CONDUCTING A NATURAL RESOURCE DAMAGE ASSESSMENT (NRDA) FOR SEA TURTLE INJURY RESULTING FROM AN OIL SPILL NEAR FORT LAUDERDALE, FL

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ABSTRACT

Following a mystery oil spill near Ft. Lauderdale, Florida in August 2000, natural resource trustee agencies (Trustees) conducted a natural resource damage assessment (NRDA) under the Oil Pollution Act of 1990 (OPA). During the NRDA, injury to several life stages of Loggerhead sea turtles (Caretta caretta) and Green sea turtles (Chelonia mydas) was quantified using a computer model, SIMAP (French-McCay, 2001), and the type and scale of restoration required was determined. Quantification of injury required Trustees to determine key model input parameters based on a variety of scientific data sources. The restoration scaling portion of this NRDA required Trustees to quantify the number of Loggerhead sea turtle hatchlings it would take to replace a post-pelagic juvenile (age 17 to 20 years) and an adult female (42 to 50 years old). To accomplish this, Trustees developed a simple model based on recent life stage and population dynamics assumptions for the south Florida Loggerhead sub-population. Details of the sea turtle NRDA method and rationale for determining the required model input parameters are discussed.

BACKGROUND

The Incident

An oil spill from an unidentified source affected the beaches and nearshore marine waters near Ft. Lauderdale (Broward Co.), Florida in August 2000. It was later estimated that more than 20,000 gallons of an intermediate fuel oil (IFO) had been discharged the night of August 8th, most likely by a north-bound ship within the Gulf Stream current offshore of the affected area. The oil slick affected coastal waters prior to stranding on the beaches. Approximately 15,000 gallons of weathered oil stranded on 20 miles of high use recreational sand beaches between North Miami Beach and Pompano Beach, Florida. The natural resource Trustees for this incident were the National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection (FL DEP), and they initiated a NRDA under OPA.

Summary of the NRDA Process under OPA

The goal of the NRDA process under OPA is to provide for restoration of those natural resources and their services that are lost as a result of an oil spill. It is similar to the NRDA process for chemical releases conducted under the Combined Environmental Response, Compensation, and Liability Act (CERCLA). NRDAs are conducted by designated Trustee agencies acting to restore and compensate the public for resource losses as a result of a pollution incident.. NRDAs under OPA or CERCLA do not allow for fines or penalties.

The NRDA process is conducted in steps or phases: Preassessment, Restoration Planning, and Restoration Implementation. Preassessment begins immediately upon the Trustees being notified of an incident. It includes collection of critical ephemeral dataand ends when the Restoration Planning phase begins (if there is to be a full NRDA). The Restoration Planning phase is broken into several parts: Injury Determination, Injury Quantification, Restoration Alternative Development, Restoration Alternative Scaling, and Restoration Alternative Selection. The public is involved in the decision process during restoration planning. Once restoration funds are recovered, the last NRDA phase, Restoration Implementation, can begin.

Details of the NRDA for the Ft. Lauderdale Mystery Spill of August 2000 are presented in the document "Final Damage Assessment and Restoration Plan / Environmental Assessment for the Fort Lauderdale Mystery Spill" (Trustees, 2002).

Paying for Restoration following a Mystery Spill

When the party responsible for spilling the oil cannot be identified, Trustees may submit a claim for Damages resulting from the spill to the National Pollution Funds Center (NPFC) to be paid from the Oil Spill Liability Trust Fund (OSLTF). The Damages claim includes the costs for implementing the required restoration and reimbursing the Trustees for the costs of conducting the NRDA.

For the Ft. Lauderdale Mystery Spill of August 2000, $2,213,207 was claimed and received from the NPFC, of which $1,580,911 will be used to fund the restoration projects.

Pre-Assessment and Restoration Planning

The Preassessment Phase involved the collection of the critical ephemeral data during the first few weeks following discovery of the stranded oil on the beaches. Once all the NRDA ephemeral data had been collected, Trustees determined that the best method to assess the injury was to apply a computer model. The SIMAP model is able to calculate injuries for a number of natural resource categories and was selected as the best choice for reasons discussed in detail in the DARP/EA (Trustees, 2002). . For this spill it calculated injury to sea birds, water column biota (fish and invertebrates), and sea turtles.

The remainder of this paper focuses on the injury to sea turtles.

Using SIMAP to Quantify Injury to Sea Turtles

Calculating the fate of the spilled oil

The first step of running SIMAP is to enter the volume and type of oil spilled so that the physical fate or "weathering" can be appropriately modeled. The volume of oil that stranded on the beaches was estimated based on shoreline surveys conducted by responders. Chemical analysis of the stranded oil determined the type and relative percentages of the toxic components (primarily polycyclic aromatic hydrocarbons, PAHs). To determine the likely type, volume, location, and timing of the original discharge, the physical fate portion of the SIMAP model was used "in reverse" using the wind and current data for August 7-8.

Once the physical fate and trajectory of the spill was calculated, the model then determined what biological resources were exposed and the exposure concentrations of the potentially toxic fractions of the oil. The model contains databases of biota (species and density) for each region and habitat by season, as well as data on the relative susceptibility of each group and life stage to the toxic fractions.

Specific data requirements to model sea turtle injury for this incident

The SIMAP biological database only contained estimates of the adult sea turtle population density in the exposed waters. However, the spill occurred during the peak of sea turtle nest hatching season. Trustees knew that many hatchlings and some post pelagic benthic feeding juveniles would have been exposed to the oil slick as it transited the area prior to stranding on the beaches. Therefore, Trustee technical representatives developed improved estimates of population density.

Calculating the density of hatchlings within the affected offshore waters

Hatchlings linger off their natal coastline for up to 60 days, so the trustees used the records of the number of nests that had hatched out in the prior 30 day period (the mid point) as an approximate average. Trustees also used standard assumptions for the number of eggs per nest, nest hatching rates, and survival rates to determine the number of hatchlings that had emerged and swam from the beaches in the affected area. Using these assumptions, it was estimated that 118,014 Loggerhead, 18,880 Green, and 156 Leatherback sea turtle hatchlings had left the beaches in the affected area. Due to the extreme rarity of Kemp's Ridley sea turtles, it was estimated that none were likely in the affected area.

To determine the density of hatchlings in the affected waters, Trustees then needed to estimate the aerial extent over which those hatchlings were distributed. Using the coastline as the western boundary, and N. Miami Beach and Pompano Beach as the southern and northern boundaries, respectively, Trustees only needed to determine the eastern boundary to complete the "box." Once hatchlings reach the Gulf Stream, they are rapidly transported out of the area into the open Atlantic to begin their pelagic life stage. Therefore, Trustees used the western edge (or "front") of the Gulf Stream as the eastern boundary. Trustees relied on an analysis by NOAA of the position of the Gulf Stream front as determined from satellite images to identify this boundary. This resulted in a box with an area of 532.5 km^2.

With the area of distribution calculated, it was determined that there were, on average, 221.62 Loggerhead hatchlings per km^2, 35.46 Green hatchlings per km^2, and 0.29 Leatherback hatchlings per km^2 in the area affected by the spill.

Density of post pelagic juvenile sea turtles in the affected area

Following their pelagic stage, some juvenile sea turtles return to feed in shallow benthic habitats off the coast affected by the spill. The density of this life stage was estimated based on records from the sea turtle stranding network. Using carapace size records for standings, the proportion of juveniles to adults (which was in the model) was used to calculate the number of post pelagic juvenile Loggerhead and Green sea turtles in the affected area. Juvenile Leatherbacks were not represented in the stranding records and so could not be estimated.

Exposure to oil and resulting mortality rate for hatchlings in the path of the oil

Trustees had to determine the likelihood of exposure to the floating oil slick and also the likely mortality rate if exposed for each life stage of the sea turtles. Mortality of sea turtles is estimated based on the exposure rate to an oil slick of 1mm or greater.

Adults spend only about 1% of their time at the surface. If exposed to the oil slick, Trustees determined that they are moderately susceptible to injury. Trustee technical representatives estimated that 1% of the adult sea turtles within the path of the oil were killed. Post pelagic sea turtles were treated like adults in this regard.

Hatchlings spend about 99% of their time at the surfaceand were considered at very high risk of mortality if exposed to thick oil. This is due to smothering caused by the thick oil plugging of their very small nares. Therefore, Trustees estimated that 50% of the hatchlings in the path of the oil slick were killed.

Results of the SIMAP sea turtle injury calculations

Using the input parameters provided by the Trustees, the SIMAP model calculated that 7800 hatchlings (in the relative species proportions present), 0.5 post-pelagic juveniles, and 0.12 adult sea turtles were killed by the oil slick.

Developing and Selecting Restoration Alternatives

Selecting a restoration alternative for the hatchling injury

Trustees identified a number of potential hatchling restoration alternatives. These included increasing nest protection and/or relocation, installing alternative "turtle friendly" lighting near nesting beaches, nesting beach land purchase and preservation, and increased enforcement of existing beach lighting ordinances. Using a process that adhered to OPA regulations and included a public comment period, Trustees selected the latter alternative. Trustees used records of labor time and pay rates for the previous years to estimate costs for additional patroling of beach lighting.

Selecting a restoration alternative for the juvenile and adult sea turtle injury

The injury of a fraction of a sea turtle may seem insignificant. However, the listing of all sea turtles on the Endangered Species List, and the especially tenuous and uncertain nature of their breeding success, led Trustees to determine that the calculated injury to these life stages was in need of restoration.

After considering available alternatives to directly restore these older life stages, none of them met all the requirements outlined in the OPA regulations. Therefore, Trustees selected the alternative of restoring the later life stages through additional restoration of hatchlings.

Scaling the Preferred Restoration Alternatives

For the hatchling injury, Trustees determined how many hatchlings where expected to be saved by increasing the enforcement of beach lighting ordinances on the stretches of beach that needed increased compliance. Beaches within Palm Beach and Broward Counties were determined to be most in need of additional ordinance enforcement. Calculations indicated that it would take about three nesting seasons worth of additional enforcement to produce the required extra 7800 hatchlings.

For the older life stages, Trustees needed to first determine how many hatchlings it takes to produce the 0.5 post pelagic juvenile and the 0.12 adult. For this effort, Loggerheads were used to scale all the species injured since the oil spill mostly affected them, and the most reliable population dynamics data is for Loggerheads. However, doing so was not really an issue since the restoration alternative selected was expected to restore sea turtle species in roughly the same proportion as had been injured.

Determining the survival rate of hatchlings to older life stages

Accurately determining the long-term survival rate of sea turtles from hatchling to adult is difficult since they are so long lived and they frequent remote ocean areas and undertake long migrations. Additionally, their age in the wild is not easily determined using methods such as skeletochronology and tag-release studies (TEWG, 2000).

Epperly, *et al* (2001) presented several models to predict the population trends for western north Atlantic-nesting subpopulations of Loggerhead sea turtles. These predictive models were created to assist federal and state agencies in making management decisions to protect Loggerhead populations that are listed as threatened under the Endangered Species Act (Epperly, *et al* 2001; TEWG, 2000). To create and evaluate these models a number of assumptions were made using historical and more recent data.

The assumptions used for the Epperly models related to likely growth rates, duration and initial age of the various Loggerhead life stages, and the annual survival rates during each life stage. Of Epperly's four models, models 3 and 4 were determined to be the most likely to represent the population dynamics for the southeast Florida population.

The output from these models was not in a form that would provide the necessary values for determining the number of additional Loggerhead hatchlings needed to produce an average age benthic juvenile or adult. The assumed survival rates for the pelagic stage turtles vary for each sub-population within each of the Epperly models, so the best-fit assumptions specific to the south Florida subpopulation of Loggerheads is used for this life stage.

Using similar assumptions as Epperly, *et al*, and some additional ones as discussed below, Trustees determined an overall survival rate for hatchlings emerging from nests through to the later life stages. The predicted survival rates over time are shown graphically as "decay curves" when plotted by the models. The number of hatchlings required to produce one turtle of an older age is obtained as the reciprocal value of the probability of survival. Examples of these curves are shown in Figure 1a and 1b for model 3.

Assumptions and values used for the conversion ratio

Tables 1a and 1b show the output values for the two models selected to calculate the expected probabilities of survival versus time used for a newly emerged Loggerhead hatchling. They are based on values from Tables 12 & 13 in Epperly *et al* and discussions with sea turtle experts[1] assisting the Trustees.

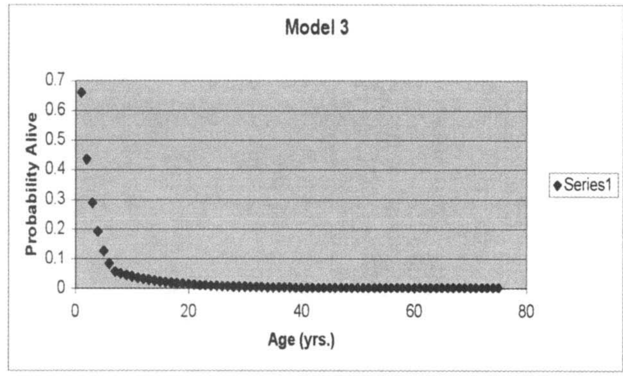
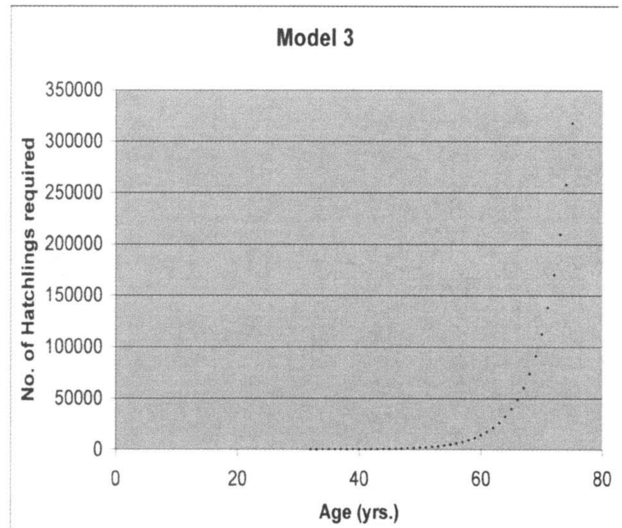


FIGURE 1A. CURVE OF PROBABILITY OF



LOGGERHEAD TURTLE SURVIVAL WITH TIME USING MODEL 3 ASSUMPTIONS. FIGURE 1B. NUMBER OF HATCHLINGS REQUIRED TO PRODUCE A LOGGERHEAD OF THE SPECIFIED AGE.

Mean ages for the benthic juvenile and adult stages were calculated as the ages that corresponded to the sum of the probabilities of survival for each year within that life stage divided by the number of years in the stage. This adjusts for the age distribution proportions expected—that young turtles are more common than old ones within each life stage. This age distribution should be similar to those turtles exposed and injured by this incident. Pelagic juveniles were not likely to have been significantly exposed to this oil spill.

The age of the injured juvenile and adult are assumed to be of the mean age for each life stage as defined in the respective models, and assuming the maximum age of Loggerheads to be 75 years. The maximum age for sea turtles is strongly debated among sea turtle experts and there is currently no consensus on how to accurately determine this. Skeletochronology (using growth rings or other markers in the animal skeleton to determine age) is difficult to use with sea turtles, due to the resorption of the inner layers of bone after several years.

Other maximum aging methods have also been unsuccessful to date, at least partly due to the likely extreme longevity of sea turtles and the inaccessibility of their pelagic habitat. The use of 75 years is a reasonably protective assumption. In any case, the number of individual turtles surviving beyond 75 years would be very small (using the survival rates in these models), so their contribution to the population numbers would be small.

Table 1a. Model 3 Assumptions and Calculation Parameters

LIFE STAGE	DURATION (YR)	TOTAL AGE (YR)	MEAN AGE (YR) (For Juvenile/Adult To Hatchling Calc.)	SURVIVAL RATE
PELAGIC JUVENILE	7	0 TO 7	N/A	0.660
BENTHIC JUVENILE	24	8 TO 31	17	0.893
ADULT	44	32 TO 75	42	0.812

Table 1b. Model 4 Assumptions and Calculation Parameters

LIFE STAGE	DURATION (YR)	TOTAL AGE (YR)	MEAN AGE (YR) (For Juvenile/Adult To Hatchling Calc.)	SURVIVAL RATE
PELAGIC JUVENILE	8	0 TO 8	N/A	0.660
BENTHIC JUVENILE	32	9 TO 40	20	0.893
ADULT	35	41 TO 75	50	0.812

Results of the conversion ratio calculations

Table 2 shows the resulting number of hatchlings needed to replace the 0.5 juvenile and 0.12 adult sea turtle calculated killed for Epperly's model 3 and 4. Figure 1a represents the cumulative declining probability of survival with time (decay curve) for a sea turtle hatchling using the assumptions in Table 1a. Figure 1b shows the number of hatchlings required to produce 1 individual of an older age (the reciprocal function of Figure 1a). Assumptions for model 4 from Table 1b give similarly shaped curves.

Epperly's model 3 and 4 indicate that 357 and 277 hatchlings, respectively, are required. Trustees determined that using the more protective results of model 3 were appropriate given the ESA listed status of sea turtles. The only differences between models 3 and 4 are the estimated ages at first recruitment into the benthic juvenile and adult life stages—model 3 assumes younger recruitment ages for both stages. Annual survival rates for each life stage are the same for both models.

Therefore, 357 hatchlings were added to the 7800 hatchlings that needed to be restored, for a total of 8157 hatchlings to be restored.

CONCLUSIONS

Using a step-by-step approach during the NRDA, and relying on available data and scientifically based assumptions, Trustees were able to quantify injury for endangered sea turtles and determine the appropriate type and amount of restoration for that injury, for a significantly large mystery spill in Florida.

BIOGRAPHY

James H. (Jim) Jeansonne is a biological oceanographer and member of the NOAA Damage Assessment and Restoration Program since 1991. His primary role with NOAA has been as a regional injury assessment coordinator for NRDA's conducted in the southeast U.S. and U.S. Caribbean islands.

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Table 2. Number of new hatchlings required to replace the lost juvenile and adult Loggerhead sea turtles as a result of the August 2000 Ft. Lauderdale oil spill.

Model 3 Hatchlings needed		Model 4 Hatchlings needed	
0.5 Juv Equiv. =	28	0.5 Juv Equiv. =	14
0.12 Adult Equiv. =	329	0.12 Adult Equiv. =	263
Total Needed =	357	Total Needed =	277

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1 Sea Turtle experts consulted for this analysis include Sheryan Epperly – NOAA/NMFS Southeast Fishery Science Center, Miami, Melissa Snover – then a PhD Candidate at Duke Univ., Dr. Blair Witherington – FWC-Florida Marine Research Institute, Sea Turtle Research Station, Melbourne, FL, and David Bernhart – NOAA/NMFS Southeast Region Office of Protected Resources, St. Petersburg, FL.