than 4.5 m (15 ft) deep and contains numerous and widely dispersed isolated grounding scars. Under proper conditions, efficiency and accuracy of mapping a grounding site by aerial photography is unequaled. For fixed-wing aircraft, experience has shown that best results are obtained when images are taken at a height of 2400 ft (733 m) by a professional aerial photographer using a 12 in. (30 cm) long focal length camera with a 9 in. × 9 in. (22.5 cm × 22.5 cm) negative format or similar camera supplied with Eastman Kodak 2445 color negative film or other film with comparable characteristics. Helicopters are usually not equipped for aerial photography and therefore the professional photographer must rely on smaller format hand-held cameras with fast film and shutter speeds to compensate for in-flight vibrations. However, the ability of the helicopter to hover and go ‘low’ help to compensate for smaller negatives. Regardless of platform used, photographs should be as ‘true’ vertical, as possible, with camera angle perpendicular (90°) to the water surface. Photos should be taken on calm sunny days in mid-morning or early afternoon to avoid wave distortion and sun glare. Scale in the photograph is provided by four 40 in. (1 m) diameter white fiberglass targets that are arranged on the seabed to form a 25 m (82 ft) per side diamond or rhombus. To construct the scale, two stakes are secured in the seabed exactly 25 m apart to form points one and two of the diamond-shaped scale. A meter tape is then fastened to each stake and both tapes unreeled and brought together so that they intersect at 25 m. When the two tapes are pulled tight, the point where they cross is marked with a stake to form the third point of the diamond. This process is repeated on the opposite side to complete the fourth point of the diamond. Additional targets should also be placed over the master transect stakes and at other critical points within the grounding site as required. Targets should be securely fastened to the seafloor and displayed on a dark background for maximum contrast. For display on sandy bottoms and highly scarified areas, targets can be placed inside a black plastic trash bag and tightly secured with duct tape. The bag should be vented and conform to target outline. The targets we use are white plastic patio tabletops that have been emblazoned with a 6 in. (15 cm) wide bright orange cross. To insure compass orientation in photographs, a 5 m (16.3 ft) long × 10 cm

(4 in.) wide directional arrow made of wood or plastic and painted black is placed on the site, aligned with a diver's compass to indicate North and fixed in position. It is advisable to have the photographer take a number of oblique photographs of the site at various angles and altitudes. These can be valuable in establishing relationships of nearby manmade or natural features to the grounding site. It is important to have a vessel onscene during the overflight to provide a high-visibility target for the approaching aircraft. Without this visual aid it is extremely difficult for the pilot to locate the exact area to be photographed. Radio communication between on-site vessel and aircraft is strongly recommended. In some instances there may be an opportunity to take aerial photographs while a vessel is still aground. This is especially true of large vessels that may take several days to remove. Due to its high cost, aerial photography is usually prohibitive for all except catastrophic category groundings.

Differential Global Positioning System Mapping

Mapping of grounding sites with DGPS is relatively new and was first used in the Florida Keys National Marine Sanctuary by Richard Shaul and his associates in 1998 to map the MV Contship Houston grounding site off Maryland Shoal in the lower Florida Keys. Criteria for cost-effective use of this equipment include water too deep or turbid for aerial photography, more than 300 m^2 of discontinuous injury sites, need for accurate baseline maps for restoration purposes, and availability of two suitable geo-reference points on a nearby land mass. The Contship Houston site met all of the above requirements.

In practice a DGPS 'slave' unit is positioned on each of the two land-based geo-reference points to communicate with orbiting geo-reference satellites and a third DGPS unit mounted on a diver-controlled pontoon float at the grounding site. An umbilical cable extends from the DGPS unit on the float to a diver on the bottom who enters waypoints as they are encountered on the grounding site. For waypoints to be accurate the antenna mast on the pontoon float must be directly above the object or feature being mapped on the seafloor. This equipment as described cannot be used with a high degree of accuracy in strong currents, rough seas or other conditions that could alter vertical alignment of the DGPS antenna mast. Special software is used to convert geo-reference data collected at the site into printed maps. For detailed information on this system and its accessories, the reader should consult Shaul et al. (1999).

Summary

This report is an introduction to the mechanics of injury assessment as conducted by personnel of the Florida Keys National Marine Sanctuary. The methodology and techniques presented here will enable the user to create an accurate map of injured biota and disturbed substrate in coral reef and seagrass habitats. Proper interpretation and quantification of mapped injury areas are the responsibility of the individual(s) conducting the assessment. In this regard, it should be remembered that if litigation arises as a result of a vessel grounding, any and all information obtained from an injury assessment is subject to challenge in a court of law.

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