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The Mini-312 Program—An Expedited Damage Assessment and Restoration Process for Seagrasses in the Florida Keys National Marine Sanctuary

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ABSTRACT

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There are approximately 650 known vessel groundings that occur annually within the Florida Keys National Marine Sanctuary (FKNMS). The majority of these groundings directly impact valuable seagrass habitat. The National Oceanic and Atmospheric Administration (NOAA), under the National Marine Sanctuary Act, and the State of Florida, under Florida statutes, act as co-trustees with the authority to recover monetary damages and restore injuries to the natural resources of the FKNMS. Previously, it was difficult to accomplish assessment and restoration planning for many of these incidents in a cost-effective manner. With the goal of expediting development of litigation-quality natural resource damage claims for seagrass grounding incidents, NOAA has developed and implemented standardized damage assessment, restoration planning, and restoration scaling protocols for seagrass injuries. The protocols center around three major components: 1) GIS-based field assessment, 2) model-based estimation of injury recovery rates, and 3) calculation of compensation using Habitat Equivalency Analysis. By standardizing the assessment and restoration planning procedures associated with these types of incidents, NOAA and the State of Florida have substantially lowered the threshold for the size and severity of grounding injuries that can be cost-effectively assessed and restored, significantly increasing the number of cases that can be addressed annually. In addition to the direct resource benefits of increased assessment and restoration, we anticipate that there will also be a deterrent effect on future groundings.

ADDITIONAL INDEX WORDS: *differential global position system, modeling, habitat equivalency analysis, habitat recovery, vessel groundings, seagrass disturbance, natural resource damage assessment.*

INTRODUCTION

As the population of Florida's coastal counties has grown, both direct and indirect anthropogenic threats to seagrass communities also increased (LIVINGSTON, 1987; SHORT and WYLLIE-ECHEVERRIA, 1996). The cumulative ecological impact of small vessel groundings on coral and seagrass ecosystems in the Florida Keys is well documented (SARGENT *et al.,* 1995; WHITFIELD *et al.,* 2002). Within the Florida Keys National Marine Sanctuary (FKNMS), there are approximately 650 reported vessel groundings annually, with the majority of these groundings impacting seagrass habitat (HORADAM, J., Florida Fish and Wildlife Conservation Commission, personal communication). SARGENT *et al.* (1995) estimated that there were 30,050 acres of scarred seagrasses within the FKNMS reflecting a dramatic increase in vessel groundings over the past two decades (DAWES *et al.,* 1997; KENWORTHY *et al.,* 2002; SARGENT *et al.,* 1995; ZIEMAN, 1976).

Injuries caused by vessels grounding in seagrass take the form of at least one of three features: propscars, blowholes, or berms (see Figure 1). Propscars are narrow, linear features that result from the vessel's propeller moving through the seagrass bed (KENWORTHY *et al.,* 2002; ZIEMAN, 1976). In addition to these narrow injuries, large

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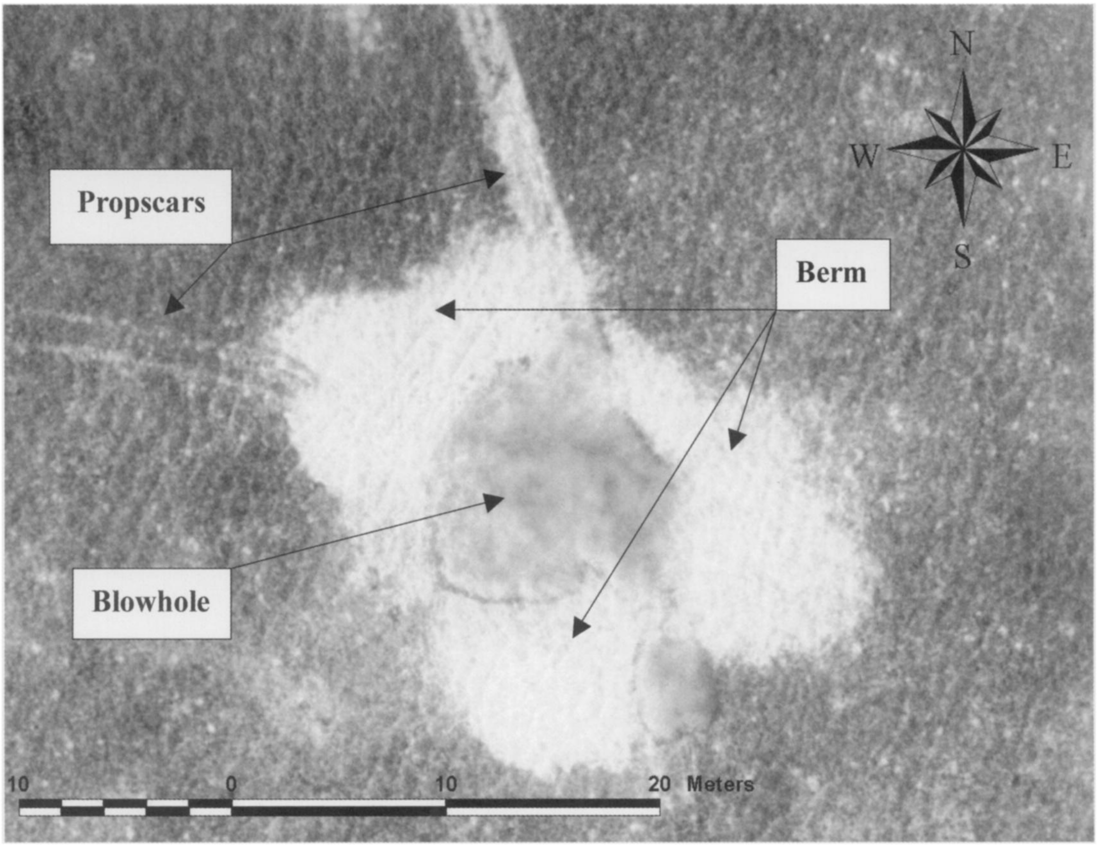

Figure 1. Typical grounding seagrass injury in the Florida Keys National Marine Sanctuary, illustrating the entrance and exit propscars, blowhole, and berm.

areas of seagrass can also be excavated as a result of attempts to dislodge a grounded vessel using the vessel's engines. These injuries are known as blowholes (WHITFIELD *et al.,* 2002). Some blowholes can exceed depths of two meters below the surrounding seafloor. The sediment excavated from these holes is often deposited on adjacent undisturbed areas, resulting in the burial of seagrass, creating injuries classified as berms. If not removed or returned to the excavation, berms can result in the death of the seagrass underneath (DUARTE *et al.,* 1997).

Under the National Marine Sanctuaries Act (NMSA), injuries occurring within the FKNMS are subject to a full natural resource damage assessment (NRDA) and restoration. The purpose of a NRDA is to investigate the extent of the natural resource injury, evaluate and select appropriate restoration actions, and calculate all of the financial costs associated with the assessment and required restoration actions. For injuries occurring within the FKNMS' borders, two government trustees—the National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection (FL-DEP)—cooperatively assess the impacts and draft restoration plans. The trustees utilize this information to present claims for natural resource damages to the responsible party (RP) in order to restore the injured resources and obtain compensation on behalf of the public for interim lost resources and services resulting from the grounding. Guidelines and criteria for conducting seagrass restoration are well documented (FONSECA, 1989; FONSECA, 1992; FONSECA *et al.,* 1988; FONSECA *et al.,* 1998). As first presented in FONSECA *et al.* (2000), seagrass NRDAs conducted in the FKNMS combine ecological field methods and economic analyses to fulfill the requirements of a NRDA.

The purpose of this paper is to describe the set of procedures and protocols that NOAA uses to assess vessel injuries to seagrass beds, which is known as the "Mini-312" program. The "312" refers to Section 312 of the National Marine Sanctuaries Act, which contains the natural resource damage provisions, and "Mini" reflects the generally smaller size of these damage assessment cases (10's to 100's of m^2). This process is part of restoration planning and the precursor to restoration, but is an absolutely essential component to developing a complete, defensible claim. The techniques outlined here were developed through several years of practical experience by field biologists in the FKNMS and research scientists at the Center for Coastal Fisheries and Habitat Research (CCFHR), interactions with resource managers and economists, litigation, and review of scientific investigations on disturbance and recovery dynamics in tropical seagrass ecosystems in the South Atlantic, Gulf of Mexico, and Caribbean (BELL *et al.,* 2001; BELL *et al.,* 2002; BELL and HICKS, 1991; GUICHARD *et al.,* 2001; HOVEL and LIPCIUS, 2001; IRLANDI, 1994; IRLANDI, 1996; IRLANDI, 1997; IRLANDI *et al.,* 1995; IRLANDI and CRAWFORD, 1997; IRLANDI *et al.,* 1999; UHRIN and HOLMQUIST, 2003; WITH and CRIST, 1995).

METHODS

Field Assessments

The first step in the Mini-312 assessment protocol is to quantitatively determine the extent of injury created by a boat grounding. This is accomplished by an on-site assessment conducted by a two-person field team in collaboration with law enforcement. The field assessment involves three quantitative techniques: (1) mapping the spatial extent of the injury site area with a surveyor-grade differential Global Positioning System (DGPS) receiver, (2) using a rapid visual assessment technique to estimate the abundance of undisturbed and injured resources (*e.g.,* seagrass, macroalgae, and coral), and (3) bathymetrically surveying scar and/or blowhole excavation depths.

The field assessment depends on the ability to accurately determine a location using a DGPS. With the use of a DGPS, highly accurate, spatially articulated maps of the injured area can be merged with quantitative measurements of resource abundance to determine resource impacts and the need for primary restoration action(s). Primary restoration is defined as restoring the injured resource to pre-injury conditions at the site of the grounding (NOAA, 1997, revised 2000). This information is also necessary to determine the scale of compensatory restoration needed to fully compensate the public for interim lost services. Compensatory restoration is the action taken to provide resources and services equivalent to those that are lost from the time of the incident until recovery to pre-incident conditions (NOAA, 1997; NOAA, 1997, revised 2000).

Injury Mapping

Given the irregular shapes of vessel grounding injuries, simple length and width measurements will not accurately represent the extent of these injuries (FONSECA *et al.,* 2004). Previously, accurate portrayal of the shape of the injury was accomplished using a Cartesian coordinate system of measurements similar to the fishbone method described in HUDSON and GOODWIN (2001). Placing a fiberglass tape measure down the center of the injury and taking measurements at right angles to this center line can create a graphical representation of the injury created by plotting all measured points using the beginning of the center tape measure as the axis of the coordinate system. By connecting the points and creating a polygon, the area of the feature is then calculated. While this method does not require expensive equipment, it does require a considerable investment in time and manpower to achieve a detailed representation (*i.e.,* large number of points) of the injury.

Using the Global Positioning System (GPS) and a surveyor-grade receiver (Trimble™ GPS Pathfinder Pro XR), the time required to map the injury and the manpower requirement (one individual versus a minimum of two) is significantly reduced. The GPS receiver allows real-time differential GPS and postprocessing options for the data resulting in horizontal accuracies typically less than 0.5 meters. This system allows the user to map the injury by "walking the perimeter" or towing the DGPS in an inflatable craft. The total number of points collected is dependent upon the complexity of the feature. More complex, high fractal dimensions require more points to accurately represent the shape of the feature. These points can then be connected to form a polygon from which the area of the feature can be calculated using commercially available software, such as ESRI™ Arcview or Trimble™ Pathfinder Office. Additionally, because the coordinates collected are based on the WGS-84 datum, they are easily transformable to allow use in a geographic information system (GIS). The result is a two-dimensional representation of the size and shape of the injury that is referenced to a specific geographic location. Another advantage of using a GIS system is the ability to integrate the injury dimensions with other geospatial information (*i.e.,* aerial photos, charts, benthic surveys).

The primary advantages of using DGPS based procedures are (1) lower workforce requirements, (2) rapid acquisition of accurate mapping information in a digital format that can be converted into quantitative measures of injury shape and size, (3) nearly seamless electronic transfer of information collected in the field to a GIS, and (4) the capability to precisely locate injuries for assessment purposes or to relocate injuries and identify sensitive resources for monitoring and management attention.

For injuries for which it is not possible to conduct injury geometry measures on-site (*e.g.,* large and geometrically complicated injuries, deeper water, soft bottom sediments), aerial photography is used. Using GIS, injury features are quantitatively delineated in goerectified vertical aerial photographs. Prior to photographing the site, a minimum of six DGPS-positioned ground control targets are placed on site in a manner that ensures distribution throughout the photograph. These points are later used to geo-reference the photograph. Each ground control target consists of a 1.15-meter-diameter, commercially available PVC tabletop painted bright yellow, inserted over a vertical pole to allow the target to float with the tide. Depending on the size of the area to be photographed, six targets can be rapidly deployed in less than an hour (before the aircraft arrives on-scene). DGPS positions on the poles that secure the targets are taken just before the photograph is shot, and immediately afterward, to ensure no movement has occurred. In addition to enabling quantification of injury area, aerial photography serves as an essential exhibit in litigation if necessary.

Habitat Characterization

Community composition, percent cover, and density of the benthic community—both of the injured area and the surrounding undisturbed area immediately adjacent to the injury—are assessed using a modified Braun-Blanquet technique (BRAUN-BLANQUET, 1932; FOURQUREAN *et al.,* 2001; KENWORTHY and SCHWARZCHILD, 1998). This technique is used because it is accepted by marine scientists, widely used, and highly replicable. This method involves placing a 0.25-m^2 quadrat on the substrate and visually inspecting the contents. Placement of the quadrat is haphazard both inside and outside of the injury. Control quadrats are recorded within 1–3 meters of the injury and measured around the entire injury to account for any heterogeneity exhibited by the habitat. Typically, a minimum of three quadrats is recorded within each type of injury present (berm, blowhole, or propscar), and a minimum of ten control quadrats are recorded. The submerged aquatic vegetation (seagrass and macroalgae) and/or coral are identified and assigned a cover-abundance scale value: 0.0 = not present, 0.1 = solitary specimen, 0.5 = few with small cover, 1 = numerous but less than 5% cover, 2 = 5 to 25% cover, 3 = 26 to 50% cover, 4 = 51 to 75% cover, and 5 = greater than 75% cover. To determine the percent cover per individual species, as well as the total seagrass cover, the Braun-Blanquet scores by species and total cover are averaged over all of the quadrats assessed within each feature (propscars, blowholes, berms, and undisturbed area). The Braun-Blanquet scores are then converted into percentage coverage by interpolation of the midpoints of the Braun-Blanquet scores. For purposes of interpolation, a score of 1 is considered equal to 1% to 5% cover. For example, the midpoint of a Braun-Blanquet score of 1 is equal to 3%, and the midpoint of a Braun-Blanquet score of 2 is equal to 15%. In the case of a Braun-Blanquet score being less than 1 but greater than 0, a percent cover of 1% is given. The loss of seagrass as a result of the grounding can then be assessed by comparing the percent cover of the injured area to that of the undisturbed reference area.

Bathymetric Survey

In addition to their two-dimensional component, these grounding injuries often have a three-dimensional aspect ensuing from the creation of blowholes. This excavation results in the removal of below-ground organic matter, which is a primary nutrient source for seagrass (WILLIAMS, 1990). Moreover, these excavations can result in severe impediments to vegetative recolonization by seagrasses. As a result of their upward branching architecture, the tropical climax seagrass, *Thalassia testudinum,* is limited in its ability to propagate

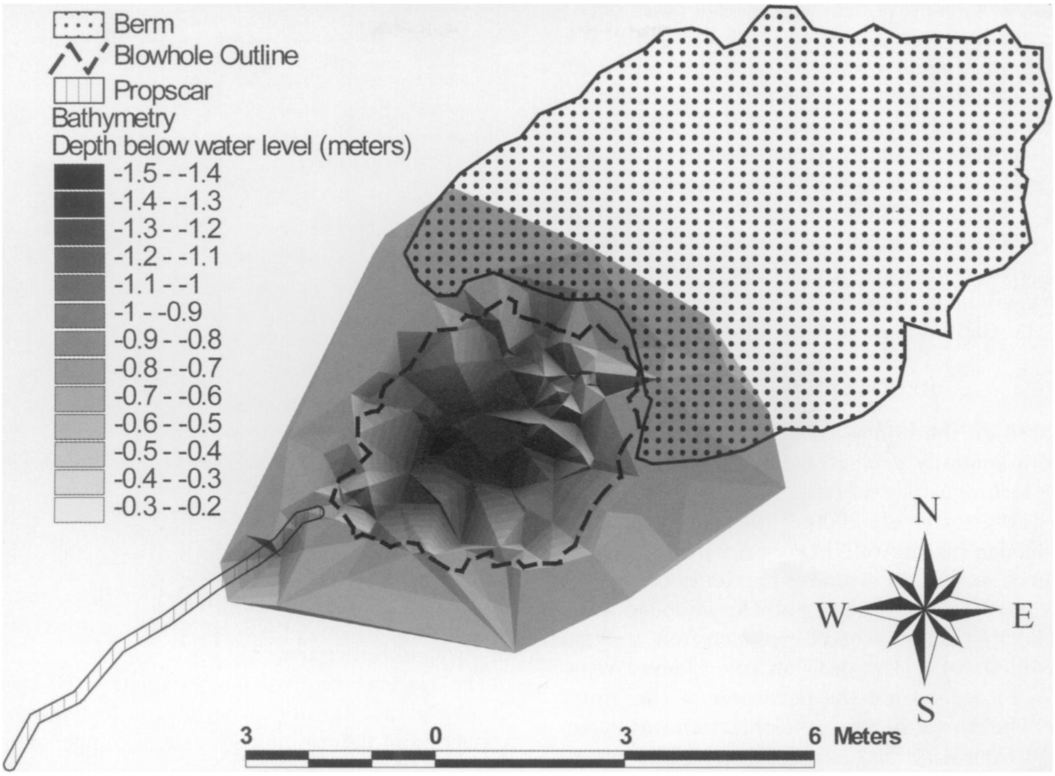

Figure 2. Delineation and bathymetric survey of a common seagrass grounding injury.

across these scarps (DUARTE *et al.,* 1994; MARBA *et al.,* 1994; TOMLINSON, 1974). Additionally, the resultant instability of the injury margins can lead to expansion of the injury due to erosion caused by tidal flow or storms (WHITFIELD *et al.,* 2002). To counter the potential erosion of the site and allow for recolonization by seagrasses, sediment is needed to restore the seafloor to grade as part of the primary restoration. A bathymetric survey is the most efficient way to determine the amount of fill required. A commercially available depth sounder (Lowrance LCX-15MT™) was integrated with a surveyor-grade DGPS receiver to allow collection of spatially referenced bathymetric data (0.1 meter vertical accuracy) across the injury and the adjacent undisturbed seagrass beds. By slowly floating the depth sounder/GPS across the injury in a small float, geo-referenced depth measurements are collected, using the water surface as a level plane. The data is imported into a GIS, and a triangulated irregular network (TIN) is applied to create a surface of depth values; a three-dimensional graphic of the injury is produced, and the volume of the injury is calculated (Figure 2). A typical bathymetric survey takes less than one hour in the field. Whereas previous bathymetric analyses capable of meeting the strictest standards of litigation were feasible for only the largest cases, this methodology now allows for cost-effective bathymetric surveys to be done on all cases without lowering data quality standards.

Injury Report/Case Study

The data collected from the field assessment is compiled into a report that is distributed to all the trustees and the responsible party. Representatives of all the trustees scrutinize this report to ensure that it provides an accurate, concise description of the injury without subjective inferences.

Figure 2 illustrates a common seagrass grounding. The injury was created by a 8.5-meter vessel in a mixed seagrass bed. The bottom cover of the seagrass bed was composed of 35.75% *Thalassia testudinum* (mean Braun-Blanquet score of 2.90) and no greater than 1% each of *Halodule wrightii* (mean Braun-Blanquet score of 0.81) and *Syringodium filiforme* (mean Braun-Blanquet score of 0.25). The blowhole excavated an area of 14.26 m^2 with a volume of 7.00 m^3. The berm covered an area of 44.66 m^2 and the propscar was 6.45 meters long with an average width of 0.19 meters. This injury will be used to illustrate the recovery model and the Habitat Equivalency Analysis.

RECOVERY MODEL

Based on the injury assessment report, we applied a spatially explicit, cellular automata modeling technique to evaluate injury recovery trajectory (FONSECA *et al.,* 2000; FONSECA *et al.,* 2004). The model, run in ArcINFO or SAS, utilized a cost/distance module to evaluate proximity of unfilled to filled (colonized) pixels and then applied a decision rule that governed conversion from unfilled to a filled state. The decision rule allowed vegetative recovery from the perimeter of the injury only. The rate of habitat recolonization was determined from empirical assessments and literature review (FONSECA *et al.,* 2004; KENWORTHY *et al.,* 2002). The resolution of the model (here, 0.5 m cell size) determines the time step represented by each iteration of the model. For the blowhole portion of the injury depicted in Figure 2, we predicted that *T testudinum* recovery would have returned to pre-injury conditions in approximately 30 years (see Figure 3). It is critical to note, however, that this recovery assumes ideal conditions and ignores the fact that there is actually a 1.5m-deep hole at the site; it also does not assume mortality of any plants or any intervening disturbance that causes plant mortality or slows the colonization rate. Nonetheless, these injuries are so egregious that even given these extraordinary concessions to the responsible party, the intrinsic recovery is forecast to be quite slow and will incur significant restoration costs.

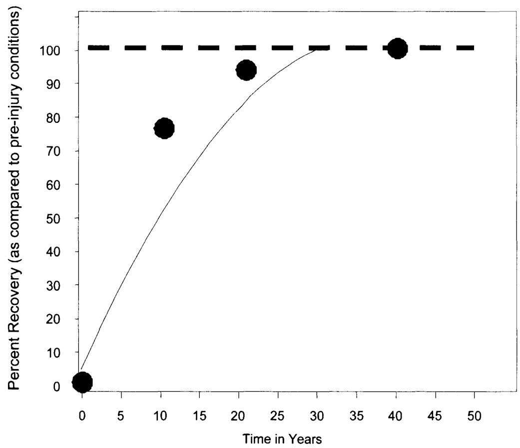

Figure 3. Recovery function for the 14.26 m^2 blowhole portion of the injury illustrated in Figure 2.

HABITAT EQUIVALENCY ANALYSIS

Each seagrass injury processed under the Mini-312 program is slated to be restored through primary restoration and is expected to eventually produce the same level of services as it did pre-injury. However, the public and the environment must be adequately compensated for the resource services lost between the time of the injury and the time of full recovery.

The Habitat Equivalency Analysis (HEA) was developed to quantify these interim lost resource services and determine the scale of compensatory restoration. The principle concept underlying HEA is that the public and the environment can be made whole for injuries to natural resources in the interim period through the implementation of compensatory restoration projects (usually at "orphan" sites, or sites for which the responsible party is unknown) that provide resources and services of the same type, same quality, and comparable value as those that were lost (FONSECA *et al.,* 2000). Thus, the HEA ultimately calculates the size of a replacement project such that the present value of the compensatory project equals the present value of interim losses due to the injury (see Figure 4) (FONSECA *et al.,* 2000).

The HEA is unique in that it calculates compensation for interim lost services with habitat/resource replacement projects rather than dollars. The dollar amount the party responsible for the injury is asked to pay relates to the cost of implementing the required compensatory restoration project.

Three criterion must be met for the HEA to function: (1) the primary category of lost on-site services must pertain to the biological function of an area (as opposed to its direct human uses, such as recreational services); (2) feasible compensatory

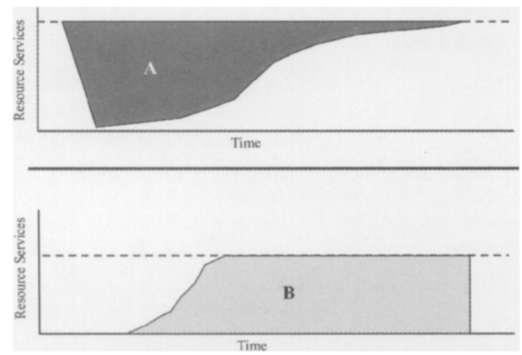

Figure 4. HEA's ultimate function is to equate (A) the interim losses as an injury recovers to pre-injury, or baseline, conditions to (B) the services gained through a compensatory restoration project so that the size of the injury in lost services equals the size of a replacement project in services gained. These curves, however, represent undiscounted (not discounted) service flows to better represent the recovery and maturity processes.

restoration projects must be available that provide services of the same type, same quality, and comparable value to those that were lost; and (3) sufficient data on the required HEA input parameters must exist and be cost-effective to collect (FONSECA *et al.,* 2000). The steps involved in conducting a HEA for seagrass injuries are described below.

Quantifying the Injury Service Losses

The first step in the HEA process is to calculate the total interim resource service loss. This is achieved by determining the extent, severity, and duration of the injury from the time of the injury until the resource reaches its point of maximum recovery (FONSECA *et al.,* 2000). For seagrass injuries, this process is repeated separately for each applicable injury component (blowhole, propscars, and berm).

However, it is neither feasible nor reasonable to measure and quantify each of the individual resource services provided by injured seagrass habitats. Thus, for seagrass HEA depends on a resource metric that is closely correlated with the services provided by both the injured and compensatory habitats (FONSECA *et al.,* 2002). Above- and below-ground biomass is the resource metric used in Mini-312 program HEAs. This metric is relatively easy to assess and the plant coverage it represents plays a crucial role in allowing the seagrass habitat to provide essential services, such as food, shelter, nutrient cycling, and sediment stabilization. It also allows the HEA to capture differences in the quality of services provided by the injured versus replacement resources (FONSECA *et al.,* 2002).

The field assessment determines the above-ground percent cover of each species (*S. filiforme, H. wrightii,* and *T. testudinum*) in the control area and in the injured area, thus allowing a percentage of above-ground biomass coverage lost in the injury to be calculated. To compute lost below-ground biomass for each species, the percentage of above-ground biomass lost is applied to research-based below-to-above-ground biomass ratios (1.669 for *H. wrightii,* 0.651 for *S. filiforme,* and 3.144 for *T. testudinum*). Both the above- and below-ground biomass percentages are used to determine the fraction of total biomass attributable to each species.

The percent cover loss is then converted into a percent service loss for each species. Total service loss (100%) is defined as complete removal of seagrass biomass from the injury site. The service losses for each species are weighted by their respective fractions of total biomass to determine a percent service loss for the injury as a whole.

The result (or more precisely, the equation describing the intrinsic change in percent cover over time of the injury) of the previously described recovery model is then applied to the percent service lost in the injury in six-month, or half-year, increments. This determines the recovery path for each species in stages as the injury recovers. A weighted average of the percent cover loss of the three species is then calculated for each half-year.

The total number of square meters in the respective injury component is then multiplied by this weighted average percentage in each period. This loss quantity is then translated into present value terms using a discount rate of 3% (a value linked to the federal discount rate: essentially, the rate at which our society considers postponed services to lose value with time). Discounting is a standard economic measure that puts more value on present resources rather than those occurring at a specified period in the future. Because of discounting, future seagrass services are worth less than those that are provided today (FONSECA *et al.,* 2000).

The discounted services lost per square meter per half-year are then totaled over the recovery period to arrive at the total square-meter half-years of services lost in the injury component (see

Table 1. *HEA for a common blowhole injury.*

HEA Parameters	
Habitat injured	Seagrass
Total sq. meters of habitat injured in blowhole	14.26
Year of initial injury	2001.00
Primary Restoration	
Is primary restoration required	Yes
Year primary restoration starts	2002.00
Years to full recovery following restoration (given HEA run)	22.50
Year primary restoration reaches maturity	2023.50
Functional form of recovery function (from recovery model)	Quadratic
Periods per year	2.00
Compensatory Restoration	
Is compensatory restoration required	Yes
Year compensatory project is completed	2002.00
Years to full maturity following restoration activities	5.00
Functional form of maturity function	Linear
Relative productivity of restored to natural habitat	100.00%
Initial service level of compensatory restoration site	0.00%
Recovery of injured habitat	100.00%
Time horizon for service production of restored habitat	Perpetuity
Real discount rate per year	3.00%
Periods per year	2.00
Summary	
Total sq. meter half years lost	68.27
Total sq. meter half years gained from one sq. meter of compensatory restoration	61.97
Total sq. meters necessary to be created as compensation for blowhole injury	1.10
Total acres necessary to be created as compensation for blowhole injury	0.0003

Table 1). One square-meter half-year equals the resources and services provided by one square meter of seagrass for one half year. This output is then summed for all injury components.

Quantifying the Compensatory Project Service Gains

After the injury is quantified, the resource services provided by the compensatory project over its lifespan must also be quantified to measure the benefits attributable to compensatory restoration. To do so, the following items must be determined: 1) time required for the compensatory restoration project to reach its maximum level of service provision; 2) the functional form of the maturity curve; 3) the lifespan of the project; and 4) the relative productivity of the restored-to-natural habitat (FONSECA et al., 2000; NOAA, 1997, revised 2000). Because compensatory projects are often unidentified at the time of the scaling exercise, their exact resource benefits are undefined, but are assumed to eventually provide the same services and species cover as did the injured area prior to the grounding. The Mini-312 program assumes that compensatory projects will take five years to reach full maturity, have a linear recovery curve (thus they recover 10% per half year), and provide services in perpetuity. The relative productivity of the restored-to-natural habitat is conservatively assumed to be a one-to-one ratio. This rate of service return is consistent with the rate of establishment evinced by successful seagrass restoration projects (FONSECA and BELL, 1998)

Table 2. *Summary of the HEA for a common seagrass injury.*

Injury	Area Injured (sq. meters)	Total Sq. Meter Half Years Lost	Total Sq. Meter Half Years Gained	Compensatory Habitat Required (sq. meters)
Blowhole	14.26	68.27	61.97	1.10
Berm	44.66	156.22	61.97	2.52
Propscars	1.23	0.98	61.97	0.02
Total	60.15			3.64

Scaling the Size of the Compensatory Project

The scale of the compensatory project is adjusted until the projected future resource service gains from the compensatory project are equal to the interim losses associated with the injury (FONSECA *et al.,* 2000). This is achieved by dividing the total square-meter half-years lost in the injury by the total square-meter half-years of services provided by compensatory restoration. The result is the size of the compensatory project (or number of square meters of seagrass habitat that must be restored) necessary to compensate the public and the environment for the interim losses created by the injury (see Table 2).

DISCUSSION

To review, the ultimate goal of any grounding case processed under the Mini-312 program is the restoration of the injured resource and compensation to the public for lost services. The first step in the process is the development of an accurate determination of the extent and severity of the injury, an estimation of recovery time, and the determination of services lost using the methods described (HEA). The next step is restoration planning utilizing tested methodologies (FONSECA *et al.,* 1998; KENWORTHY *et al.,* 2000). The third step is reaching an agreement to settle the damage assessment and restoration claim with the responsible parties. While this is often a cooperative process, the possibility of litigation exists. Accordingly, both the methods used by the Mini-312 program and the data collected must be admissible and defensible in federal court. The admissibility of scientific theory and evidence was addressed in *Daubert v. Merrell Dow Pharmaceuticals, Inc.,* 509 U.S. 579 (1993). In *Daubert,* the Supreme Court set forth four factors that a trial judge may consider in determining the admissibility of scientific testimony: (1) whether a theory or technique can be and has been tested; (2) whether a theory or technique has been subjected to peer review and publication; (3) the known or potential rate of error of a particular scientific technique; and (4) whether a theory or technique has been generally accepted (*Daubert* at 593–4). In a recent appeal, the admissibility and defensibility of the HEA and its underlying data was challenged and upheld in *U.S. v. Great Lakes Dredge & Dock,* 259 F. 3d 1300 (11th Cir. 2001). In an earlier case, the defensibility of the HEA was challenged and upheld in *U.S. v. Fisher,* 22 F. 3d 262 (11th Cir. 1994).

CONCLUSION

By standardizing the assessment and restoration planning procedures associated with vessel grounding incidents involving injury to seagrass, NOAA and the State of Florida have substantially lowered the threshold for the size and severity of grounding injuries that can be cost-effectively assessed and restored. By significantly increasing the number of cases that can be addressed annually, the problem of incipient damage by numerous small injury events is being addressed. Combining three things—accepted field survey techniques, a conservative recovery model, and a court-accepted economic tool—has produced a formula for rapidly assessing the injury and fairly determining the appropriate level of restoration. Whereas historically, injuries to seagrasses had to measure in the hundreds of square meters to pursue restitution in a cost-effective manner, we now address cases in the tens of square meters that are the primary mechanism responsible for the thousands of acres of lost seagrasses in the FKNMS (SARGENT *et al.,* 1995). In addition to the direct resource benefits of increased assessment and restoration, there has been a substantial educational outreach regarding the importance of seagrass and the advent of the Mini-312 program in hope of creating a deterrent effect against future groundings.

Initially, all of the assessment and restoration activities conducted under this program have been done within the FKNMS, although the underlying techniques could be applied to any other protected seagrass habitats or other resources (*e.g.,* coral reefs) (MILON and DODGE, 2001) with similarly well-defined statutory authority on liability and damages.

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