Groundings and Spills: Addressing Anthropogenic Insults Through Natural Resource Damage Assessment and Restoration

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ABSTRACT

Hazardous material spills (including oil) and vessel groundings, including the ensuing salvage efforts, are examined in the context of natural resource damage assessment as acute anthropogenic activities resulting in both long and short term impacts to marine and freshwater fisheries and their habitats in particular. Two case studies and their restoration approaches are presented. The grounding of the M/V FORTUNA REEFER on the reefs of Mona Island, Puerto Rico resulted in approximately 2.75 hectares of coral injury. The grounding resulted in a discreet impact zone, but the salvage effort increased the injury to many times the size of the grounding area. Emergency restoration efforts at the site entailed the use of stainless steel wire and nails to reattach detached and broken colonies of Acropora palmata. A restoration status report is provided. A phosphate industry spill of approximately 189 - 211 million liters (50-56 million gallons) of process water containing phosphoric acid (pH 2) resulted in the instantaneous kill of over 1.3 million freshwater and marine fish in the Alafia River and Tampa Bay, Florida. The fish injury, including both the direct kill and the lost future somatic growth, was estimated at 64,892 kilograms of biomass lost. In addition, the spill injured approximately 377 acres of freshwater wetlands and contributed to nutrient loading in Tampa Bay. Restoration or creation of emergent estuarine habitat and/or reef creation are being considered to compensate for the fish injuries.

KEYWORDS: Assessment, restoration, spills

INTRODUCTION

Under several Federal environmental statues, NOAA is the principal federal Trustee for marine and estuarine natural resources in U.S. waters of the Gulf of Mexico and the Caribbean. As a Trustee, NOAA's Damage Assessment and Restoration Program (DARP) conducts natural resource damage assessments (NRDA) and restoration of coastal and marine resources injured as a result of oil spills, releases of hazardous materials and ship groundings where there is a threat of a spill, herein referred to as incidents.

NOAA's trust resources include living marine and estuarine resources and the physical habitats that support them. Commercially and recreationally important species as well as species that often seem inconsequential to the public are covered by NOAA's stewardship mandate. Additionally, this trust responsibility encompasses intangible services that flow from one natural resource to another or from natural resources to humans. Such services may include habitat services in the case of resource to resource services, or recreational services in the case of human use services.

Stewardship for these marine and estuarine resources and services is shared by other government and tribal entities in the Gulf and Caribbean. In the coastal states of the Gulf of Mexico and Puerto Rico and the Virgin Island's territorial waters, the Governors are the natural resource Trustees. However, this Trustee responsibility is typically delegated down to the head of the natural resource agencies within each government. It is at the natural resource agency level that NOAA works with each government to resolve liability from spills and groundings with potentially responsible parties.

In the past 25 years, Congress and the President have enacted a suite of environmental laws to address the degradation of the Nation's natural resources. Explicit statutory authority to restore injured natural resources began with the Clean Water Act amendments of 1977 and continued with the later enactment of the Comprehensive Environmental Response, Compensation and Liability Act (CERLCA or Superfund), the National Marine Sanctuaries Act (NMSA), and the Oil Pollution Act of 1990 (OPA) and other related laws. As the primary Federal natural resource Trustee for coastal resources, NOAA has responsibility for ensuring the restoration of coastal resources injured by releases of hazardous materials and of national marine sanctuary resources injured by physical impacts. The Clean Water Act, CERCLA and OPA mandate that parties that release hazardous materials and oil into the environment are responsible not only for the cost of cleaning up the release, but also for restoring any injury to natural resources that resulted. The National Marine Sanctuaries Act mandates that parties who destroy, cause the loss of, or injure sanctuary resources are responsible for their restoration.

The damage assessment and restoration process provides the framework for determining:

i) what resources have been injured and what is the loss to the public?; and
ii) how can the resources be restored and what type and amount of restoration is appropriate?

The process involves three overall steps: preassessment, restoration planning (including injury assessment and selection of restoration activities) and restoration implementation.

Preassessment

NOAA and other Trustees evaluate whether injury was sustained by examining the resources at risk, the nature of their exposure, potential and direct observations of injury. Trustees begin by coordinating with response agencies to determine whether response actions are sufficient to eliminate the threat of ongoing injury. If injuries are expected to continue, and feasible restoration alternatives exist to address such injuries, Trustees proceed to conduct an assessment.

Restoration Planning

Efforts during this phase are directed at evaluating potential injuries to determine the need for, and scale of, restoration actions. Two closely coordinated activities take place during this phase: injury assessment, to determine the nature and extent of injuries to natural resources and services; and restoration selection, to select restoration action(s) which will compensate the public for the loss of natural resources and services resulting from the incident. Trustees evaluate the alternatives available for returning the injured resources and services to their baseline condition (the condition of the resource had injury not occurred) and compensating for the loss from the onset of injury until recovery. The responsible party is liable for paying the cost of restoration plus reasonable assessment costs.

Restoration Implementation

NOAA works with co-Trustees and, in some circumstances, responsible parties, to design and implement restoration actions. Restoration plans are developed and presented for public comment before implementation unless an emergency situation exists. All restorations include monitoring provisions to allow for corrections, to measure progress and determine the restoration effort's overall success. In many cases, the responsible party assumes responsibility for implementing the restoration with Trustee oversight.

The ultimate goal of a damage assessment is to restore injured coastal and marine resources. The process outlined above ensures an objective and cost-effective assessment of damages to the benefit of both the party responsible for injury and the public interest.

The case studies below illustrate how NOAA is addressing its stewardship responsibilities for restoring injured resources in a coral reef grounding incident and in an incident resulting in the spill of hazardous material.

METHODS

M/V Fortuna Reefer Grounding

In July 1997, the 99 meter (325-foot) container ship Fortuna Reefer ran aground on the fringing coral reef surrounding Mona Island, Puerto Rico. This natural resource damage action was pursued under the Oil Pollution Act of 1990 because natural resource injuries resulted from response actions taken to abate a substantial threat of discharge of oil from the grounded vessel to sensitive habitats. The Commonwealth of Puerto Rico is a Trustee along with NOAA.

Preassessment activities focused on determining the extent and degree of coral injury but were otherwise limited. Biologists from the Trustee agencies and consulting firms representing the vessel owners and their insurance company jointly examined the injury area using SCUBA and aerial photography. The injury site was dominated by a well-established community of Elkhorn coral, *Acropora palmata*, at a depth of 3-9 meters. Visual observations by divers determined that injury was caused by two factors:

i) The pressure exerted by the weight of the vessel; and,
ii) The use of steel tow cables by tugboats during salvage operations.

The pressure of the vessel crushed and fractured the reef framework leaving very few living corals within the impact footprint. Those few colonies that survived complete destruction were broken into many fragments. The steel tow cables attached to the stern of the freighter which were used to pull the freighter free were dragged across the bottom. The cable severed and broke the standing coral colonies over a 2.75 hectare (6.8 acres) area as it dragged across the bottom.

The need to address ongoing loss of live tissue from broken coral fragments from wave and surge action was identified as a priority concern. Further injury assessment studies were not immediately undertaken. After evaluation of the preliminary injury assessment data, a cash settlement for $1.25 million dollars was quickly reached between the responsible party and the Trustees to fund restoration. The quick settlement eliminated the need for more lengthy and costly injury determinations and focused attention on emergency restoration planning and implementation, and compensatory restoration.

The primary objective of the emergency restoration was to salvage and stabilize live coral fragments and minimize ongoing coral mortality. Without stabilization of the fractured coral pieces, coral tissue quickly abrades away in the high energy environment of Mona Island's fringing reef. The long-term goal of the restoration is to provide the best possible conditions for the coral to naturally re-establish its structural complexity to baseline conditions.

The coral stabilization consisted of immobilizing loose and broken branches of elkhorn coral to the reef buttress and to existent relic reef framework with stainless steel wire and stainless steel nails. Due to the density and hardness of the reef structure, the procedure involved drilling holes into the reef, driving nails into the holes and wiring the broken and/or loose corals to the hard substrate. Use of cement was first identified as the preferred stabilization methodology but rejected due to the strong underwater surge created by ocean swells. Plastic tie wraps were also used to secure smaller pieces of coral; however, the wave surge at the site loosened the tie wraps. As a result, corals that were secured with tie wraps were further stabilized with wire.

To track the success of the restoration and determine the need for mid-course corrections, monitoring stations were established. Monitoring was designed to measure mortality rate of transplants, survival rate on different substrate types used as transplant sites, success of different transplant sizes, coral re-attachment to the substrate and percent of remaining live tissue cover. Three monitoring attempts were thwarted by poor weather and only limited data was collected. A fourth monitoring effort was conducted in 1999 and data are currently being analyzed.

RESULTS

Within a 2.5 month period after the grounding, all restoration work was complete. At the conclusion of the restoration effort, 1,857 coral fragments had been stabilized over the 2.75 hectare area (Spadoni 1997). This total includes 653 small (25 cm - 50 cm), 869 medium (50 cm- 1.0 m), and 335 large (>1.0 m) fragments.

Assessment of stabilized fragment status in summer 1999 showed that over half of the fragments still contained live tissue (Table 1). An analysis of variance indicated that large fragments (>1m maximum length) had significantly more remaining live tissue than small fragments (25-50 cm) as shown in Figure 1. Additional observations showed both positive and negative outcomes. *A. palmata* was observed overgrowing the stainless wire with no adverse impacts. Other positive signs of success were active tissue growth, new proto-branches (suggesting net upward growth), and for some corals, active coral re-attachment to the substrate. Some wire failure was observed around the site and is the most significant threat of long term project failure. Analysis of wire collected from the site after two years in service indicates severe pitting that leads to accelerated corrosion and ultimately wire failure. The rate of wire failure is much faster than the coral's observed ability to re-attach to the substrate. Only 14% of corals examined during monitoring have reattached to the substrate and the bonds that have formed will not provide long-term stability for years to come. Because wire failure will outpace coral re-attachment, a mid-course correction is being considered over the entire site.

Table 1. Summary of mortality monitoring data fro August 1999 (Bruckner and Bruckner, unpubl.)

Total # Fragments Monitored	Living Fragments	Missing Fragments	Dead Fragments
705	405 (57%)	118 (16.7%)	182 (25.8%)

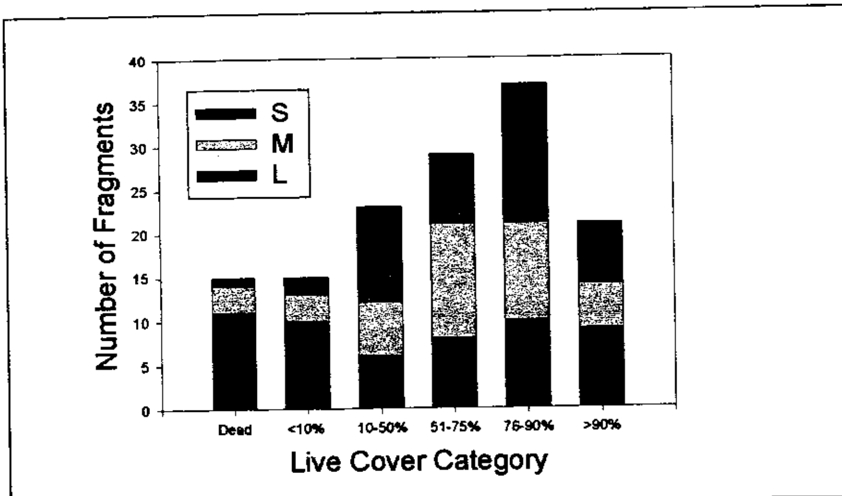

Figure 1. Percent live cover (tissue) vs size class. Bars represent large fragments (>1 m in length), medium fragments (>50 cm - 1 m), and small fragments (25 - 50 cm). Large fragments fared significantly better than small fragments with medium fragments doing intermediately well (1-way ANOVA; p = 0.026, n = 42-54

DISCUSSION

This emergency restoration action utilized a novel attachment technique to meet the requirements of a rigorous environment. Based on monitoring data, over half of the restored fragments persist and have live tissue almost two years after the incident. The site has also survived hurricane Georges, a class three storm. If no emergency restoration had been undertaken, it is likely that none of the fragments would have survived (Bruckner and Bruckner unpublished data). Wire failure did occur and further analysis of the wire issue has raised the possibility of a mid-course correction. Assessment has also indicated that large fragments are better candidates for restoration than small ones.

METHODS

Alafia River Acid Spill

On December 7, 1997, the wall of a phosphogypsum stack breached at the Mulberry Phosphates Inc. (MPI) phosphoric acid/fertilizer production facility in Mulberry, Polk County, Florida. Approximately 189 - 211 million liters (50 - 56 million gallons) of acidic process water flowed through the breach, overflowed return and collection systems and flowed into the Alafia River. Over the course of the next week to 10 days, the volume of released process water traversed approximately 58 km (36 miles) of the river to Tampa Bay. The process water contained about 1.5% phosphoric acid, a hazardous substance under CERCLA, and exhibited a pH of approximately two standard units.

One of the primary categories of natural resource injury was a significant fish kill in the Alafia River. Due to space limitations, injuries to other natural resources will not be presented here.

The fish kill injury determination consists of the sum of two components: the estimate of instantaneous mortality resulting from the spill (i.e., the direct kill) and the future somatic production or growth normally to be expected of the killed organisms over the remainder of their life span (i.e., lifetime production). That is, in addition to the direct mortality, if the spill had not occurred, the killed organisms would have continued to grow until they died naturally or to fishing. This lost future (somatic) production is estimated and added to the direct kill injury. The total is the total production lost, and is determined on a biomass basis (kg).

Preassessment data gathering focused on estimating the magnitude of the instantaneous fish kill (including blue crab and pink shrimp) which resulted from exposure to the acidic process water. Biologists representing both the Trustee agencies and MPI conducted sampling in the lower, tidally-influenced portion of the Alafia River. Due to the location of the dead fish at the time of response, all sampling efforts were conducted within the tidally-influenced portion of the river, from the mouth of the river to river km ~16. Three types of data were collected:

i) smaller animal seine and trawl data,
ii) larger animal visual survey data, and
iii) larger animal "clean-up" data, and are described below.

For the seine and trawl and larger animal visual survey data collections, basic area sampling principles were applied. Dead fish observed in randomly selected areas are counted and measured; these counts are then expanded over the entire affected area to provide an estimate of the total number of large dead fish present in the study area.

Seine and Trawl Sampling

Smaller animal data was collected by Florida DEP's Florida Marine Research Institute, Fisheries-Independent Monitoring Program (DEP/FIM) using methods consistent with an existing seine and trawl sampling program. Following DEP/FIM protocols, small-mesh seines and trawl data were used to assess juvenile populations of larger species and juvenile-to-adult populations of smaller species (< 8 cm total length).

A stratified random sampling design was used for sample site selection. The seine stratum included shoreline areas with water depths less than 1.8 m, assumed to be representative of the shoreline community. The trawl stratum included non-shoreline areas with water depths greater than 1.0 meter, assumed to be representative of the river channel community. All fish were identified to the lowest practical taxonomic level and counted, and representative length frequencies were recorded. A total of 14 seine and 5 trawl samples were collected during the sampling effort.

Visual Surveys

Data on larger animal (>8 cm total length) mortalities were collected by visual surveys. Floating and beached fish specimens in the tidally-influenced segments of the river were sampled following the American Fisheries Society (AFS) visual survey protocols (AFS 1992) for the estimation of fish kills. In this assessment, the lower Alafia was divided into six segments, and each segment was divided into countable units, or transects. A total of 40 transects were counted in the lower portion of the river. Expansion factors were derived from the area covered by the surveyors in a given river segment, relative to the total area in that segment.

Larger Animal Clean-up Data

Dead fish were removed from the river by fish clean-up contractors, and collected in roll-off boxes for disposal. Data from this larger animal clean-up effort was provided by Florida Game and Freshwater Fish Commission (FGFC) based on their examination of the dead fish removed from the river. Data on species composition, numbers, length frequencies and average weight was recorded by FGFC for subsamples of the dead fish, as well as the total weight of all dead fish removed from the river.

RESULTS

The data from these three preassessment activities were compiled and used by FMRI to estimate mortalities for both smaller and larger animals.

Smaller animal mortality, the estimate of smaller fish, blue crab and pink shrimp killed, was derived from consideration of the seine and trawl data using an "observed mortality method". This method estimates the population of dead animals in the lower portion of the river sampled, based on data gathered from seine and trawl data on December 12, and is calculated as the number of each species collected per area sampled (e.g., catch per unit effort reported as number/m^2). The mean population estimate for dead animals (following stratified random sampling) was then calculated following Snedecor and Cochran (1967). Lower and upper mortality estimates for the observed mortality method were calculated by either subtracting (for lower estimate) or adding (for upper estimate) the standard error to the mean dead-animal population estimates. Lower, mean and upper dead animal population estimates were multiplied by the total area of the segments used in the analysis to estimate the total number of small dead animals in the lower portion of the river. The data and the methods used by FMRI to calculate these estimates are presented in detail in the DEP/FMRI report dated December 10, 1998. Smaller fish and shellfish killed estimated by this method is 1,244,800 (mean).

The estimate of larger fish killed is the sum of two estimates:

i) the number of dead fish present in the surveyed portion of the river, as calculated using the visual survey data following AFS methods for estimating fish kills, and
ii) the number of additional dead fish removed from the river by clean-up contractors, as calculated using the larger fish clean-up data provided by FGFC.

These estimates were 57,900 and 15,000, respectively for a total of 72,900 large fish killed.

While the impact on each species was locally significant, loss of future production and recruitment associated with the estimates of the direct kill are unlikely to be large enough to significantly alter future populations in the river. The Trustee agencies believe that production from unaffected organisms and recruitment from unimpacted tributaries, upstream areas, and Tampa Bay will provide sufficient egg and young production to sustain populations of fish injured by the spill. Under these circumstances, further studies to assess an impairment of reproductive capacity are not required.

The loss of future productivity associated with the estimates of direct kill was calculated based on information contained in the biological database in the CERCLA type A model, Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME, Version 2.5), other information augmenting the database for species killed by this spill, and the population model component in the NRDAM/CME model to predict the duration of such losses.

Under this approach, based upon species composition, the direct kill is quantified by age class using standard population models. The net (somatic) growth normally to be expected of the killed organisms is computed and summed over the remainder of their life spans (i.e., lifetime production), and future interim losses are calculated in present day values using discounting at a 3% annual rate. The survival rates per year and length-weight by age relationships are used to construct a life table of numbers and kg for each annual age class. Lifetime production is estimated as the sum of the net somatic growth normally to be expected of the killed individual over the remainder of its life span. The age-class specific weight gain per year times the percent expected to be left alive by the end of that year is summed over all years to calculate total lifetime production. The total injuries by species for direct kill and production foregone is summarized in Table 2 .

DISCUSSION

This assessment approach facilitates restoration planning in that it allows the Trustees to select one or more restoration projects that will produce an equivalent biomass of fish lost, with scaling based on secondary productivity estimates (i.e. kg production/acre/year). In addition to determining the extent of injury, DEP/FIM's regular sampling of the estuarine portion of the river under its historic sampling program continues and is an ongoing source of information for use in monitoring the recovery of small species populations and juvenile populations of larger species post-spill.

The restoration goal for the all injury categories is to restore, replace or acquire natural resources or services like those injured as a result of the spill as a basis for compensating for the interim losses of natural resources and resource services which occurred. The restoration objective for fish injuries is to replace the biomass of fish, crabs and shrimp lost due to the spill through creation or enhancement of habitat(s) capable of generating an equivalent biomass over time. Restoration planning therefore, is several habitat types capable of providing the lost fishery biomass. Emergent marsh (*Spartina alterniflora*), oyster reefs and artificial reefs are among the habitats likely to play a part in the fish restoration.

Table 2. Summary of total injuries by species, number killed and estimates of direct biomass loss and production foregone. (French 1999)

Species	kill (#)	kill (kg)	Production Foregone (kg)	Total Injury (kg)
bay anchovy	1,107,745	1,329	160	1,489
gizzard shad	112	13	8	20
Menidia (silverside)	19,465	14	6	20
gulf killifish	3,013	3	1	5
rainwater killifish	4,954	5	2	7
sheepshead minnow	2,107	2	1	3
snook	2,389	2,055	2,892	4,947
spotted seatrout	602	56	8	64
sand seatrout	17,930	136	28	164
kingfish	956	83	13	96
ladyfish	1,925	321	490	810
red drum	628	226	1,639	1,865
hogchoker	48,292	72	6,785	6,857
grunt	19	2	1	3
mullet	1,219	188	76	264
sheepshead	10,253	1,743	3,956	5,699
mojarras	53,280	6,926	17,375	24,302
blue crab	6,828	816	135	951
pink shrimp	2,941	204	0	204
common carp	19	52	52	104
bullhead catfish	8,340	835	1,920	2,755
channel catfish	168	39	42	81
other catfish	4,516	1,032	1,117	2,150
gar	7,641	5,977	3,645	9,622
largemouth bass	709	220	82	302
sunfish	5,988	240	591	831
butterfly ray	19	76	0	76
gafftopsail catfish	37	50	0	50
Gobiosoma (goby)	4,113	21	0	21
spadefish	38	17	0	17
gulf toadfish	39	2	0	2
sailfin molly	1,170	12	0	12
tilapia	1,805	1,101	0	1,101
Total	1,319,260	23,868	41,024	64,892

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