FINAL

M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Restoration Scaling for Bird Injuries

by

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Prepared for:

Industrial Economics, Incorporated
2067 Massachusetts Avenue
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for Submission to:

NOAA Damage Assessment Center
Silver Spring, MD
Frank Csulak, Task Order Manager

NOAA Contract: 50-DSNC-7-90032

ASA 03-084

November 13, 2006

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SUMMARY

The injury to birds caused by the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach* was estimated as 175 birds, including 89 seabirds (including 75 pelicans), 69 shorebirds, 16 wading birds, and less than the equivalent of one bird (as a probability) of others. Table 1-1 lists the injuries, as numbers killed, bird-years lost, and number of fledgling equivalents.

Estimates of the scale of restoration required to compensate for the injuries (with the project initialed in 2007) were made as summarized in Table S-1.

Table S-1. Summary of estimated scale of compensatory restoration required for injuries to birds.

Basis of Restoration Scaling	Injury Units	Injury Amount	Compensation
Food requirements to produce fledglings and trophic transfer modeling to the bird prey trophic level	# fledgling equivalents (in 2007)	789 fledglings	2.28 ha (5.64 acres) of saltmarsh

Trophic transfer modeling to the birds' trophic level could underestimate the saltmarsh area that would be compensatory if there are more trophic levels between the benthic invertebrate level and the birds injured than that assumed in modeling, and that some of the prey production is not consumed by the target (injured) species of birds. Thus, the method used was to estimate food requirements to produce fledglings and use trophic transfer modeling to the bird prey trophic level. An assumed rate of trophic transfer from prey to bird is not needed, and instead food requirements and fledgling production were modeled in detail. This method does assume the saltmarsh provides food that would be consumed by the target species of birds or their prey, a reasonable assumption for the present case.

1. INTRODUCTION

Oil spill fates and biological effects modeling was performed for the 30 September 2002 spill into Charleston Harbor, SC, from the container ship *M/V Ever Reach*. The injury caused by the spill was evaluated for birds, marine mammals, sea turtles, and subtidal fish and invertebrates. The report "M/V Ever Reach Spill of 30 September 2002 in Charleston Harbor, SC: Modeling of Physical Fates and Biological Injuries" contains the description of the modeling and injury quantification (French McCay et al., 2005). Table 1-1 contains the injury estimates for the birds. Injuries to marine mammals, sea turtles, and subtidal fish and invertebrates were estimated as negligible.

Table 1-1. Summary of estimated injuries to birds. The model estimate is a probability, and thus may be a fraction of an animal.

Group Totals	Birds Killed (#)	Dominant Species	Interim Loss (#-years)	# Fledgling Equivalents (in 2002)	# Fledgling Equivalents (in 2007)
Waterfowl	0.06	Canada goose	0.1	0.1	0.1
Seabirds	89.2	Brown pelican	556	384	446
Wading birds	16.4	Egrets, herons	31	36	41
Shorebirds	68.8	Ruddy turnstone	531	260	301
Raptors	0.14	Osprey	1.0	0.5	0.6
Total birds	**174.6**	**-**	**1120**	**681**	**789**

2. SCALE OF COMPENSATORY HABITAT RESTORATION

Food web modeling and Habitat Equivalency Analysis (HEA) calculations were performed to estimate the amount of saltmarsh that would be compensatory to the bird injury, following the methods in French McCay and Rowe (2003) and with some additional methods to be described below. This was a two step process:

1. Use trophic transfer modeling to estimate compensatory bird food production rate per unit of salt marsh created.
2. Determine the food required to produce additional fledglings and then use the compensatory (bird) food production rate per unit of salt marsh created to calculate the area of marsh required.

The scaling of the compensatory restoration uses methods currently in practice by NOAA and state trustees, i.e., Habitat Equivalency Analysis (HEA). Scaling methods used here were initially developed for use in the *North Cape* case, as described in French McCay and Rowe (2003). These methods have also been used in several other cases, as well as in successful claims for 23 cases submitted by the Florida Department of Environmental Protection to the US Coast Guard, National Pollution Fund Center (French McCay et al., 2003a).

Restoration should provide equivalent quality biota to compensate for the losses. Equivalent quality implies same or similar species with equivalent ecological role and value for human uses. The equivalent production or replacement should be discounted to present-day values to account for the interim loss between the time of the injury and the time restoration provides equivalent ecological and human services.

Habitat creation or preservation projects have been used to compensate for injuries of wildlife, fish and invertebrates. The concept is that the restored habitat leads to a net gain in wildlife, fish and invertebrate production over and above that produced by the location before the restoration. The size of the habitat (acreage) is scaled to just compensate for the injury (interim loss).

In the model used here, the habitat may be seagrass bed, saltmarsh, oyster reef or other structural habitats that provide such ecological services as food, shelter, and nursery habitat and are more productive than open bottom habitats. The injuries are scaled to the new primary (plant) or secondary (e.g., benthic) production produced by the created habitat, as the entire food web benefits from this production. A preservation project that would avoid the loss of habitat could also be scaled to the production preserved. The latter method would only be of net gain if the habitat is otherwise destined to be destroyed.

One approach is to use primary production to measure the benefits of the restoration project. The total injuries in kg are translated into equivalent plant (angiosperm) production as follows. Plant biomass passes primarily through the detrital food web via detritivores consuming the plant material and attached microbial communities. When macrophytes are consumed by detritivores, the ecological efficiency is low because of the high percentage of structural material produced by the plant, which must be broken down by microorganisms before it can be used by the detritivore. Each species group is assigned a trophic level relative to that of the detritivores. If the species group is at the same trophic level, it is assumed 100% equivalent, as the resource injured would presumably have the same ecological value in the food web as the detritivores. If the injured resource preys on detritivores or that trophic level occupied by the detritivores, the ecological efficiency is that for trophic transfer from the prey to the predator. Values for production of predator per unit production of prey (i.e., ecological efficiency) are taken from the ecological literature, as reviewed by French McCay and Rowe (2003).

Alternatively, the habitat requirements may be scaled using secondary (e.g., benthic invertebrate) production instead of primary production. Scaling to primary production assumes that all the benefits to animals are generated by the additional plant production as food. However, the habitat provides other ecological services to animals, such as supplying shelter, nursery areas, refuge from predators, etc. Benthic invertebrate production gains are calculated as the difference between production in shallow unvegetated habitats and in vegetated or otherwise structured habitat. Similarly, scaling could be based on differences in nekton production (before and after restoration). The animal production in the habitat is typically larger than that which can be accounted for by additional primary (plant) production. Using benthic (or other animal) production for scaling implicitly includes these habitat services gained.

Equivalent compensatory angiosperm (plant) or secondary (benthic) production of the restored resource is calculated as kg of injury divided by ecological efficiency. For primary production, the ecological efficiency is the product of the efficiency of transfer from angiosperm to invertebrate detritivore and efficiency from detritivore to the injured resource. For secondary production, the ecological efficiency is the product of the efficiency of transfer for each step up the food chain from the secondary level to the trophic level of concern. Discounting at 3% per year is included for delays in production because of development of the habitat, and delays between the time of the injury and when the production is realized in the restored habitat. The equations and assumptions may be found in French McCay and Rowe (2003).

The needed data for the scaling calculations are:

- number of years for development of full function;
- annual primary or secondary production rate per unit area (P) of restored habitat at full function;
- delay before restoration project begins; and
- project lifetime (years).

In South Carolina, it is most likely that saltmarsh restoration would be undertaken as restoration for bird injuries. Oyster reef restoration is also an option. However, this requires good water quality and appropriate environmental conditions to be successful.

HEA calculations for saltmarsh are performed here, following the methods in French McCay and Rowe (2003). It is assumed that the saltmarsh requires 15 years to recover (based on French et al., 1996a) ultimately reaching 80% of full function, the restoration begins 5 years after the spill, and the project lifetime is 50 years. Above-ground primary production rates of saltmarsh cord grasses in the southeast US (Georgia marshes) have been estimated as 1290 g dry weight m^{-2} yr^{-1} (Teal, 1962) and 2,555-4,526 g dry weight m^{-2} yr^{-1} (Dai and Wiegert, 1996). The annual primary production rate used in these analyses is the mean for the two studies, 2,415 g dry weight m^{-2}. In addition, saltmarsh benthic microalgal production provides another 40% (966 g dry weight m^{-2}; Currin et al., 1995). Thus, estimated primary production rates in southeast US (Georgia) saltmarshes total 3381 g dry weight m^{-2} yr^{-1}. Rates of secondary production are not available.

2.1 Trophic Transfer Modeling

It is assumed that creation of saltmarsh that increases invertebrate and fish production will be of direct benefit to the bird species where restoration is required, i.e., the additional production will be appropriate bird food (i.e., additional prey biomass). The amount of saltmarsh required in compensation for the quantified bird injuries was estimated using trophic transfer efficiencies for each step in the food web from benthic invertebrates to the prey of each of the bird categories. No correction is made for the possibility that the target species of birds will not obtain that food. If correction for availability were made, the scale of the project would increase proportionately.

Pelicans feed primarily on young menhaden, which consume primarily pelagic and benthic invertebrates. Thus, the pelican's prey is at the trophic level of small fish feeding on plankton and benthic invertebrates. The ecological efficiency of small fish preying on benthic invertebrate detritivores is 20% (French McCay and Rowe, 2003). Similar assumptions are made for the other groups based on their trophic level (Table 2-1). These efficiencies are used to translate the compensatory bird prey production requirements to saltmarsh area (as described above). Calculations were made per 1000 kg of bird food required, as shown in Table 2-1. To the extent that there are more trophic levels between the benthic invertebrate level and the prey of the birds injured, and/or some of the prey production is not consumed by those species of birds, this compensatory scale is a low estimate.

Table 2-1. Scaling of compensatory restoration (if project begun in 2007) per unit of required bird food (of 1000 kg) for saltmarsh based on primary production as the measurement of net gain.

Species Category	Unit Requirement (kg)	Trophic Level	Production Yield Relative to Benthic Detritivores (%)	Compen-satory Produc-tion (kg wet wt) per Unit Require-ment	Habitat Area (m^2) per Unit Require-ment	Habitat Area (acres) per Unit Require-ment
Benthic invertebrates	1000	detritivores	100	5,083	111	0.027
Small fish and decapods	1000	bottom feeders	20	25,416	556	0.137
Large fish	1000	piscivores	4	127,079	2781	0.687

2.2 Food Requirements to Produce Fledglings

The scaling was performed using the food web model and trophic efficiencies described in French McCay and Rowe (2003) and described above, up to the step of the prey of the bird species groups involved. The amount of saltmarsh required in compensation was then estimated by developing an estimate of food requirements to rear an additional fledgling, multiplied by the number of fledgling equivalents to the interim loss (from Table 1-1). Thus, this method evaluates in more detail the benefits of food production to the bird species injured than a full trophic transfer model. The assumption is that food is limiting to bird production.

The majority and most significant injuries were to pelicans. Hingtgen et al. (1985) reviewed the life history of eastern brown pelicans, stating that the major limitation to fledgling production was the ability of the adults to obtain sufficient food for rearing. Thus, provision of additional food (fish) should increase fledgling production of the remaining pelican population in the area of the spill.

Hingtgen et al. (1985) state that pelican chicks require 57 kg of fish between hatching and fledging. Breeding adult pelicans require 90 kg of fish for themselves during this period. However, if the adult were not breeding, it would require some lesser amount of fish over that period than the 90 kg. Thus, the net amount of fish to rear a chick to fledging is 57 + 90 kg, minus the amount required for non-breeding adult birds in the same time period.

Furness and Cooper (1982) describe a bioenergetics model for seabirds (and other aquatic birds) where food requirements can be estimated from body weight (W). The calculation begins with an estimate of basal metabolic needs (EE, kJ/g/day), a function of temperature. These equations were used, assuming a summer-time temperature of 30^{o}C:

$$\text{At } 30^{o}\text{C: } EE = 4.472 * W^{0.6637}$$

To account for normal daily activities, total daily energy needs are 2.444 times the basal rate (Furness and Cooper, 1982). Assuming a digestive efficiency of 80% (Furness, 1978), the daily ration required is 2.444*EE/0.8. Conversion from kJ to g wet weight was made assuming 5.33 kJ/g (Gremillet et al., 2003). The daily ration was converted to the mass of food required by non-breeders over the time from hatching to fledging (using the data in the injury quantification report, French McCay et al., 2004, Tables 3-8 to 3-12).

For pelicans, the breeding-period ration for a non-breeder was subtracted from the total of 57 + 90 kg required by a breeding bird to rear a chick to estimate the amount of fish required to rear an additional chick. Similar data of food needs to rear chicks of the other species were not available. Thus, the ratio of food need for rearing a pelican chick divided by the ration for a non-breeding pelican was used to estimate the food needs to rear extra chicks of the other species. The results of the calculations of food requirements are in Table 2-2.

Using the trophic transfer model, it is assumed that creation of saltmarsh that increases invertebrate and fish production will be of direct benefit to the bird species where restoration is required. No correction is made for the possibility that breeding birds will not obtain that food. If correction for availability were made, the scale of the project would increase proportionately. Thus, food requirements to rear a fledgling are used to scale the saltmarsh area.

Pelicans feed primarily on young menhaden, which consume primarily pelagic and benthic invertebrates. Thus, the pelican's prey is at the trophic level of small fish feeding on plankton and benthic invertebrates. The ecological efficiency relative to benthic invertebrate detritivores is that for the prey, 20%. Similar assumptions are made for the other groups based on their trophic level (Table 2-2). This efficiency is used to translate the compensatory food requirements to saltmarsh area (as described above).

Table 2-2. Estimated food needs for metabolism and rearing chicks and compensatory wetland areas (if project begins in 2007).

	Waterfowl	Seabirds	Wading Birds	Shorebirds	Raptors
Body weight (g)	5000	3500	1300	30	1900
Daily ration of a non-breeder (g/day)	730.7	576.7	298.9	24.5	384.5
Ration of a non-breeder during rearing period (kg)	43.9	44.4	17.9	0.73	23.1
Ration for rearing an additional fledgling (kg)	101.3	102.6	41.4	1.7	53.3
Total food required to compensate for injuries (kg wet weight)	13	39,439	1,482	442	29
Production yield of prey relative to benthic detritivores (%)	100	20	20	100	20
Saltmarsh area required (m^2)	1	21,936	825	49	16
Saltmarsh area required (acres)	0.0003	5.42	0.204	0.012	0.004

The results of the calculations of food requirements and the scale of compensatory restoration (assuming saltmarsh creation begins in 2007) are in Table 2-2. The total area required is 2.28 ha (5.64 acres). To the extent that there are more trophic levels between the benthic invertebrate level and prey the injured birds would consume, and that some of the prey production is not consumed by those species of birds, this compensatory area is a low estimate.

The inferred small fish production via trophic transfer from primary production using this trophic transfer model is 3.2 g dry weight/m^2/yr. Small fish production in Delaware marshes has been estimated as about 10 g dry weight/m^2/yr (Kneib, 2000). If the higher small fish production rate were used, the required acreage would be about 1/3 that in Table 2.2. However, given that all the small fish production would not be consumed by pelicans and other injured bird species, the estimates based on the 3.2 g dry weight/m^2/yr are reasonable.

The suggestion was made that acreage requirements might be based on feeding the restored fledglings for their entire lifespan. However, the scaling calculations were made translating the older bird injuries to units of equivalent fledglings lost. Thus, replacement of the required number of fledglings would compensate for the injury. This does implicitly assume that once the fledglings are produced they will survive at the same rates as the injured birds before the spill. While there is evidence that the production of new birds (i.e., fledglings) is food-limited, mortality of older birds is from a mix of causes and not specifically starvation. Thus, the assumption that post-fledgling survival will be similar to that for the same species before the spill without providing additional food resources is a reasonable approximation.

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