# FINAL REPORT

# BIRD AND WILDLIFE INJURY ASSESSMENT

# *M/T ATHOS I* OIL SPILL, DELAWARE RIVER SYSTEM

Prepared by:

Bird and Wildlife Technical Working Group

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# PREFACE

This report was prepared by the Bird and Wildlife Technical Working Group for the *M/T Athos I* oil spill in consultation with Responsible Party representatives. Membership included the following agencies and individuals:

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# EXECUTIVE SUMMARY

On 26 November 2004, the *M/T Athos I* struck several submerged objects while preparing to dock at the CITGO refinery in Paulsboro, NJ, resulting in the release of an estimated 265,000 gallons of Bachaquero Venezuelan crude oil into the Delaware River. Wildlife rescue efforts were initiated within 24 hours, with search teams patrolling oiled shorelines and coordinating observations of dead and oiled wildlife with response/clean up crews. By May 2005, 206 birds were collected dead, died at the rehabilitation center, or were not returned to the wild and 337 birds were rehabilitated and released alive. Five mammals and four reptiles were also found dead.

To estimate the extent and degree of oiling of non-recovered wildlife, Trustee and Responsible Party (RP) representatives conducted ground surveys between 30 November 2004 and 21 January 2005. All birds for which the degree of oiling could be determined, as well as visible, unoiled birds in open water, adjacent wetlands, spoil banks, and adjacent upland habitats were recorded as observations. Nearly 157,500 bird observations were recorded during the ground surveys, with about 16,500 (10 percent) having some degree of oiling. About 72 percent of all oiled birds observed had trace or light oiling; 19 percent of oiled birds were moderately oiled; and nine percent of oiled birds were heavily oiled. Geese, dabbling ducks, and gulls made up nearly 98 percent of oiled birds observed, and 96 percent of all birds observed.

Eleven aerial surveys were conducted between 28 November 2004 and 21 December 2004 to assess the species composition and abundance of birds in the spill area. Birds were identified to the lowest taxonomic level possible (typically species). The spill occurred during late autumn, which is a very dynamic period of bird migration in the Mid-Atlantic Region. Birds were immigrating, emigrating, and/or remaining to winter in the impact area. While this turnover of individuals is difficult to quantify precisely, more birds were present in the area later in December as it became colder.

Data from ground and aerial surveys were used in a risk-based assessment to determine the full extent of bird and wildlife losses resulting from the *M/T Athos I* incident. In general, the total number of non-recovered birds present in the area was estimated from detectability-adjusted aerial survey data for each of nine guilds or species in three time periods. The number of birds in different oiling categories for each of these same guilds and time periods was estimated from ground survey data. This oiling information, with mortality rates derived from the literature and expert opinion, was then used to estimate the number of non-recovered birds that were oiled and died in the field, or that survived with potentially sublethal impacts. These estimates, combined with data on recovered birds from the wildlife rescue effort, were used to determine the total number of birds impacted.

Indirect injury in terms of production foregone due to the loss of future generations was included in the estimation of total injury. For the three guilds with the largest injury, lost production models were developed based on the characteristics of a representative species. These three guilds - dabbling ducks, swans/geese, and gulls - represented 94 percent of the direct mortality. The indirect injury was composed of two parts: (1) the discounted loss of production from dead individuals, projected 7 or 9 years from the time of the spill based on one-third of life expectancy, and (2) the discounted loss of production due to individuals that were oiled and survived, but failed to breed in the subsequent spring, calculated for one additional generation. Demographic and reproductive statistics for model species from each guild were used to estimate this loss with simple age-structured population models. Lost production in the remaining guilds was calculated based on the model for the most appropriate representative species.

Table ES-1 summarizes total estimated injury to birds, in individuals, from the spill by species guild. Direct injuries totaled 3,308 adult birds, the majority (75 percent) of which were gulls and geese. Additional estimated lost production from mortality and reproductive failure was 8,561 fledged young.

The Trustees also considered potential injuries to other wildlife. Separate assessments of potential injuries to muskrats, otters, and bald eagles concluded that there was no recorded mortality and little or no overall impacts. In addition, the Trustees concluded that there was not sufficient evidence of potential injuries to any other non-fish vertebrate wildlife species in the Delaware River spill area.

**TABLE ES-1.** Total (direct and indirect) estimated bird injury from the *M/T Athos I* oil spill by guild.

| **Guild** | **Direct Injury (Adults)** | **Discounted Indirect Injury (Fledged Young)** | | **TOTAL (Adults and Fledged Young)** |
|---|---|---|---|---|
| | **Died** | **Lost Prod. (Mortality)** | **Lost Prod. (Repr. Failure)** | |
| Dabbling ducks | 605 | 1,187 | 577 | 2,369 |
| Diving ducks | 82 | 163 | 24 | 269 |
| Diving birds | 64 | 92 | 2 | 158 |
| Gulls | 1,072 | 1,543 | 331 | 2,946 |
| Shorebirds | 55 | 79 | 0 | 134 |
| Wading birds | 10 | 14 | 3 | 27 |
| Swans/geese | 1,416 | 3,369 | 1,171 | 5,956 |
| Kingfishers | 4 | 6 | 0 | 10 |
| **Total** | **3,308** | **6,453** | **2,108** | **11,869** |

# BIRDS AND WILDLIFE INJURY ASSESSMENT
# *M/T ATHOS I* SPILL, DELAWARE RIVER SYSTEM

## 1.0 INTRODUCTION

At 9:30 PM on 26 November 2004, the *M/T Athos I* struck submerged objects while preparing to dock at the CITGO refinery in Paulsboro, NJ, puncturing the No. 7 center cargo and the No. 7 port ballast tanks. The vessel was carrying approximately 13 million gallons of Bachaquero Venezuelan crude oil, a heavy crude oil that is heated during transport. The U.S. Coast Guard determined that about 265,000 gallons were released into the Delaware River. Figure 1 shows the location of the spill within the Delaware River System.

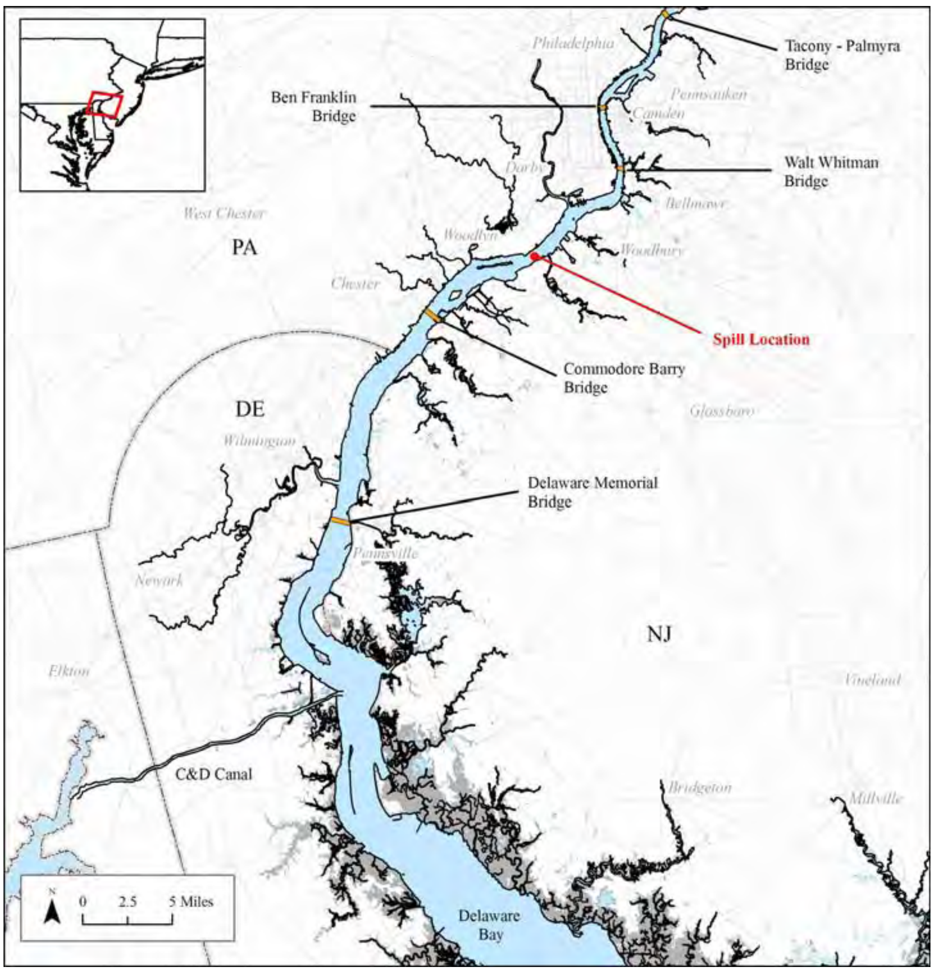



**FIGURE 1.** Map of the location of the *M/T Athos* oil spill and areas discussed in this report within the Delaware River system.

Initially, the spill formed thick slicks and moved upriver with the flood tide. A southeast wind moved oil to the Pennsylvania side of the river. With the second flood tide, the oil was transported as far north as the Tacony-Palmyra Bridge. Several days later a storm developed and strong, generally westerly winds transported oil to the New Jersey side. After the storm, the oil weathered and formed tarballs that persisted for several months. Eventually, the oil spread in the Delaware River from just above the Tacoma-Palmyra Bridge to the entrance of Delaware Bay, affecting resources in Pennsylvania, New Jersey, and Delaware.

This report provides an assessment of the injuries to birds and wildlife resulting from the spill. It was prepared by the natural resource Trustees, as part of a natural resource damage assessment being conducted pursuant to the Oil Pollution Act of 1990. The Trustees include: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA); U.S. Department of the Interior, U.S. Fish and Wildlife Service (USFWS); Pennsylvania Department of Conservation and Natural Resources (PaDCNR), Pennsylvania Department of Environmental Protection (PaDEP), Pennsylvania Game Commission (PaGC) and Pennsylvania Fish and Boat Commission (PaFBC); New Jersey Department of Environmental Protection (NJDEP); and Delaware Department of Natural Resources and Environmental Control (DNREC). Representatives from these agencies have formed a Bird and Wildlife Technical Working Group (TWG) to assess the injuries to birds and wildlife resulting from the spill. Research Planning, Inc. (RPI) was contracted to advise the Trustees; Polaris Applied Sciences, Inc. was contracted to represent the Responsible Party.

## 2.0 RESPONSE ACTIVITIES

Following the spill, State and Federal response officials and representatives of the shipping company initiated response and clean up activities. Two of the response activities that were subsequently used as part of the bird and wildlife injury assessment included:

1) Wildlife rescue efforts that provided an initial assessment of the types of wildlife impacts that occurred; and
2) Oil distribution mapping and trajectory prediction that was used to guide subsequent fieldwork.

### 2.1 Wildlife Rescue Efforts

Wildlife rescue efforts began within 24 hours following the spill. Search teams patrolled designated oiled shoreline areas and coordinated observations of dead and oiled wildlife with response crews and bird ground survey crews. Wildlife rehabilitation occurred at the Frink Center for Wildlife in Newark, DE and the John Heinz National Wildlife Refuge south of Philadelphia, PA. By May 2005, 206 birds were collected dead, died at the rehabilitation center, or were not returned to the wild, and 337 birds were rehabilitated and released. Other wildlife collected included four dead mammals, five dead reptiles, and 25 dead fish (Table 1).

Wildlife search teams operated on the ground from 30 November 2004 to 23 January 2005. Typically these teams searched on foot or by boat. The actual spatial coverage of the bird and wildlife recovery effort was quite limited as compared to the spatial extent of oiling. The majority of the oiled and/or dead birds and wildlife recovered were located and recovered by response and cleanup crews in the field and not by wildlife search teams. There are several factors that lead to a small proportion of oiled and dead birds being recovered.

1) Setting: The surrounding area consists of industrial and commercial development, residential housing, forests, and marshes. On the upper river, buildings and other structures, uneven terrain, marshes, and tree and shrub lined shorelines provided visual obstructions that made it difficult to see or recover birds. Restricted access to private property also limited the areas that could be surveyed. On the lower river, difficult-to-traverse marshes, narrow creeks, and a lack of manpower and equipment prevented adequate recovery of oiled wildlife.
2) Behavior and appearance: Oiled birds tended to pick up oil on the feet and/or belly. Oil on birds swimming or standing in water is difficult to observe. Oil is also difficult to see on dark-colored birds.
3) Oil: The oil was heavy, relatively sticky crude oil. Birds that come into contact with oil tend to behave abnormally and may preen excessively, ingest oil, eat less, and lose the ability to swim or retain body temperature. In this weakened state, birds are more likely to be preyed upon. To prevent this, sick birds will hide under vegetation, thus making it more difficult for potential predators and people to detect or recover oiled birds.

The spill occurred during late autumn, which is a very dynamic period of bird migration in the Mid-Atlantic Region. Although birds were immigrating, emigrating, and/or remaining to winter in the impact area, this turnover of individuals is difficult to quantify. Oiled birds were reported in areas far outside of search and rescue areas, such as Bombay Hook National Wildlife Refuge and Avalon Beach on the outer coast north of Cape May. Marshes froze overnight during the coldest periods of the spill forcing birds to move to open water areas at night and likely causing some to move along on migration (Forsell, pers. comm., 2006). Migrating oiled birds are likely to have died over a large area, perhaps tens or hundreds of miles from the impact area. Search and recovery efforts in the impact area were limited to bird concentration areas that were accessible. Scavengers were common, and it was difficult to find scavenged carcasses in the remote wetland areas. All these factors are likely to have contributed to the low numbers of oiled, dead birds recovered.

**TABLE 1.** Summary of data on recovered wildlife from the rehabilitation center.

| Guild | Species | Rehabilitated/ Released | Dead/ Not Released To Wild |
|---|---|---|---|
| Dabbling ducks | American black duck | 2 | 1 |
| | Blue-winged teal | - | 1 |
| | Duck sp. | - | 2 |
| | Mallard | 11 | 25 |
| Diving ducks | American coot | - | 1 |
| | Bufflehead | 3 | 1 |
| | Black scoter | - | 1 |
| | Canvasback | - | 1 |
| | Long-tailed duck | - | 1 |
| | Ruddy duck | - | 1 |
| Diving birds | Double-crested cormorant | - | 9 |
| | Northern gannet | - | 1 |
| Gulls | Great black-backed gull | - | 2 |
| | Gull sp. | - | 22 |
| | Herring gull | 7 | 26 |
| | Ring-billed gull | 25 | 17 |
| Kingfishers | Belted kingfisher | - | 3 |
| Swans / Geese | Canada goose | 287 | 80 |
| | Mute swan | - | 1 |
| | Snow goose | 2 | 6 |
| Wading birds | Great blue heron | - | 2 |
| Other | Other | - | 2 |
| **Total Birds** | | **337** | **206** |
| **Total Mammals** | | **1** | **4** |
| **Total Reptiles** | | **1** | **5** |
| **Total Fish** | | **-** | **25** |

## 2.2 Oil Distribution Mapping and Trajectory Modeling

During the course of the response, frequent aerial surveys in helicopter and fixed-wing aircraft, as well as detailed shoreline surveys, were performed to map oil distribution and guide cleanup efforts. Also, computer trajectory models were used to predict the movement of floating oil in the Delaware River system during the course of the spill. Figure 2 depicts the results of shoreline cleanup and assessment team (SCAT) surveys in the impacted area. Figure 3 depicts an example of output from the GNOME trajectory model. These data generated during the response were used to plan the bird and wildlife ground and aerial survey efforts described in the following section.

## 2.3 Spilled Oil Characteristics

The spilled oil was a heavily biodegraded crude oil that was depleted in low molecular weight hydrocarbons (Michel et al., 2004). Donlan et al. (2005) prepared an evaluation of the composition and potential environmental fate and aquatic toxicity of the oil. Although the spilled oil has limited acute toxicity, heavy crude oil, in general, is known to pose significant risks to wildlife from ingestion and fouling of fur and feathers.

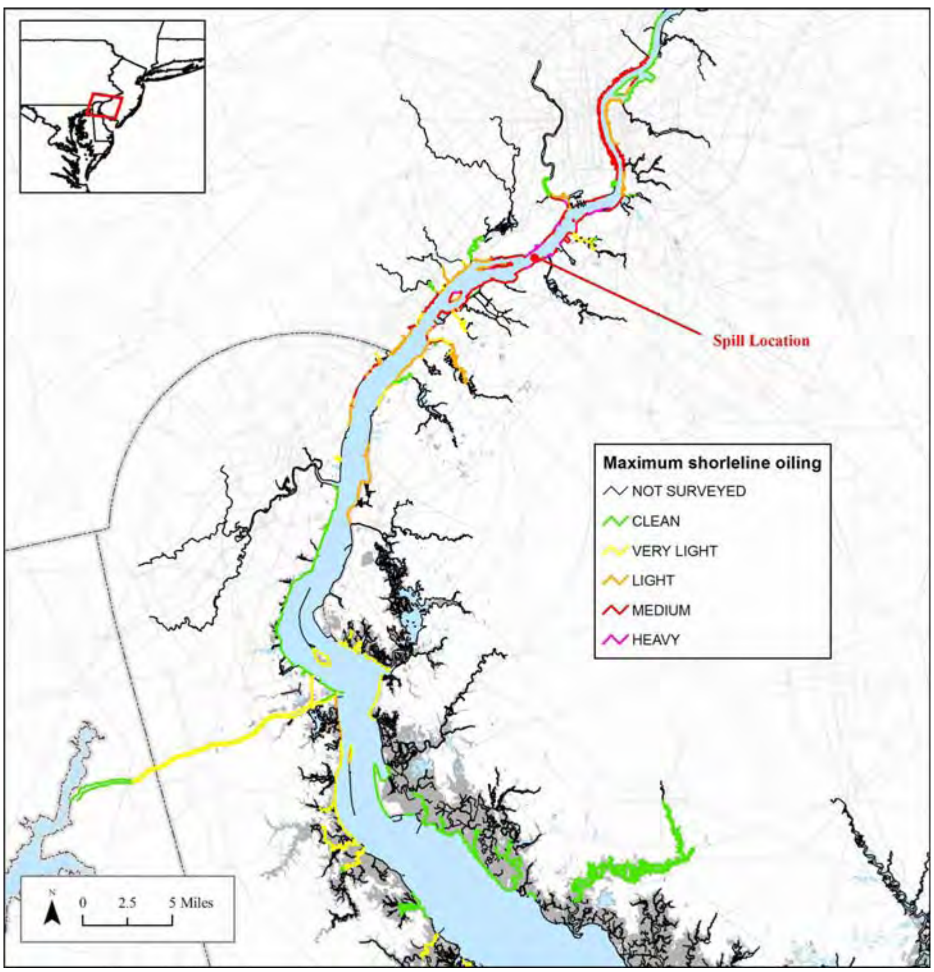



**FIGURE 2.** Map of shoreline oiling based on SCAT surveys.

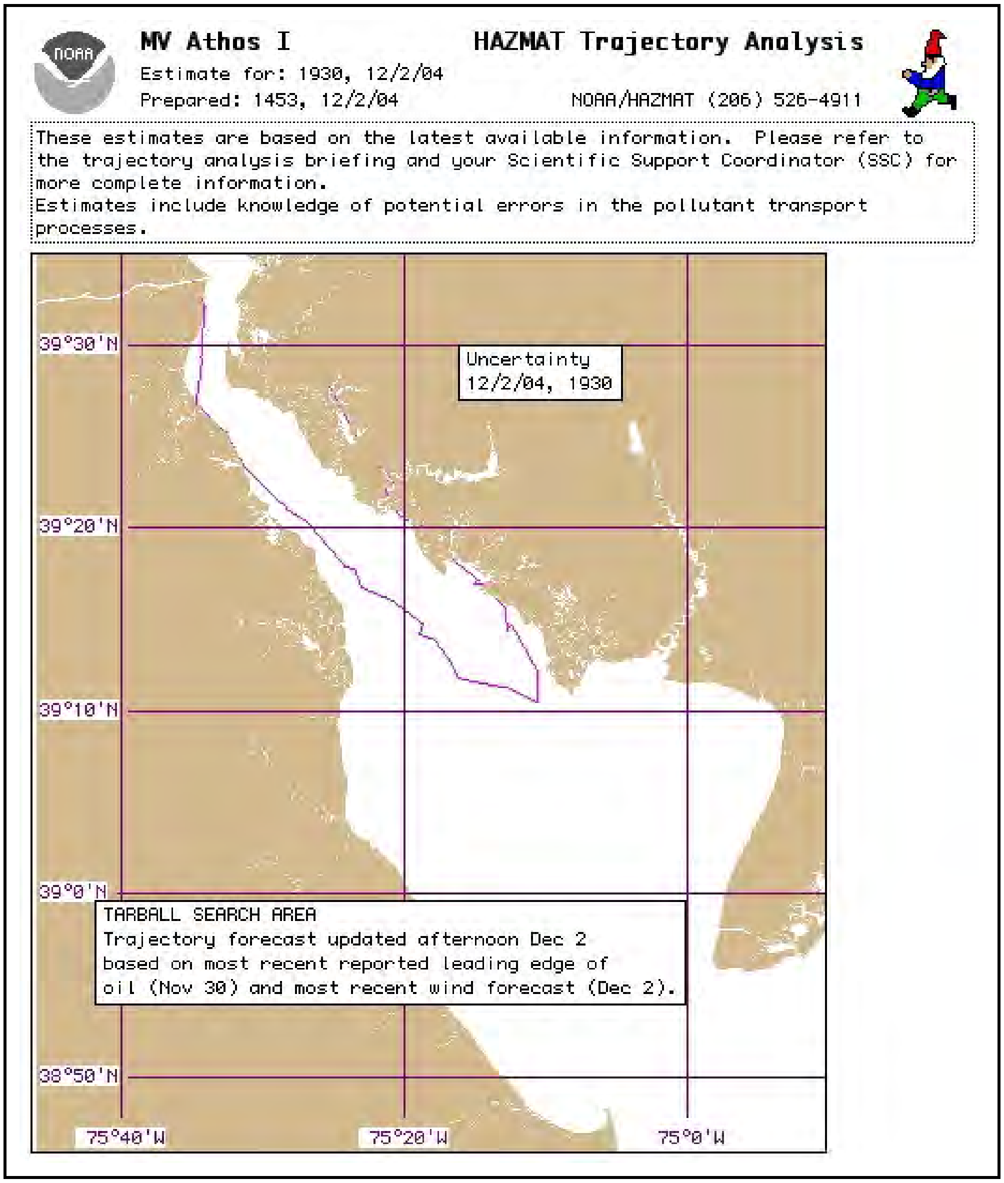



**FIGURE 3.** Example trajectory model output. The area within the purple line represents the estimated location with uncertainty of floating oil on 2 December 2004.

## 3.0 BIRD INJURY QUANTIFICATION APPROACH

The number of birds retrieved after an oil spill represents only a fraction of the actual number of birds affected by the spill. Oiled and dead birds are not recovered because they hide, sink, drift out to sea, are scavenged, or are overlooked by search teams (Burger, 1993; Sperduto et al., 1998; 2003). The Trustees considered several approaches to estimate the actual mortality resulting from this incident, including:

1) **Selection of a Multiplier.** In this approach, data from the oiled and dead bird recovery effort is multiplied by a factor to arrive at an estimate of the total bird mortality. Burger (1993) summarized data for 21 spills where the actual and estimated bird mortalities were reported. On average, the estimates were 4.4 times higher than the actual counts. For the *North Cape* oil spill off Rhode Island, the natural resource Trustees used a multiplier of 6, after evaluating the spill conditions (Sperduto et al., 1998; 2003). The Trustees did not feel that it was appropriate to use multipliers for this spill because those that are reported in the literature are generally developed in physical settings different from the riverine and upper estuarine environment of Delaware Bay. Also, most of the birds affected were Canada geese and gulls that spend most of their time on shores or upland areas compared to seabirds that spend most or all of their time on the water. Many of the spills for which the multipliers were developed impacted marine birds that came ashore because they were oiled. The coastal area consisted of linear shorelines, where oiled birds have a relatively narrow shoreline band in which to seek refuge. In Delaware Bay, many of the birds that were oiled normally feed and rest in the extensive marshes along the river and bay. They routinely move between the river and the marshes. So, they would widely disperse into these marshes for protection when stressed by oiling. Furthermore, the multiplier approach is used when there are insufficient data collected during the spill on the populations at risk. The main point in the analysis done by Burger (1993) was that he found no relationship between spill volume and numbers of *seabirds* (emphasis added) killed. He found no justification for using a rule of thumb for estimating total mortality as one order of magnitude greater than the body count and concluded that "Each spill should be investigated independently." During the *M/T Athos I* spill, a large amount of information was collected on species distributions and counts over time in the area and the degree of oiling by species. Therefore, it is more appropriate to use robust, spill-specific data rather than simple multipliers.

2) **Computer Modeling.** The Trustees also considered developing a computer model using the trajectory of the oil, the spatial distribution of birds, and probability functions to predict the number of oiled birds. These models have been used for spills where large numbers of seabirds were affected or potentially at risk, such as the *Nestucca* spill off Washington where an estimated 56,000 birds were killed (Ford et al., 1991) and the *Apex Houston* spill in central California where over 10,000 birds were estimated to have died (Page et al., 1990). This approach would be difficult to apply to the *M/T Athos I* oil spill because of the many assumptions that have to be made. The oil quickly broke up and spread into widely distributed patches that moved throughout the river and bay for a long period, making it difficult to estimate the oil's location relative to bird's distribution. Furthermore, during the spill migratory birds were moving through the area and may

have only been present for a short period, making it difficult to model daily changes in population. Most models require data on the concentrations of birds on the water and the distribution of the oil to predict the number of birds oiled. These data are lacking for the *M/T Athos I* spill, where the surveys mostly counted birds when they were in the marshes. Also, many of the birds oiled during the *M/T Athos I* spend as much or more time in marsh and other inland habitats. They are exposed to oil on the surface of the marshes, not just to floating oil slicks on open water areas.

3) **Risk–based Assessment Approach.** In this approach, both bird recovery data and field data collected during the spill are used to estimate the bird population at risk and the percent of the population oiled, and data from the literature are used to estimate total mortality. It considers the life history and behavior of different groups of birds. This approach is appropriate where field teams can make good field observations during the spill. It uses a combination of field data and literature reviews, which are two of the assessment methods listed in the NRDA regulations (15 CFR Part 990). The extensive surveys conducted during the *M/T Athos I* spill generated robust datasets that provided the best data on which to assess injury. This approach was used to quantify injury to birds and diamondback terrapins at the Chalk Point spill of 126,000 gallons of a mixture of No. 2 and No. 6 fuel oils into the Patuxent River, Maryland in April 2000 (Michel et al., 2003).

The Bird and Wildlife TWG agreed that injuries to birds resulting from the *M/T Athos I* oil spill would be estimated using the risk-based assessment method. In general, this approach involved aerial surveys to estimate the total number of non-recovered birds present in the area, and ground surveys to estimate the percentage of oiled versus unoiled birds and the degree of oiling. These data were then used to estimate the number of non-recovered birds that were oiled and died in the field, or that survived with potentially sublethal impacts. These estimates, combined with data on recovered birds from the wildlife rescue effort, were used to determine the total number of birds impacted. Mortality rates derived from the literature and expert opinion were used to estimate injury and, combined with demographic and reproductive statistics, to estimate indirect injury via production foregone. Different approaches were used for rare species such as the bald eagle, where each nest and nesting pair were observed over time. The injury quantification methods were based on the types of data collected during these species-specific studies. Figure 4 describes the overall flow of the analysis.

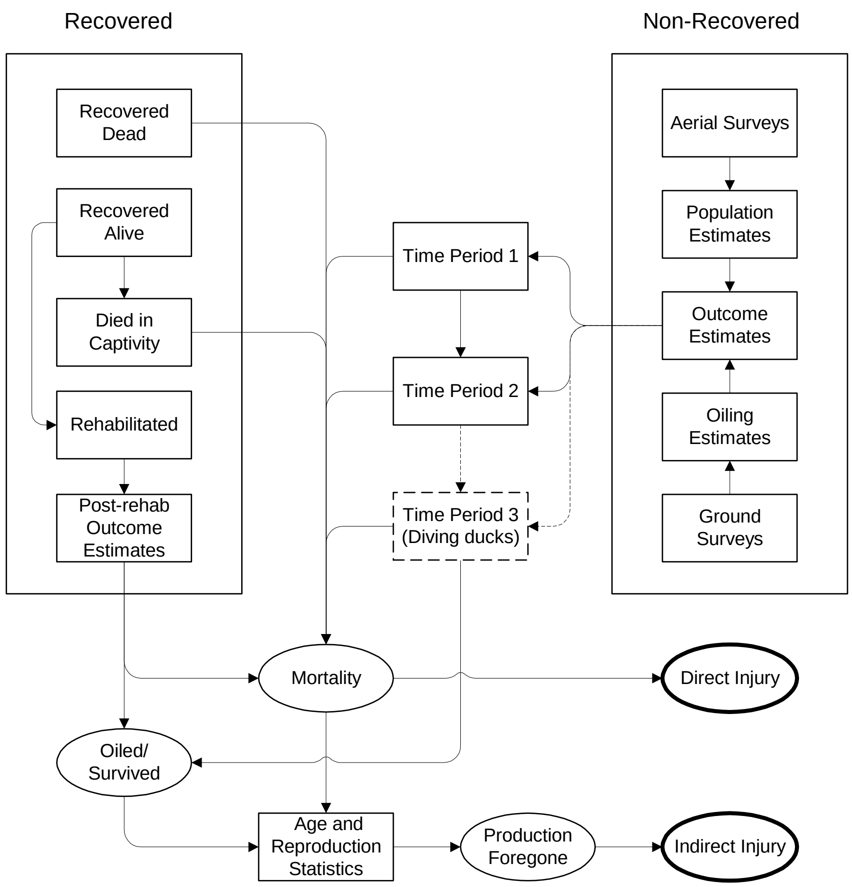



**FIGURE 4.** Analysis steps for quantification of the total injury to birds as a result of the *M/T Athos I* oil spill in the Delaware River system.

## 4.0 DATA COLLECTION METHODS

### 4.1 Aerial Surveys

Aerial surveys in the impacted area were conducted on 11 dates between 28 November and 21 December 2004 to estimate the species composition and abundance of birds in the impacted area. The impacted area was determined via review of oil distribution maps and trajectory models produced as part of the response, as in Figures 2 and 3. The impacted area in each state was divided into survey segments (Fig. 5). For New Jersey, this area was initially defined as the northern region, including the Delaware River from Petty Island to the Delaware Memorial Bridge including all of the tributaries between those two points. Later, this area was extended southward to cover extensive portions of the New Jersey side of the Delaware Bay shoreline. In Pennsylvania, the impacted area was defined as the Delaware River from the Betsy Ross Bridge to the Delaware state line as well as the Schuylkill River and Darby Creek. In Delaware, the northern region was defined as the Delaware River from the Pennsylvania state line to Delaware Memorial Bridge; later the southern region was defined as the area from the Delaware Memorial Bridge to approximately 6 miles south of the Bombay Hook National Wildlife Refuge, as well as the tributaries and estuarine marsh complexes adjacent to the bay.

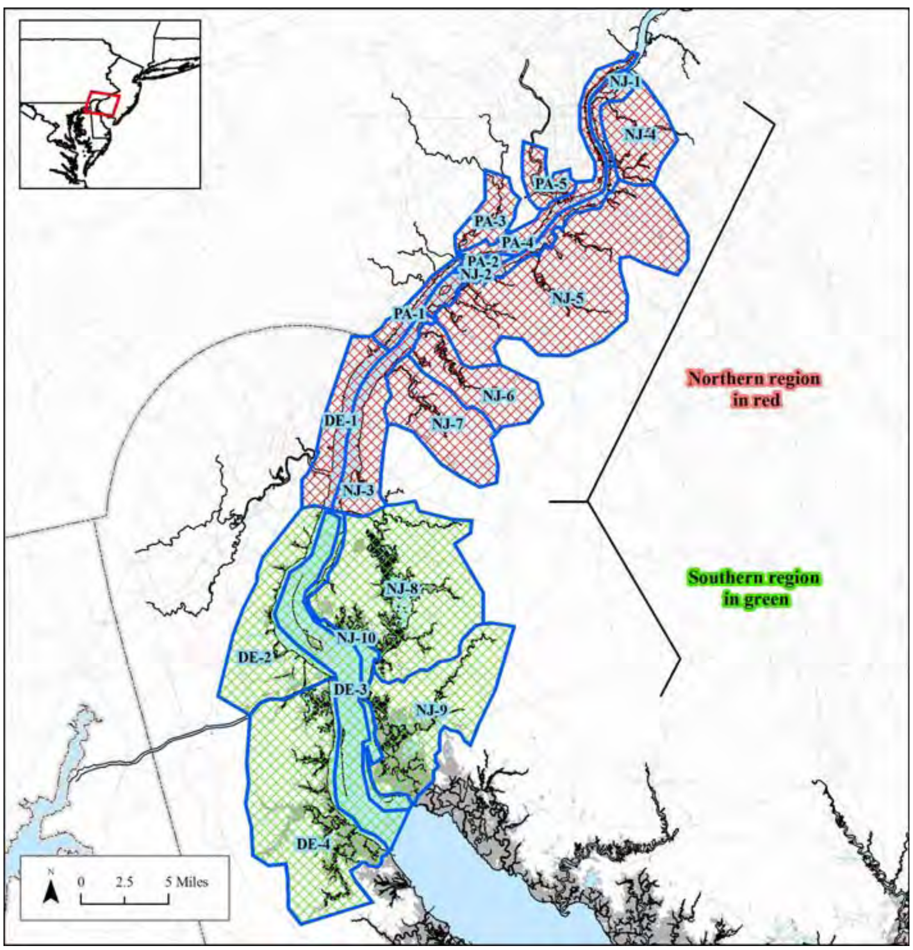
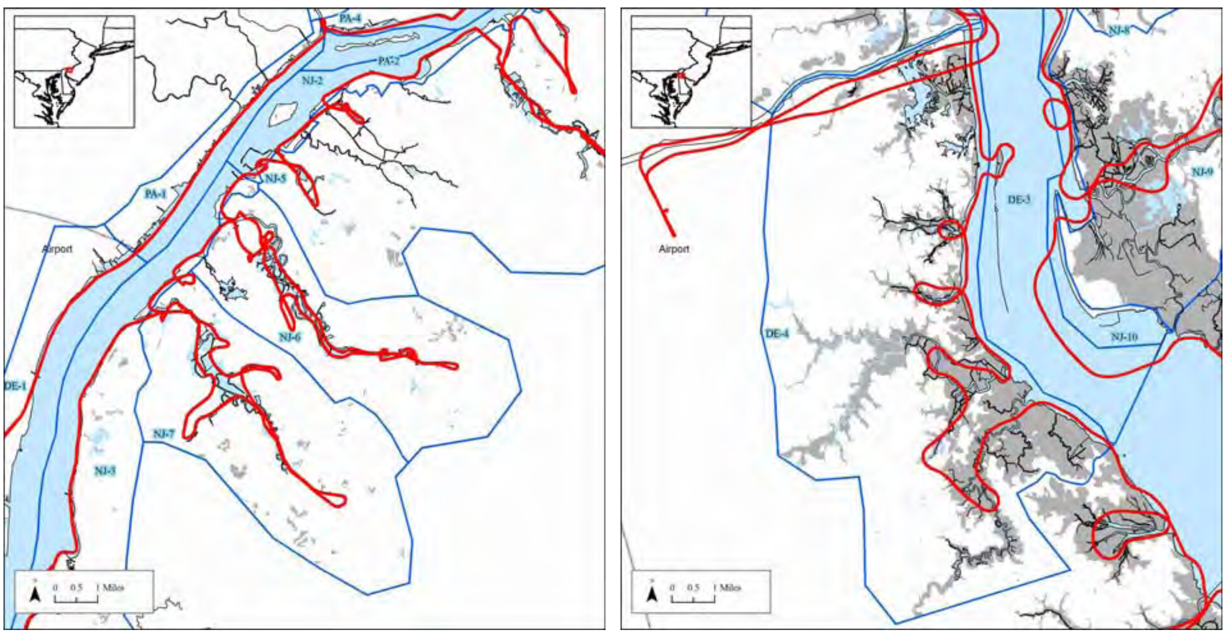



**FIGURE 5.** Map of survey segments outlined in blue, with larger analysis regions indicated.

In New Jersey, helicopter aerial surveys were typically conducted at 3-5 day intervals. Partial coverage of the Pennsylvania segments was completed on 30 November and 2 December. Thereafter, an effort was made to coordinate surveys between New Jersey and Pennsylvania. The 2 December survey in New Jersey was coordinated with the 3 December survey in Pennsylvania. For the 5 December and the remaining surveys, both New Jersey and Pennsylvania bird surveys were completed within a 3 hour window during each day. Surveys in Delaware and New Jersey south of the Delaware Memorial Bridge, while not as frequent as those further north, occurred on 2, 5, and 15 December and were also coordinated with those in New Jersey and Pennsylvania.

The surveys in the northern region covered main-stem shorelines and all tributaries upstream to the point where overhanging tree canopies obscured visibility of birds below. In the southern region, surveys covered the majority of the main-stem shoreline below the Delaware Memorial Bridge and much smaller portions of tributaries and adjacent marsh complexes. Figure 6 compares aerial survey strategies for northern and southern segments. Note the more complete coverage and lack of extensive marshes in the northern areas.




**A.** **B.**

**FIGURE 6.** Comparison of typical aerial survey flightlines for selected (A) northern and (B) southern segments conducted on 2 December. Survey flightlines are shown as red lines. Note the larger areas of emergent marsh (in gray) and less survey coverage in the southern area compared with the northern segments.

All aerial surveys in the northern region were conducted with one or two observers using Bell 206 helicopters piloted by private vendors contracted by the Responsible Party. All visible birds in open water, adjacent wetlands, spoil banks, and adjacent upland habitats (e.g., farm fields, parks, tops of structures such as oil storage tanks, and corporate lawns) were counted. Observations were recorded on a hand-held tape recorder and transcribed after the flight. Most helicopter surveys were performed at altitudes of 30 to 120 meters (m) and airspeeds of 40 knots, depending on flight conditions, proximity of obstructions, and other factors. All aerial surveys in the southern region were conducted with one observer and one pilot-observer using U.S. Fish and Wildlife Service Cessna 206 on amphibious floats. Fixed-wing aircraft surveys were typically flown at altitudes of 55 to 60 m and airspeeds of about 90 knots. All birds observed along the coast and in the mouths of major rivers were counted. Over marsh areas in Delaware and southern New Jersey, birds were counted within a 200 m strip extending from 50 m to 250 m from each side of the aircraft. For all aerial surveys, the route of the aircraft on any given survey was adjusted for wind speed and direction, sun angle, obstructions, and restricted air space.

For all aerial surveys, birds were identified to the lowest taxonomic level possible. Some species were difficult to differentiate from the air; for example, greater and lesser scaup; ring-billed, herring, and greater black-backed gulls; and shorebirds. Aerial bird surveys are best suited for detecting species that are large, brightly colored, abundant, and fly when disturbed. Smaller or cryptically colored species are less likely to be detected by observers. As an example, observers are more likely to see tundra swans (large and bright) and Canada geese (large) than they are to see green-winged teal (small) or shorebirds (very small). Less abundant birds mixed with flocks of more abundant birds are often missed in surveys. For example, 10 northern pintails mixed in with a flock of 500 American wigeon are likely to be mis-identified and counted as wigeon. Individuals or pairs of black ducks in heavy vegetation that do not fly at the approach of the aircraft are likely to be missed.

## 4.2 Ground Surveys

State, Federal, and contractor personnel conducted over 3,400 fixed-point ground surveys between 30 November and 21 January to assess the percentage of birds oiled and degree of oiling of the oiled birds (e.g., heavy, moderate, light, trace). Ground surveys were conducted after these dates as well, but the data were not included in these analyses because the corresponding population data were not gathered. Ground surveys were typically conducted at a fixed point accessible via foot, vehicle, or boat. Site locations were selected based on accessibility, review of oil distribution maps and trajectory models produced as part of the response, and observations from aerial surveys.

Between one and six observers were present at each ground survey. Most of the teams consisted of 3-5 observers, with smaller teams used later in the response and where the lead observer was the local expert in that species. FWS staff purposely requested observers that were experienced in bird identification, and each team had at least one experienced bird observer. Observers were instructed to begin counting and estimating degree of oiling from the bird closest to them, proceeding outward until they could no longer determine if a bird was oiled. Birds visible beyond this distance were not to be counted for purposes of determining the degree of oiling. The degree of oiling was estimated using trace, light, moderate, or heavy descriptors. A field guide (included in Appendix A) was distributed to the field teams to assist them in estimating the percent oil cover on birds. Ancillary data included location, date, time, duration on site, behavior, and total counts of birds by species in some areas where aerial surveys were not conducted. Birds were identified to the lowest taxonomic level possible. Observations were recorded on standard field forms. Typically, observers remained at a given site only as long as needed to record data for all birds present at arrival. Initially, three descriptors (heavy, moderate, light) were used to describe degree of oiling. Starting on 3 December, a “trace” descriptor was added. From 5 December onward, the descriptors shown in Table 2 were used.

**TABLE 2.** Bird oiling descriptors used during ground surveys.

| Descriptor | Percent Body Surface Oiled |
|---|---|
| **Trace** | ≤ 5 |
| **Light** | 6 - 20 |
| **Medium** | 21 - 40 |
| **Heavy** | > 40 |

## 5.0 POPULATION ESTIMATION METHODS

Population estimates for birds were derived from aerial survey data collected during the spill response. All data were compiled into a MS Access database and standardized for analysis. All spatial data analyses were conducted with ESRI ArcGIS software. Data from two different dates or date ranges were selected as being relatively complete and synoptic data sets depicting populations during those time periods. For most species guilds, data from 2-5 December and 13-16 December were used to derive population estimates for “early spill” and “late spill” time periods respectively (referred to as time periods 1 and 2 below). These time periods were selected based upon the timeline of oiling, changes in bird migration, and survey coverage. Data from a third date, 21 December, were used to derive population estimates for a third time period for diving ducks only, as it was determined that there was a substantial influx of diving ducks after 19 December. Diving ducks were more susceptible to oiling than most other guilds since they spend all their time in the water and, in this particular region, are most prevalent in the main stem of the Delaware River. This time period is referred to as time period 3 below. Detailed calculations used to estimate population can be found in the MS Excel spreadsheet accompanying this report and described in Appendix B.

### 5.1 Species Groups

Species were grouped into guilds based on their taxonomy, size, behavioral characteristics, and sensitivity to oil. In instances where large numbers of different species are involved, such “grouping” is well-accepted in natural resource injury estimation restoration scaling (Zafonte and Hampton, 2002; Peterson and Lipcius, 2003) and simplifies calculations and evaluation of restoration options. Guilds used for analysis were: dabbling ducks; diving and sea ducks (elsewhere in the document this group is only referred to as “diving ducks”); swans and geese; diving birds (cormorants, gannets, loons and grebes); gulls; raptors; passerine or passerine-like birds; shorebirds; and wading birds. Table 3 lists species recorded in surveys and their respective guilds. Population estimates of snow geese were treated separately from other swans and geese for population estimation and direct injury calculations due to the large numbers of individuals, localized concentrations, and high visibility of this species. Belted kingfishers were included as a separate guild due to their water-dependent feeding and habitat requirements. Passerine birds are not included due to their low overall rates of oiling. Bald eagles were considered separately due to their conservation status.

### 5.2 Survey Methods: Censuses vs. Samples

Aerial survey data from Pennsylvania, and New Jersey and Delaware north of the Delaware Memorial Bridge consisted of complete counts of all birds observed by species by survey segment. These surveys were considered to be complete *censuses* of all potential bird habitat. Estimates of potentially impacted bird population estimates were derived by guild and survey segment from the number of birds counted along the main-stem river shoreline and tributary waterways and marshes. Aerial data for Delaware and New Jersey south of the Delaware Memorial Bridge consisted of individual geo-referenced sightings and counts by species along a track with a GPS position recorded every 5 seconds. In these cases, the data were assigned to a survey segment by overlaying the sighting locations with survey area boundaries. Each survey was considered to be a complete unadjusted count of the main-stem shoreline of the Delaware River and Bay and major rivers, and a *sample* of the more expansive inland estuarine marsh complexes.

For large estuarine marsh complexes with both *sample* and *census* data, a twofold approach was used to derive estimates of potentially impacted birds. All sightings for these survey segments were divided into those located within approximately 50 m of the main-stem shoreline or open waters of the Delaware River and Bay, and those located in the inland estuarine marsh complexes, as in Figure 7. For the main-stem shoreline and open waters of the Delaware River and Bay, potentially impacted bird population estimates were derived by guild and survey segment from the count of birds along the main-stem river shoreline.

**TABLE 3.** Species list and grouping of species into guilds for injury assessment.

| Guild | Common name | *Scientific name* |
|---|---|---|
| Dabbling ducks | Wood duck | *Aix sponsa* |
| | Northern pintail | *Anas acuta* |
| | American wigeon | *Anas americana* |
| | Northern shoveler | *Anas clypeata* |
| | Green-winged teal | *Anas crecca* |
| | Blue-winged teal | *Anas discors* |
| | Mallard | *Anas platyrhynchos* |
| | American black duck | *Anas rubripes* |
| | Black duck - mallard hybrid | *Anas sp.* |
| | Gadwall | *Anas strepera* |
| | Muscovy duck | *Cairina moschata* |
| Diving ducks | Lesser scaup | *Aythya affinis* |
| | Ring-necked duck | *Aythya collaris* |
| | Greater scaup | *Aythya marila* |
| | Canvasback | *Aythya valisineria* |
| | Bufflehead | *Bucephala albeola* |
| | Goldeneye | *Bucephala spp.* |
| | Long-tailed duck | *Clangula hyemalis* |
| | American coot | *Fulica americana* |
| | Hooded merganser | *Lophodytes cucullatus* |
| | Black scoter | *Melanitta nigra* |
| | Surf scoter | *Melanitta perspicillata* |
| | Common merganser | *Mergus merganser* |
| | Red-breasted merganser | *Mergus serrator* |
| | Ruddy duck | *Oxyura jamaicensis* |
| Diving birds | Common loon | *Gavia immer* |
| | Red-throated loon | *Gavia stellata* |
| | Northern gannet | *Morus bassanus* |
| | Double-crested cormorant | *Phalacrocorax auritus* |
| | Great cormorant | *Phalacrocorax carbo* |
| | Cormorant | *Phalacrocorax sp.* |
| | Horned grebe | *Podiceps auritus* |
| | Pied-billed grebe | *Podilymbus podiceps* |
| Swans and geese | Greater white-fronted goose | *Anser albifrons* |
| | Canada goose | *Branta canadensis* |
| | Snow goose | *Chen caerulescens* |
| | Tundra swan | *Cygnus columbianus* |
| | Mute swan | *Cygnus olor* |
| Gulls | Herring gull | *Larus argentatus* |
| | Laughing gull | *Larus atricilla* |
| | Yellow-legged gull | *Larus cachinnans* |
| | Ring-billed gull | *Larus delawarensis* |
| | Lesser black-backed gull | *Larus fuscus* |
| | Iceland gull | *Larus glaucoides* |
| | Glaucous gull | *Larus hyperboreus* |
| | Great black-backed gull | *Larus marinus* |
| | Bonaparte's gull | *Larus philadelphia* |

**TABLE 3.** cont.

| Guild | Common name | *Scientific name* |
|---|---|---|
| Shorebirds | Ruddy turnstone | *Arenaria interpres* |
| | Sanderling | *Calidris alba* |
| | Dunlin | *Calidris alpina* |
| | Purple sandpiper | *Calidris maritima* |
| | Western sandpiper | *Calidris mauri* |
| | Killdeer | *Charadrius vociferus* |
| | Black-bellied plover | *Pluvialis squatarola* |
| | Greater yellowlegs | *Tringa melanoleuca* |
| Wading birds | Great egret | *Ardea alba* |
| | Great blue heron | *Ardea herodias* |
| | Snowy egret | *Egretta thula* |
| | Glossy ibis | *Plegadis falcinellus* |
| Raptors | Cooper's hawk | *Accipiter cooperii* |
| | Sharp-shinned hawk | *Accipiter striatus* |
| | Red-tailed hawk | *Buteo jamaicensis* |
| | Rough-legged hawk | *Buteo lagopus* |
| | Red-shouldered hawk | *Buteo lineatus* |
| | Broad-winged hawk | *Buteo platypterus* |
| | Turkey vulture | *Cathartes aura* |
| | Northern harrier | *Circus cyaneus* |
| | Peregrine falcon | *Falco peregrinus* |
| | American kestrel | *Falco sparverius* |
| | Bald eagle | *Haliaeetus leucocephalus* |
| | Osprey | *Pandion haliaetus* |
| | Barred owl | *Strix varia* |
| Kingfishers | Belted kingfisher | *Ceryle alcyon* |
| Passerines and other landbirds | Red-winged blackbird | *Agelaius phoeniceus* |
| | Stripe-headed sparrow | *Aimophila ruficauda* |
| | American goldfinch | *Carduelis tristis* |
| | Northern flicker | *Colaptes auratus* |
| | Rock dove | *Columba livia* |
| | American crow | *Corvus brachyrhynchos* |
| | Horned lark | *Eremophila alpestris* |
| | Red-bellied woodpecker | *Melanerpes carolinus* |
| | Wild turkey | *Meleagris gallopavo* |
| | Swamp sparrow | *Melospiza georgiana* |
| | Song sparrow | *Melospiza melodia* |
| | Downy woodpecker | *Picoides pubescens* |
| | Hairy woodpecker | *Picoides villosus* |
| | European starling | *Sturnus vulgaris* |
| | Carolina wren | *Thryothorus ludovicianus* |
| | Winter wren | *Troglodytes troglodytes* |
| | Mourning dove | *Zenaida macroura* |
| | White-throated sparrow | *Zonotrichia albicolis* |

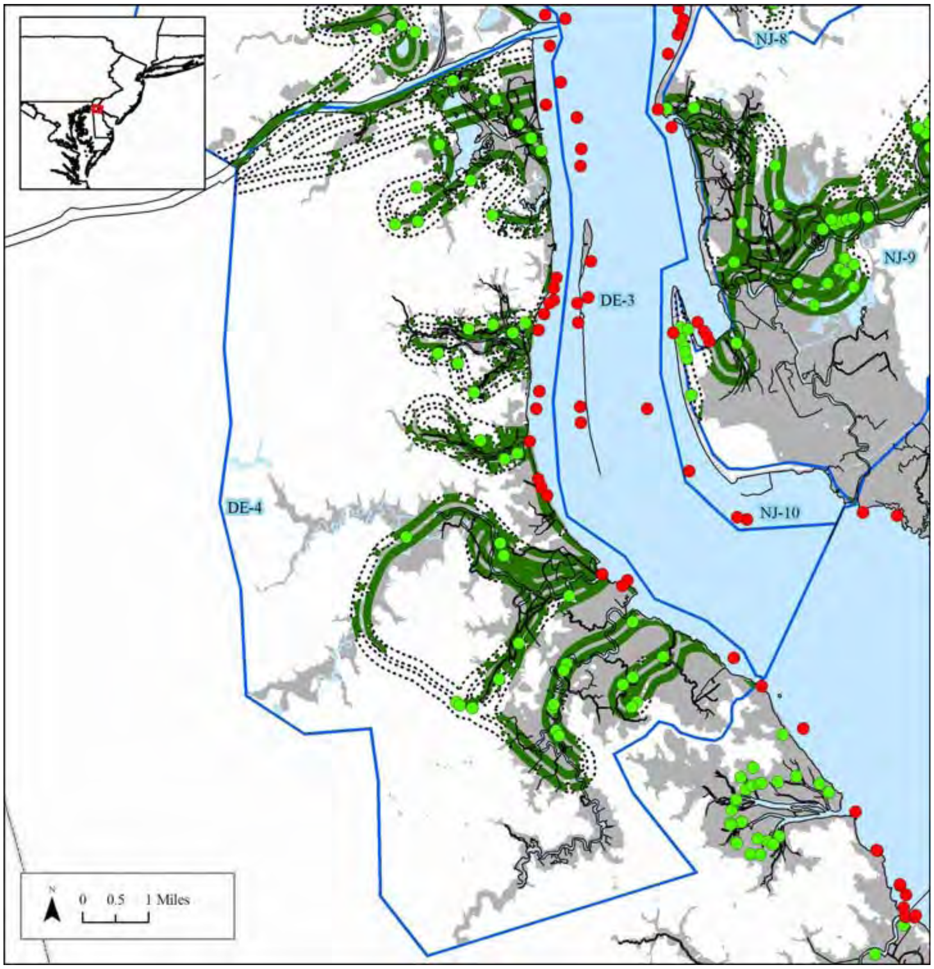



**FIGURE 7.** Example of sample vs. census population estimation procedure for segment DE-4 and time period 1 (2-5 December). Buffered (200 m) flight line areas in green, where used to derive sampled marsh area. Actual bird sighting locations as red markers for main-stem shoreline sightings, and as green markers for estuarine marsh complex sighting locations (*sample*).

To derive population estimates for the rivers, streams, and marsh complexes, the proportion of habitat sampled was calculated for each date using the survey flight line. The survey footprint consisted of a 500 m wide strip centered on the aircraft centerline, minus a 100 m wide strip immediately below the aircraft. Bird habitat was considered to be all tributary channels, isolated water bodies and emergent herbaceous marsh adjacent to or contiguous with the main shoreline of the river and bay. Habitat data were extracted from the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) vector polygon data set (USFWS, 2006). As an example, for segment DE-4 during time period 1 in Figure 7, approximately 40 percent of the estuarine marsh complex habitat was sampled by aerial survey. This was determined by comparing the total area of potential habitat in these estuarine marshes to the area covered by the flight-line footprints.

These sampled areas and number of birds counted within them were then used to calculate bird density by survey segment and guild. In turn, these density estimates were used to estimate potentially impacted population. Only sightings reported as being within the 500 m wide strip surveyed by observers were included in estimating densities and population estimates. Snow geese were handled separately. It was assumed that the counts of snow geese represent a complete census for all dates and survey segments because these birds are so highly visible and congregate in very large groups. Raw counts were used as the estimated population at risk for this species.

The aerial survey of segment DE-4 on 15 December surveyed only approximately 80 percent of the mainstem shoreline. For this segment and date alone, the mainstem counts were considered as a sample and were used to derive estimated populations for the entire mainstem shoreline in this segment based upon a procedure similar to that described above for the estuarine complexes.

## 5.3 Detectability by Guild

Detectability was estimated for each guild as a percentage of individuals actually present that were observed from the air. Detectability was estimated by personnel from each field team involved in data collection based upon professional judgment. For both the census and sample counts in all survey segments, actual numbers of individuals reported were corrected by these detectability estimates using the following equation:

$$P_E = P_O / D$$

where $P_E$ is the adjusted estimated population, $P_O$ is the observed count, and $D$ is the detectability estimate, after Thompson (2002). For the sampled areas, this correction was applied prior to calculation of densities and extrapolation to estimated population. Detectability was assumed to be perfect, or 100 percent, for snow geese. Detectability estimates are summarized in Table 4.

For gulls, $D$ was lower in the northern survey units because gulls were mostly observed on structures (often white oil storage tanks) where they were less visible when compared to southern survey units where they were mostly observed in the marsh. Detectability was further modified due to survey specific conditions. Estimated detectability was reduced by a fixed amount (15 percent) for all guilds except gulls and snow geese for surveys on 15 and 16 December due to high winds and reduced visibility. Also, estimated detectability was further reduced by a fixed amount (20 percent) for these same groups for aerial surveys conducted on that date in segments NJ-8 and NJ-9 due to the pilot not being able to count due to flight hazards from power lines, and low light. Note that counts of zero were fairly common for some guilds, including wading birds, shorebirds, and diving birds. The detectability adjustment described above does not account for instances when zero individuals were observed from the aircraft, but individuals may have actually been present.

**TABLE 4.** Bird detectability (*D*) estimates for aerial surveys by location and guild as derived from professional judgment of surveying biologists.

| North (NJ and PA) | | South (NJ and DE) | | South (NJ and DE) | |
|---|---|---|---|---|---|
| All habitats | | Main-stem shoreline | | Tributaries and marshes | |
| **Guild** | **D** | **Guild** | **D** | **Guild** | **D** |
| Dabbling ducks | 0.90 | Dabbling ducks | 0.90 | Dabbling ducks | 0.90 |
| Diving ducks | 0.90 | Diving ducks | 0.90 | Diving ducks | 0.80 |
| Diving birds | 0.75 | Diving birds | 0.75 | Diving birds | 0.75 |
| Swans / Canada geese | 0.975 | Swans / Canada geese | 0.975 | Swans / Canada geese | 0.975 |
| Snow geese | 1.00 | Snow geese | 1.00 | Snow geese | 1.00 |
| Gulls | 0.75 | Gulls | 0.90 | Gulls | 0.90 |
| Shorebirds | 0.10 | Shorebirds | 0.80 | Shorebirds | 0.10 |
| Wading birds | 0.75 | Wading birds | 0.75 | Wading birds | 0.75 |

## 5.4 Averaging Dates

For time periods 2 and 3 few survey segments were flown more than once. For time period 1, aerial surveys for most segments were conducted twice. For the main-stem shoreline of the Delaware River and Bay in time period 1, because the surveys from the two dates covered nearly the same areas, the higher of the two counts for each segment and guild was selected and used to estimate populations. To derive population estimates for the waterway and marsh complexes for time period 1, the proportion of habitat sampled was calculated by summing the surveyed areas from both dates, because the surveys from the two dates covered nearly completely different areas. Sightings from both surveys in these complexes were summed, and densities and extrapolated counts then calculated. Using summed areas and counts for waterway and marsh complexes for the two dates time period 1 yielded lower and more stable total estimated populations than using either single date alone. Note that this same procedure was also used to average data for surveys conducted on 15 and 16 December in segments NJ-9 and NJ-10 in time period 2. For snow geese, the higher of the two counts was selected, because snow geese were considered to have been completely censused even in marsh complexes.

## 5.5 Supplemental Counts

Supplemental data from the ground survey data, as described below, were used to augment the aerial surveys for some guilds or species in some locations. The maximum daily counts of wading birds, belted kingfishers, and pied-billed grebes at each unique ground survey location were summed by survey segment in each time period. This methodology provided an estimate of impacted population without accounting for movement of individuals from location to location or the incomplete coverage of a given segment. For wading birds, which were difficult to detect during the aerial surveys, these supplemental population estimates were compared with the population estimates derived from the aerial survey data as described above in each segment, and the higher of the two counts was used. For belted kingfishers, which are difficult to detect during the aerial surveys, these estimates were used for all survey segments. For pied-billed grebes, which were nearly impossible to detect during the aerial surveys, population estimates were calculated and these numbers were added to the overall diving bird population estimates derived from the aerial surveys. These adjustments were made in an effort to more accurately estimate populations for these difficult-to-detect species, but are very small in magnitude and contribute less than 0.2 percent to the total estimated bird populations. For gulls, ground surveys were used to estimate populations for segment DE-1 as this segment was not surveyed from the air, but was considered an important location for this guild due to the presence of a major landfill.

## 5.6 Aggregation to Regions

After examining population and other data at multiple levels of geographic resolution, estimated population data were aggregated to two regions to simplify further analyses – a northern area from the upstream extent to the Delaware Memorial Bridge, and a southern area from the bridge to the boundaries of segments NJ-9 and DE-4, as shown in Figure 5. It was determined that these regions represent the best tradeoff between simplicity and actual geographic differences in population distributions. Although higher numbers of birds were found on segments further to the south, they were not included in further analyses because few oiled birds were found on limited surveys of these segments. For gulls, all population estimates were aggregated to the entire study area, due to the wide daily range of these species. Table 5 contains final population estimates. Note that surveys for diving ducks in time period 3 only were conducted in the northern survey area.

**TABLE 5.** Final population estimates for birds at risk from the *M/T Athos I* oil spill by time period and guild.

| Guild | Period 1 - Early | | Period 2 - Late | | Period 3 - > 19 Dec. |
|---|---|---|---|---|---|
| | North | South | North | South | North |
| Dabbling ducks | 2,063 | 10,572 | 6,979 | 7,365 | - |
| Diving ducks | 492 | 131 | 280 | 141 | 563 |
| Diving birds | 111 | 8 | 146 | 170 | - |
| Gulls | 13,063 | | 10,817 | | - |
| Shorebirds | 300 | 484 | 0 | 0 | - |
| Wading birds | 67 | 48 | 102 | 26 | - |
| Swans / Canada geese | 5,960 | 18,207 | 6,498 | 15,130 | - |
| Snow geese | 0 | 8,000 | 0 | 32,150 | - |
| Kingfishers | 27 | 1 | 24 | 1 | - |

## 6.0 DIRECT INJURY ESTIMATION

### 6.1 Oiling Estimates

Oiling estimates for non-recovered birds were derived from ground survey data collected by State and Federal agency and other personnel. Ground surveys were conducted on a range of dates spanning nearly the entire study period. All data after techniques were standardized (5 December) were located to the highest accuracy possible using a variety of data sources. Approximately 50 percent of the unique survey locations were located using latitude and longitude coordinates and approximately 45 percent were located only as being within a particular survey segment. Approximately 5 percent remained un-located and thus were not considered further.

The majority of data were aggregated into the two or three time periods described above. Oiling description information was not recorded consistently prior to 3 December so these data were not included. The lowest oiling descriptor used on 3-4 December was light, so observations on those dates with trace or light descriptors were not used. Figure 8 is a timeline of data collection activities for the bird injury assessment that shows the aerial and ground survey data used for each time period. For each time period, percentages of observed individuals by oiling condition, guild, and region were calculated. Observations lacking either a known date or a location to at least segment-level accuracy were not included in this analysis. Almost no ground surveys were conducted in southern New Jersey during the first three weeks of the data collection effort, so very little oiling data exists in this region.

| Time period | Period 1 – Early | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 11/26/04 | 11/27/04 | 11/28/04 | 11/29/04 | 11/30/04 | 12/1/04 | 12/2/04 | 12/3/04 | 12/4/04 | 12/5/04 | 12/6/04 | 12/7/04 | 12/8/04 | 12/9/04 |
| Day | F | S | S | M | T | W | Th | F | S | S | M | T | W | Th |
| # Ground surveys | SPILL | 0 | 0 | 0 | 29 | 17 | 198 | 161 | 232 | 237 | 162 | 181 | 276 | 177 |
| Aerial surveys | | | | | | | | | | | | | | |
| DE | | | | | | | F | | | F | | | | |
| NJ – N | | | P | | P | | F | | | F | | | | P |
| NJ – S | | | | | P | | F | | | F | | | | |
| PA | | | | | P | | | F | | F | | | | P |

| Time period | Period 2 – Late | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | 12/10/04 | 12/11/04 | 12/12/04 | 12/13/04 | 12/14/04 | 12/15/04 | 12/16/04 | 12/17/04 | 12/18/04 | 12/19/04 |
| Day | F | S | S | M | T | W | Th | F | S | S |
| # Ground surveys | 91 | 235 | 258 | 43 | 202 | 122 | 97 | 205 | 0 | 2 |
| Aerial surveys | | | | | | | | | | |
| DE | | | | | | F | P | | | |
| NJ – N | | | | F | | | | | | |
| NJ – S | | | | | | F | P | | | |
| PA | | | | F | | | | | | |

| Time period | Period 2 – Continued<br>Period 3 – Diving ducks only | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 12/20/04 | 12/21/04 | 12/22/04 | 12/23/04 | 12/24/04 | 12/25/04 | 12/26/04 | 12/27/04 | 12/28/04 | 12/29/04 | 12/30/04 | 12/31/04 | 1/1/05 | 1/2/05 | 1/3/05 | 1/4/05 | 1/5/05 | 1/6/05 | 1/7/05 | 1/8/05 | 1/9/05 | > 1/10/2005 |
| Day | M | T | W | Th | F | S | S | M | T | W | Th | F | S | S | M | T | W | Th | F | S | S | |
| # Ground surveys | 0 | 114 | 84 | 29 | 0 | 0 | 0 | 0 | 96 | 0 | 58 | 0 | 0 | 0 | 0 | 48 | 6 | 49 | 0 | 0 | 0 | 19 |
| Aerial surveys | | | | | | | | | | | | | | | | | | | | | | |
| DE | | | | | | | | | | | | | | | | | | | | | | |
| NJ – N | | F | | | | | | | | | | | | | | | | | | | | |
| NJ – S | | | | | | | | | | | | | | | | | | | | | | |
| PA | | F | | | | | | | | | | | | | | | | | | | | |

**FIGURE 8.** Time periods used for analysis and timeline of bird injury assessment data collection activities for the *M/T Athos I* oil spill. Dates and coverage (P – partial, F – full) of aerial surveys and number of ground surveys site visits per day indicated. Data collected but not used in analysis are indicated in grey. Note that time period 3 was only used for diving ducks.

The locations of ground survey points were relatively evenly distributed across the study area, as shown in Figure 9, but the locations were not generated randomly. Instead, as described above, the locations were based on many factors including accessibility. To test for bias in the location of survey points in favor of areas with more shoreline oiling, the proportion of shoreline length by shoreline oiling category was compared with the proportion of ground survey points with known locations categorized by oiling descriptor of the nearest surveyed shoreline. This process was carried out for the entire study area, as well as for the northern and southern regions independently. Figure 10 contains histograms displaying the results of this analysis. It is clear that the locations of the ground survey points are not biased closer to more heavily oiled shorelines. Indeed, the opposite seems true.

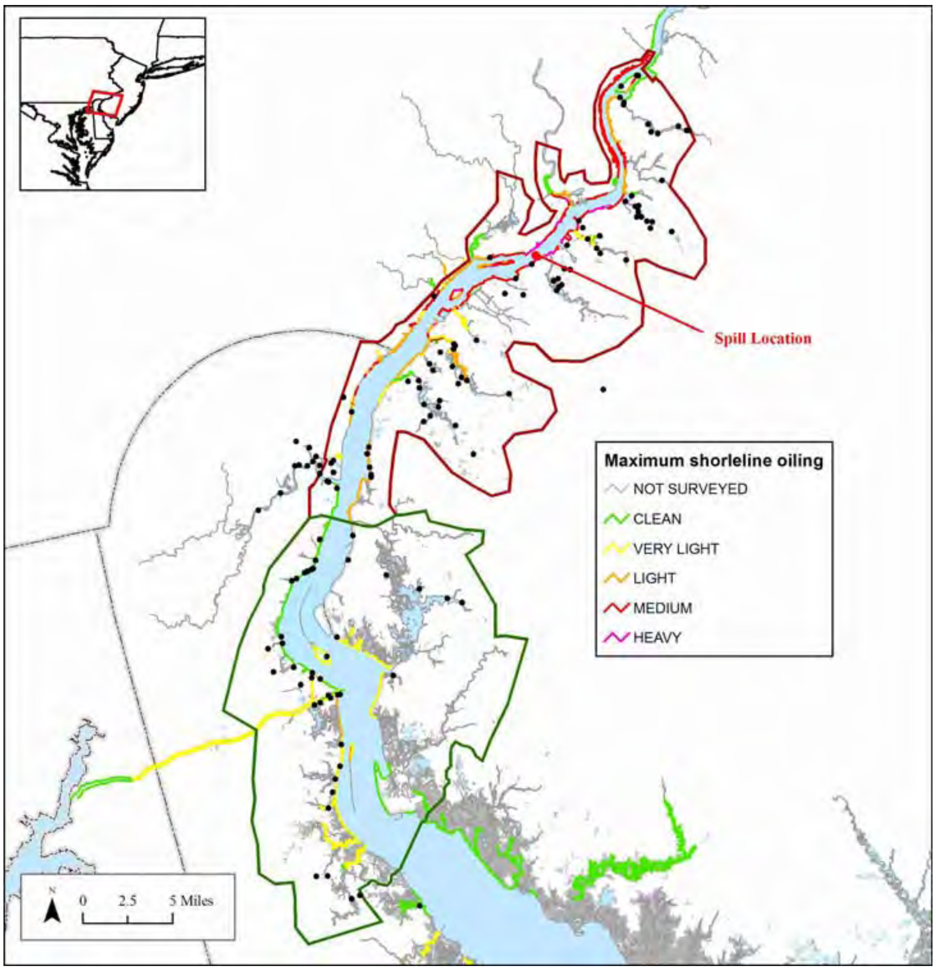
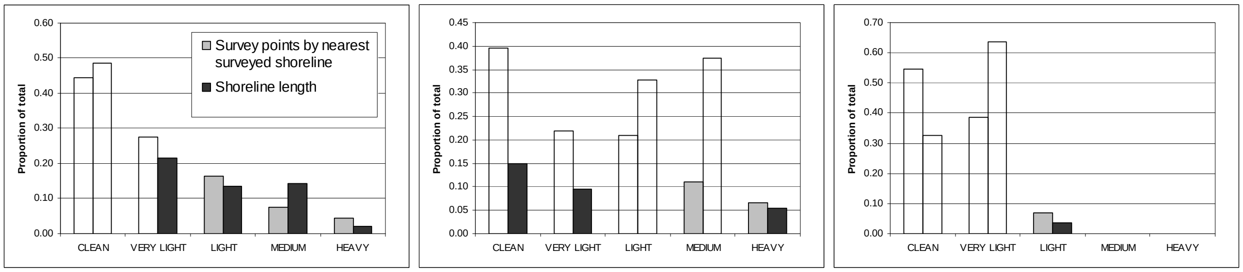



**FIGURE 9.** Map of 135 ground survey points with known coordinates used to derive oiling percentages with region boundaries and shoreline oiling from SCAT surveys.




**A.** **B.** **C.**

**FIGURE 10.** Proportions of total shoreline length and total number of ground survey locations (classified by descriptor of nearest surveyed shoreline) by oiling descriptor for entire study area (A), the northern region (B), and the southern region (C).

These percentages by oiling category were combined with estimates of potentially impacted populations to derive the numbers of birds in each oiling category for a given time period and region. Percentages by category were conducted differently for snow geese, because so few snow geese were observed during the ground surveys. For this species, all ground observations in the database were used to calculate global oiling percentages for all time periods. Table 6 contains oiling percentages and resulting estimated number of birds in the impacted population by oiling category.

## 6.2 Mortality Estimates by Guild by Degree of Oiling

The next step in the injury quantification process was to estimate the number of oiled birds in different oiling categories that eventually died, both in the rehabilitation center and in the field. Table 1 shows the number of birds by species that were recovered (both live and dead) and that were eventually released alive or died. The following discussion provides the basis for estimating the number of oiled birds that died in the field.

The two major pathways of oil exposure for birds are ingestion and fouling of the feathers (NRC, 2003). Birds can ingest oil during preening or ingestion of oil adhered to food items. Potential effects of ingestion include Heinz-body hemolytic anemia, immunosuppression, pneumonia; intestinal irritation, kidney damage, altered blood chemistry, impaired osmoregulation, decreased growth, decreased production and viability of eggs, and abnormal conditions in the lungs, adrenals, liver, nasal salt gland, and fat and muscle tissue (Fry and Addiego, 1987; NRC, 2003). Thus, oil ingestion can result in three categories of toxic effects: 1) reduction in reproduction; 2) destruction of red blood cells leading to anemia; and 3) increased stress resulting in an increased susceptibility to disease, all of which reduce the health and survival of oiled birds. Oiled feathers on birds lose their water-repellency, which leads to loss of buoyancy and insulating characteristics (Fry and Lowenstine, 1985; Wiens, 1995). When oiled, birds may lose their ability to dive and fly, have difficulty feeding, and increase their energy demands. The results include death by starvation, drowning, and hypothermia (Wiens, 1995).

The effects of oil on birds vary by behavior, ecology, and life history. Fry and Lowenstine (1985) reported 2 of 3 Cassin's auklets died from application of 3-5 milliliters of oil to the feathers. Tuck (1961) reported that only a small spot of oil on the belly was sufficient to

**TABLE 6.** Final estimates for percentages and number of oiled non-recovered birds by guild from the *M/T Athos I* oil spill, time period (1 – early spill, 2 - late spill, 3 - after 19 December), region (North/South), and oiling category.

| Guild | Time period | Region | Est. population | % Tr. | % Lt. | % Md. | % Hv. | # Tr. | # Lt. | # Md. | # Hv. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dabbling ducks | 1 | N | 2,063 | 0.9 | 1.0 | 0.8 | 0.8 | 19 | 21 | 17 | 16 |
| | 1 | S | 10,572 | 0.3 | 1.0 | 0.6 | 0.4 | 27 | 104 | 59 | 45 |
| | 2 | N | 6,979 | 1.9 | 1.2 | 0.2 | 0.3 | 132 | 82 | 16 | 19 |
| | 2 | S | 7,365 | 7.9 | 2.5 | 0.5 | 0.0 | 583 | 186 | 33 | 0 |
| Diving ducks | 1 | N | 492 | 3.2 | 3.4 | 2.1 | 0.3 | 16 | 17 | 11 | 1 |
| | 1 | S | 131 | 0.0 | 1.3 | 2.7 | 0.0 | 0 | 2 | 4 | 0 |
| | 2 | N | 280 | 2.8 | 1.3 | 0.1 | 0.0 | 8 | 4 | 2 | 0 |
| | 2 | S | 141 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| | 3 | N | 563 | 8.4 | 2.0 | 0.5 | 0.0 | 47 | 11 | 3 | 0 |
| Diving birds | 1 | N | 111 | 1.9 | 5.6 | 14.2 | 3.1 | 2 | 6 | 16 | 3 |
| | 1 | S | 8 | 4.8 | 4.8 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| | 2 | N | 146 | 1.8 | 8.1 | 3.6 | 0.9 | 3 | 12 | 5 | 1 |
| | 2 | S | 170 | 8.3 | 0.0 | 4.2 | 0.0 | 14 | 0 | 7 | 0 |
| Gulls | 1 | All | 13,063 | 5.5 | 6.1 | 4.2 | 0.6 | 723 | 802 | 543 | 80 |
| | 2 | All | 10,817 | 10.7 | 3.1 | 0.8 | 0.2 | 1159 | 335 | 89 | 19 |
| Shorebirds | 1 | N | 300 | 0.0 | 4.4 | 0.0 | 13.9 | 0 | 13 | 0 | 42 |
| | 1 | S | 484 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| | 2 | N | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| | 2 | S | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| Wading birds | 1 | N | 67 | 3.1 | 5.4 | 0.0 | 0.8 | 2 | 4 | 0 | 1 |
| | 1 | S | 48 | 0.0 | 12.5 | 0.0 | 0.0 | 0 | 6 | 0 | 0 |
| | 2 | N | 102 | 3.8 | 13.1 | 0.6 | 0.0 | 4 | 13 | 1 | 0 |
| | 2 | S | 26 | 6.7 | 13.3 | 0.0 | 0.0 | 2 | 3 | 0 | 0 |
| Swans / Canada geese | 1 | N | 5,960 | 4.0 | 6.4 | 5.7 | 4.1 | 238 | 380 | 341 | 247 |
| | 1 | S | 18,207 | 2.7 | 5.2 | 3.9 | 1.0 | 490 | 945 | 706 | 186 |
| | 2 | N | 6,498 | 4.2 | 3.3 | 1.4 | 1.2 | 270 | 215 | 93 | 78 |
| | 2 | S | 15,130 | 5.6 | 4.2 | 1.1 | 0.1 | 847 | 638 | 162 | 13 |
| Snow geese | 1 | N | 0 | 0.2 | 0.0 | 0.1 | 0.0 | 0 | 0 | 0 | 0 |
| | 1 | S | 8,000 | 0.2 | 0.0 | 0.1 | 0.0 | 14 | 0 | 5 | 0 |
| | 2 | N | 0 | 0.2 | 0.0 | 0.1 | 0.0 | 0 | 0 | 0 | 0 |
| | 2 | S | 32,150 | 0.2 | 0.0 | 0.1 | 0.0 | 55 | 0 | 18 | 0 |
| Kingfishers | 1 | N | 27 | 2.3 | 7.0 | 0.0 | 0.0 | 1 | 2 | 0 | 0 |
| | 1 | S | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |
| | 2 | N | 24 | 5.6 | 0.0 | 0.0 | 0.0 | 1 | 0 | 0 | 0 |
| | 2 | S | 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 |

kill murres. Birkhead et al. (1973) reported observations of visibly oiled gulls successfully cleaning themselves after several weeks.

Further information on the effects of oiling of feathers and oil ingestion can be derived from recent publication on the survival of oiled, rehabilitated, and released birds. There are four studies, all conducted in California, of oiled, rehabilitated, and released birds: brown pelicans, American coots, common murres, and western gulls. The survival rate for 112 oiled, rehabilitated, and released brown pelicans following the *American Trader* oil spill in southern California was compared to 19 unoiled control birds (Anderson et al., 1996). After about six months, the survival rate for unoiled control birds was 91 percent compared with 69 percent for the oiled and rehabilitated birds. After two years, the survival rate for unoiled birds was 53 percent (10 out of 19 birds) compared to 9 percent (8 out of 91 birds; 6 were juveniles) for oiled and rehabilitated birds. The oiling of large birds, such as pelicans, results in high mortality even when the animals are rehabilitated. Oiled birds remaining in the wild will likely have very low survival rates, particularly during winter conditions when they would be most susceptible to hypothermia. Under these conditions, energy reserves are quickly lost and body temperatures fall, which can lead to death (Hartung, 1967; Hughes et al., 1990; Leighton, 1995).

Anderson et al. (2000) studied the survival, condition, and behavior of oiled/rehabilitated American coots, compared to unoiled, wild-caught coots over a four-month period. Both groups were randomly mixed and released into fenced marshes. They reported 51 percent mortality in the oiled/rehabilitated birds, compared to 24 percent for unoiled birds. Oiled/rehabilitated birds lost weight for six weeks, then recovered to normal; those that died were unable to gain or maintain body condition for 2-3 months. Oiled (but rehabilitated) birds spent more time preening, bathing, feeding, and drinking and less time sleeping.

Newman et al. (2000) studied the effects of oiling and rehabilitation on the survival, behavior, and blood health indices of 31 common murres oiled during the 1999 *Stuyvesant* spill at the entrance to Humboldt Bay, California, compared with 25 unoiled control birds. The oiled birds were selected randomly from live birds that passed the release criteria. Although no records were kept of the degree of oiling of the birds, many were heavily oiled (Golightly, pers. comm., 2006). Oiled birds were four times more likely to die than control birds, with 13 out of 31 oiled birds dying after 140 days compared to 3 out of 25 unoiled control bird deaths. The difference in survival occurred between 15-40 days post-release. Factors contributing to the high post-release mortality included blood parameters that showed inflammation and possibly infection secondary to petroleum exposure, captivity, and handling.

Golightly et al. (2002) assessed survivorship and behavior of seven oiled and rehabilitated western gulls following the 1997 Torch/Platform Irene pipeline spill in south-central California, compared with ten unoiled but rehabilitated gulls and ten unoiled not rehabilitated gulls. As described by Golightly et al. (2002), all the oiled gulls would be classified as heavily oiled because they were “unable to fly and many were non-ambulatory, with wings or legs stuck to their bodies due to the viscosity and volume of petroleum contamination.” The oiled gulls were released after 21-24 days of rehabilitation. All groups were tracked by aerial telemetry for nine months. All the oiled and rehabilitated birds survived despite unfavorable El Nino conditions, whereas one unoiled not rehabilitated gull died. There was no statistically significant difference in the size of geographical areas used by all three groups. The authors concluded that modern rehabilitation methods can reduce post-release mortality. These data also indicate that gulls may be more tolerant of stresses, such as those associated with oiling, captivity, and handling.

These studies show that some rehabilitated oiled birds have high mortalities after oiling and rehabilitation and some do not. Birds that spend most of their time on the water are likely to have the highest mortalities during winter spills. Birds such as gulls and geese, that spend less time on the water, had the lowest mortalities. Oiled birds that remain in the field are expected to have even higher mortalities than rehabilitated oiled birds because of continued effects of hypothermia, failure of waterproofing, starvation, and oil ingestion (Leighton, 1995).

For the birds observed oiled in the field during the spill, percent mortality estimates were made for birds in the seven species guilds by oiling degree category (Table 7). These mortality estimates were developed via a compilation of the peer-reviewed literature summarized above and expert opinion of wildlife experts who worked on the *M/T Athos I* (Stout, pers. comm., 2005). It is important to note that the spill occurred in winter, when oiled birds are at higher risk of hypothermia. Figure 11 shows the daily mean of hourly air and water temperatures in the upper Delaware River for 26 November 2004 through 30 January 2005. Air and water temperatures were cold; water temperatures varied from the high 40s to the low 30s (degrees F) and the daily average air temperature was frequently below freezing (NOAA, 2005). Thus, these mortality estimates apply specifically to the conditions during the *M/T Athos I* spill.

Although the oiling descriptors range from heavy to trace, trace oiled birds had up to 5 percent oiling on their bodies, which is significantly more than the 3-5 milliliters on feathers that can kill seabirds (Fry and Lowenstine, 1985). Considering that heavily oiled birds had more than 40 percent oiling on their bodies and moderately oiled birds had 21-40 percent oil, it was assumed that 100 percent of nearly all heavily and moderately oiled birds eventually died. Moderately oiled swans and geese were assumed to have a 75 percent mortality rate due to their large size and ability to spend a large amount of time out of the water.

Lightly oiled birds had from 6-20 percent oiling on their bodies. At this degree of oiling, it was estimated that guilds that spent most of their time on the water, fed mostly by diving, or were very small and thus had low energy reserves would have 100 percent mortality. These guilds include diving birds, kingfishers, shorebirds, and diving ducks. Lightly oiled dabbling ducks were estimated to have 75 percent mortality. Guilds that were larger, rarely immersed in water, roost or flock on land, and generalist feeders were estimated to have lower mortality rates. Lightly oiled gulls and wading birds were estimated to have 50 percent mortality. Lightly oiled swans and geese were estimated to have zero mortality due to their large sizes.

**TABLE 7.** Percent mortality estimates for non-recovered oiled birds from the *M/T Athos I* oil spill by oiling degree and guild. An * indicates short-term mortality expected within 2 weeks of initial oiling.

| Oiling Category | Swans/ Geese | Wading Birds | Gulls | Dabbling Ducks | Diving Ducks | Shore Birds | Diving Birds |
|---|---|---|---|---|---|---|---|
| Heavy (>40%) | 100 | 100 | 100 | 100* | 100* | 100* | 100* |
| Medium (20-40%) | 75 | 100 | 100 | 100* | 100* | 100* | 100* |
| Light (6-20%) | 0 | 50 | 50 | 75 | 100* | 100* | 100* |
| Trace ($\leq$ 5%) | 0 | 0 | 0 | 25 | 50 | 50 | 50 |

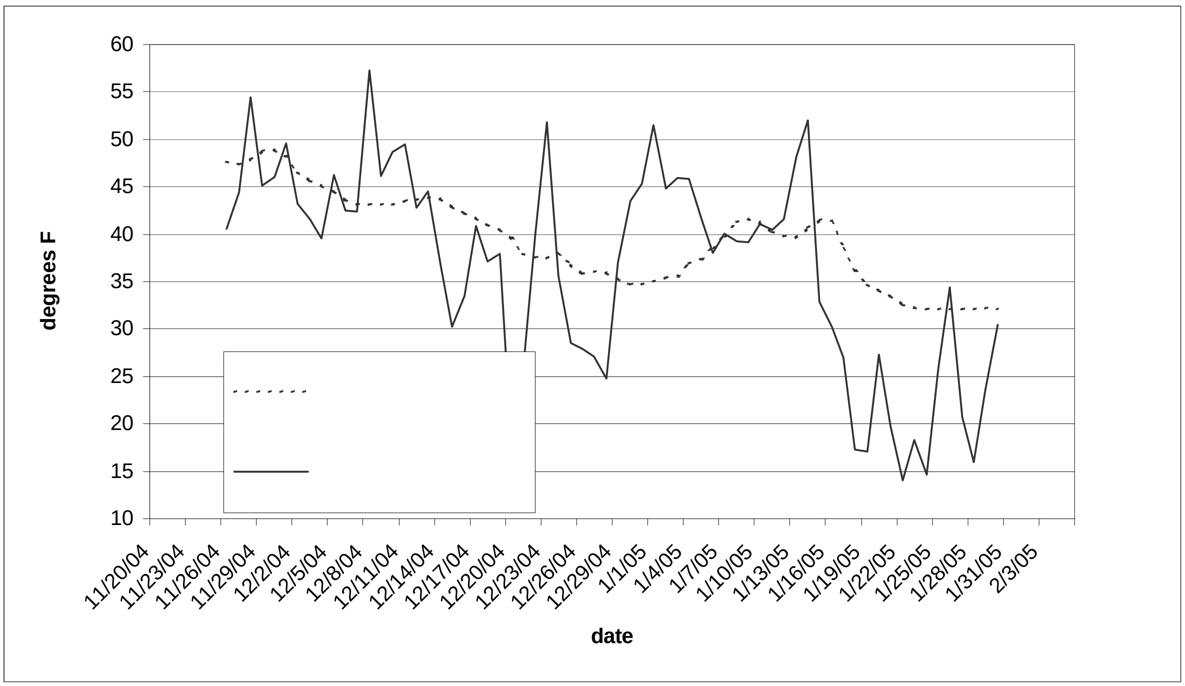



**FIGURE 11.** Daily mean air and water temperatures at the NOAA/NOS tidal station on the Delaware River at Philadelphia, PA during the time period of the spill.

Mortality estimates for birds described as having trace oiling (with 5 or less percent oiling) were zero percent for swans, geese, wading birds and gulls because of their size and behavior. For all guilds that spend most of their time on the water and small shorebirds, trace oiled birds were estimated to have 50 percent mortality, except for the larger dabbling ducks with an estimated 25 percent mortality. Experience at the rehabilitation center during the spill indicated that individuals from guilds considered sensitive to oiling (dabbling ducks, diving ducks, diving birds, shorebirds, and kingfishers) typically died within a few days to two weeks of initial oiling (Stout, pers. comm., 2005). These categories are noted in Table 7. Other categories of individuals typically survived 2 weeks or longer before dying.

## 6.3 Mortality for Rescued Wildlife

Of the birds that were collected dead or died at the rehabilitation center as summarized in Table 1, approximately 46 percent of these were collected prior to the advent of the 2 December aerial surveys. Thus, 46 percent of the dead birds in the recovered category were considered to be additive to non-recovered mortality estimated from population and oiling estimation described above. Also, 50 percent of rehabilitated and released birds were estimated to have died after release, based on the expert opinion of the rehabilitation experts who worked on the spill (Stout, pers. comm., 2005) considering the cold weather conditions of the spills, as well as the various studies described above showing 46 percent survival of oil-spill rehabilitated American coots by Anderson et al. (2000), 100 percent survival of oil-spill rehabilitated gulls (Golightly et al., 2002), and 58 percent survival of oil-spill rehabilitated murres (Newman et al., 2004). These birds were generally kept in rescue facilities for several weeks and released after the completion of population estimates in time period 2. Thus, the estimated mortality from birds dying after rehabilitation and release was considered additive to mortality as calculated above. Passerine birds and individuals where the species was not recorded were not included in these calculations. Table 8 describes actual and estimated outcomes by guild for birds recorded at the rehabilitation center.

**TABLE 8.** Actual and estimated outcomes (died or oiled and survived) for recovered oiled birds from the *M/T Athos I* oil spill by guild. Total additive mortality for recovered birds is the sum of pre-survey (died prior to Dec. 2) and post-release (died after rehabilitation and release) mortality estimates.

| Guild | Actual Dead | Estimated Died Prior to Dec. 2 | Actual Rehabilitated/ Released | Estimated Post-release Mortality | Estimated Total Additive Mortality |
|---|---|---|---|---|---|
| Dabbling ducks | *29* | 13 | *13* | 6 | 19 |
| Diving ducks | *6* | 3 | *3* | 1 | 4 |
| Diving birds | *10* | 5 | *0* | 0 | 5 |
| Gulls | *67* | 31 | *32* | 16 | 47 |
| Shorebirds | *0* | 0 | *0* | 0 | 0 |
| Wading birds | *2* | 1 | *0* | 0 | 1 |
| Swans / Canada geese | *81* | 37 | *287* | 143 | 180 |
| Snow geese | *6* | 3 | *2* | 1 | 4 |
| Kingfishers | *3* | 1 | *0* | 0 | 1 |

## 6.4 Overall Mortality Estimates

Table 9 contains population and mortality calculations. The populations, oiling, and mortalities of the various guilds are dynamic over time. The flux of birds in and out of the larger study area and movement of birds within the study area over the course of the spill makes modeling these dynamics difficult. For each guild except diving ducks, population estimates, oiling estimates, and mortality estimates were generated separately for the two time periods in question - early spill and late spill.

For birds from more sensitive guilds (dabbling ducks, diving ducks, diving birds, shorebirds, and kingfishers), mortality was tracked in two categories: short-term mortality, where death was expected in less than 2 weeks, and longer-term mortality. It was assumed that short-term mortality would result in those birds being lost from the estimated population at risk before the surveys in the subsequent time period. Thus, for these guilds, mortality was considered as the cumulative sum of short-term mortality estimated in time period 1 and total mortality estimated in time period 2. For diving ducks, the same process was assumed to take place, but over 3 time periods. In this case, mortality was considered as the cumulative sum of short-term mortality estimated in time periods 1 and 2, and total mortality estimated in time period 3. It was assumed that individuals from the more robust guilds that were oiled in time period 1 would survive to time period 2. For these guilds, the time period with the largest total mortality was selected as most representative indicator of estimated impact.

**TABLE 9.** Estimated outcomes (died or oiled and survived) for recovered and non-recovered oiled birds from the *M/T Athos I* oil spill by guild, time period (1 – early spill, 2 - late spill, 3 - after 19 December), and region.

| Guild | Region | Non-recovered | | | | | | | | Recovered | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Died | | | | Oiled/ Survived | | | | | | | |
| | | Time 1 | Time 2 | Time 3 | Cum. | Time 1 | Time 2 | Time 3 | Total | Died | Oiled/ Surv. | Died | Oiled/ Surv. |
| Dabbling ducks | N | 54 | 131 | - | 164 | 20 | 120 | - | 120 | 19 | 7 | 605 | 611 |
| | S | 189 | 318 | - | 422 | 46 | 484 | - | 484 | | | | |
| Diving ducks | N | 37 | 9 | 38 | 73 | 8 | 4 | 24 | 24 | 4 | 2 | 82 | 26 |
| | S | 5 | 0 | - | 5 | 0 | 0 | - | 0 | | | | |
| Diving birds | N | 26 | 20 | - | 45 | 1 | 1 | - | 1 | 5 | 0 | 64 | 8 |
| | S | 1 | 14 | - | 14 | 0 | 7 | - | 7 | | | | |
| Gulls | All | 1,025 | 276 | - | 1,025 | 1,124 | 1,326 | - | 1,326 | 47 | 16 | 1,072 | 1,342 |
| Shorebirds | N | 55 | 0 | - | 55 | 0 | 0 | - | 0 | 0 | 0 | 55 | 0 |
| | S | 0 | 0 | - | 0 | 0 | 0 | - | 0 | | | | |
| Wading birds | N | 2 | 7 | - | 7 | 4 | 11 | - | 11 | 1 | 0 | 10 | 14 |
| | S | 3 | 2 | - | 2 | 3 | 3 | - | 3 | | | | |
| Swans/ Canada geese | N | 503 | 148 | - | 503 | 731 | 508 | - | 703 | 180 | 144 | 1,398 | 2,458 |
| | S | 715 | 135 | - | 715 | 1,590 | 1,526 | - | 1,611 | | | | |
| Snow geese | N | 0 | 0 | - | 0 | 0 | 0 | - | 0 | 4 | 1 | 18 | 60 |
| | S | 3 | 14 | - | 14 | 15 | 59 | - | 59 | | | | |
| Kingfishers | N | 2 | 1 | - | 3 | 0 | 1 | - | 1 | 1 | 0 | 4 | 1 |
| | S | 0 | 0 | - | 0 | 0 | 0 | - | 0 | | | | |
| **Total** | | 2,620 | 1,075 | 38 | **3,047** | 3,535 | 4,050 | 24 | **4,350** | **261** | **170** | **3,308** | **4,520** |

Note: "Recovered: Died" is the estimated total additive mortality in recovered oiled birds from Table 8. "Recovered: Oiled/Surv." is the number of rehabilitated and released birds from Table 8 that are estimated to have survived (i.e. rehabilitated/released minus estimated post-release mortality).

## 7.0 INDIRECT INJURY ESTIMATION

In addition to estimating direct injury in terms of mortality due to oiling from the spill, indirect injury in terms of production foregone due to the loss of future generations was included in estimation of total injury. This loss was calculated for one additional generation. Production foregone was considered as both the loss of production from dead individuals throughout the rest of their expected lifetimes, and the loss of production due to individuals that were oiled and survived, but failed to breed in the subsequent spring. Taken together, the dabbling duck, swan and geese, and gull guilds account for 94 percent of total estimated mortality from the *M/T Athos I* oil spill.[1] Surrogate species of these three guilds were used to develop models for foregone production. Foregone production in other guilds was calculated based on the guild with the most similar life history characteristics.

The assumption of post-oiling reproductive failure is based largely upon studies by Anderson et al. (1996). The authors report that oiled and rehabilitated brown pelicans did not attempt to breed for two years after release. Waterfowl are typically smaller than pelicans, and undertake substantial migration, placing them under greater physiological stress from oiling. As such, these guilds were assumed not to breed for one year after oiling, as a conservative estimate of such reproductive failure. Golightly (pers. comm., 2005) reports that similar effects are expected for gulls and other guilds.

### 7.1 Surrogate Species

For the three primary guilds, a single surrogate species was selected and used to calculate production foregone: mallards (for dabbling ducks), Canada geese (for swans/geese), and ring-billed gull (for gulls). Each surrogate species was selected because that species represented the majority of individuals estimated to be killed within its respective guild, and because that species was relatively well studied. The use of a surrogate or representative species in wildlife injury assessments is commonly used to simplify calculations (Hampton and Zafonte, 2003; Peterson and Lipcius, 2003). For other guilds, the model for the surrogate species with the most similar life history characteristics was used - mallards for diving ducks and ring-billed gulls for the remaining guilds (Forsell, 2007).

### 7.2 Age-Structured Population Models

In order to estimate the age distributions of individuals killed and numbers of offspring lost, a simple two-stage, age-structured population model was constructed for each of the three surrogate species. Such models use two parameters, annual survival (*S*) and fecundity (*F*), to estimate production and survival of age cohorts from year to year. Each age class, in this case juveniles and adults, is assigned a value for survival and fecundity. The model consists of a component controlling development and mortality:

$$N_{x+1,t+1} = N_{x,t} S_x$$

[1] For indirect and total injury estimates, the snow geese are re-integrated into the numbers for the swans/geese guild.

where $N$ is number of individuals of age $x$ at time $t$ and $S$ is survival, and a component controlling reproduction:

$$N_{x,t+1} = \sum_{x=0}^{n} N_{x,t} F_x$$

where $F$ is fecundity at age class $x$.

Demographic parameters required to construct these models were collected from published literature sources or from parameters used in USFWS harvest models. In general, there exists convincing evidence for differences in annual survival rates between yearling and adult birds for many waterfowl species, including mallards and Canada geese (Johnson et al., 1992). Ludwig (1967) also estimates lower annual survival rates for non-breeding (less than 2.5 years) ring-billed gulls. As such, annual survival is treated separately for young (either yearling or non-breeding) and adult birds for all surrogate species, necessitating a two age-class model. Good evidence exists for sex-specific differences in adult annual survival rates in some dabbling duck species due to predation during nesting (Johnson et al., 1992), so mallards are treated as a two-sex population, with different survival rates for adult males and females.

Survival for mallards was estimated as an average of annual adult male, adult female, and yearling survival rates from USFWS mallard adaptive harvest management models (USFWS, 2005a and 2005b) for 1999 through 2004. Survival for Canada geese was estimated as an average of the annual adult and yearling survival rates from unpublished USFWS Canada geese adaptive harvest management models (Nichols, pers. comm., 2005) for 1999 through 2004. Survival for both adult and non-breeding ring-billed gulls was estimated from field studies (Ludwig, 1967).

Fecundity, typically reported as number of fledged females produced by each female per year, is a summary statistic that integrates the variable effects of likelihood of breeding, nesting density, multiple nesting, likelihood of re-nesting, nest success, clutch size, egg survival, brood survival, and other factors. For this analysis, fecundity is considered to be the number of all fledged chicks, rather than only females, as the sum injury to the population is at issue. This value can be derived as a function of estimates of these parameters, or estimated directly from field data. In general, the parameters are difficult to estimate except via field study, and they are highly variable on multiple spatial and temporal scales (Johnson et al., 1992).

Fecundity for mallards was estimated as an average of annual fecundity from USFWS mallard adaptive harvest management models (USFWS, 2005a; 2005b) derived from field data for 1999 through 2004. Fecundity for ring-billed gulls was also estimated directly from field studies (Emlen, 1956). Fecundity for Canada geese was estimated as a function of literature reported values (Nichols et al., 2003; Brakhage, 1965) for average clutch size, egg survival, nest success, and brood survival, as such:

$$F_x = CEGB$$

where $F$ is fecundity at age class $x$, $C$ is average clutch size, $E$ is average egg survival, $G$ is nesting success, and $B$ is average brood survival. Note that this assumes that all Canada geese of breeding age attempt to breed. Canada goose and ring-billed gull populations are assumed to have even sex ratios. For mallards and Canada geese, only values applicable to the Atlantic Flyway population of birds were selected for use. The estimated demographic parameters of the three model species, and source literature used to derive these values, are included in Table 10.

**TABLE 10.** Estimated demographic parameters for three model species. (Sources: A – USFWS, 2005a; 2005b; B – Nichols, 2005; C – Ludwig, 1967; D – Nichols et al., 2003; E – Brakhage, 1965; F – Emlen, 1956)

| Parameter | Mallards | Canada geese | Ring-billed gulls |
|---|---|---|---|
| Percentage males | 0.54 [A] | 0.5 | 0.5 |
| **Annual adult survival** | **0.59(M) / 0.54(F) [A]** | **0.77 [B]** | **0.87 [C]** |
| **Annual juv. survival** | **0.51 [A]** | **0.45 [B]** | **0.71 [C]** |
| Age of first breeding | 1 | 3 | 2.5 |
| Clutch size | - | 4.9 [D] | - |
| Egg survival | - | 0.85 [D] | - |
| Nest success | - | 0.56 [D] | - |
| Brood survival | - | 0.68 [E] | - |
| **Annual fecundity** | **2.07 [A]** | **1.58** | **0.67 [F]** |

It should be noted that the actual demographic parameters for the members of the sub-population of the surrogate species killed in the *M/T Athos I* oil spill are unknown. The parameters used in these models are, in most cases, averages of widely varying data, collected in different time periods, possibly from different sub-populations in different geographic regions. It is also important to consider that changes in these parameters over time drive complex annual fluctuations in the populations of these species. Other than averaging parameters for recent years, no attempt has been made to reconcile the values used in these models with the anticipated future status of the real populations of these surrogate species in the region of interest.

As a starting point, the age-structured models were iterated through 50 years with the above parameters. As expected with these population models, a stable age distribution evolves, typically after 5 or 10 years. It was assumed that the age structure of all individuals impacted by the spill in the four guilds would be similar to this modeled stable age structure. The hypothetical stable age structure of the three surrogate species is depicted in Figure 12. Mallards, with low annual survival values, have a steep age structure, with most individuals being fairly young. Females have an even steeper age structure, due to higher female mortality. Canada geese and ring-billed gulls have a more equitable age structures, due to higher annual survival rates. Longevity records for the three model species from Clapp et al. (1982) are: Mallard - 26 years, Canada goose – 28 years, ring-billed gull – 27 years. The maximum achievable age in the model was taken to be 25 years for Canada geese and ring-billed gulls, and 20 years for mallards.

### 7.3 Production Foregone

Production foregone was calculated as a two-step process. First, production lost due to direct spill mortality was calculated. For each guild, the total number of birds estimated to have died as a result of the spill from Table 9 was distributed among age-classes according the stable age distribution described above. These numbers were used as inputs to the age-structured model for that species, which was iterated for either 7 or 9 years – one third of the maximum amount of time the youngest age-class could have lived in whole years. At each yearly time step, estimated discounted lost production was calculated from birds killed in the spill that would otherwise have survived to that year, discounted using a 3 percent annual discount rate. Note that for mallards, the total numbers from Table 9 were divided into males and females based upon average Atlantic Flyway sex ratios reported by USFWS (2005b) from 2004 hunting season surveys. Each sex was then assigned to age-classes from the stable age distribution described above, and used as model input.

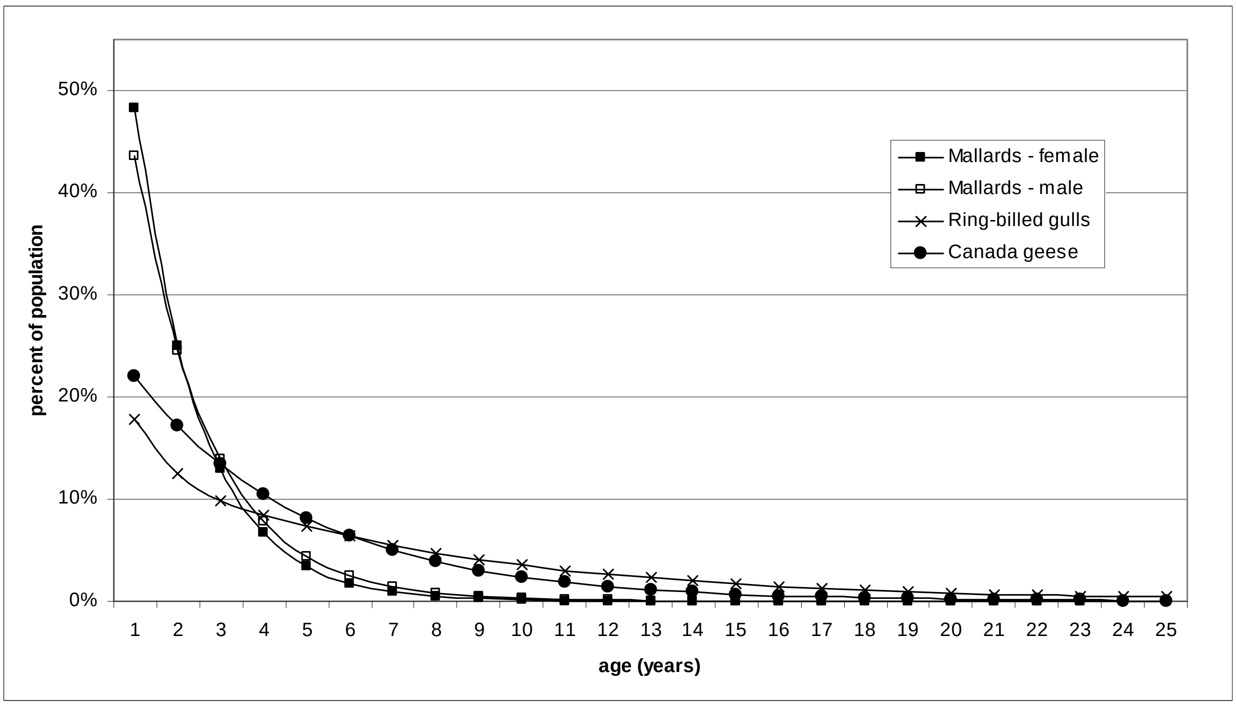



**FIGURE 12.** Age structure as percent of individuals in a given age class derived from age-structure population models with above demographic parameters for the three surrogate species.

Additionally, discounted production lost due to reproductive failure was calculated. For each guild, the total number of birds estimated to have been oiled but survived from Table 9 was assigned age-classes according to the modeled stable age distribution. These numbers were used as inputs to the same model to calculate discounted lost production for only the single year following the spill due to reproductive failure, discounted using a 3 percent annual discount rate. Production lost from mortality and reproductive failure was then summed together to calculate total production foregone for each of the four guilds, as shown in Table 11. Note that calculations were carried out in units of fractional individuals, while results are reported in units rounded to whole individuals. Some small apparent arithmetic error may result.

**TABLE 11.** Production foregone (fledged young using 3% annual discount rate) for each guild due to direct spill mortality and reproductive failure from the *M/T Athos I* oil spill, as derived from age-structured population models iterated for one third of the maximum lifespan (7 or 9 years) of youngest individual killed in whole years. # Killed Surviving is the number of birds killed in the spill that would otherwise have survived to that year.

| | **Guild:** | **Dabbling ducks** | | **Swans/geese** | | **Gulls** | | **Diving Ducks** | | **Diving Birds** | | **Shorebirds** | | **Wading Birds** | | **Kingfishers** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Surrogate:** | **(Mallard)** | | **(Canada Goose)** | | **(Ring-Billed Gull)** | | **(Mallard)** | | **(Ring-Billed Gull)** | | **(Ring-Billed Gull)** | | **(Ring-Billed Gull)** | | **(Ring-Billed Gull)** | |
| **Mortality** | **Year** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** | **# Killed Surv.** | **Lost Prod.** |
| | 0 | 605 | - | 1,416 | - | 1072 | - | 82 | - | 64 | - | 55 | - | 10 | - | 4 | - |
| | 1 | 343 | 571 | 1090 | 658 | 888 | 265 | 46 | 78 | 53 | 16 | 46 | 14 | 8 | 2 | 3 | 1 |
| | 2 | 195 | 299 | 839 | 631 | 758 | 259 | 26 | 41 | 45 | 15 | 39 | 13 | 7 | 2 | 3 | 1 |
| | 3 | 111 | 157 | 645 | 606 | 656 | 232 | 15 | 22 | 39 | 14 | 34 | 12 | 6 | 2 | 2 | 1 |
| | 4 | 63 | 82 | 496 | 452 | 567 | 195 | 9 | 11 | 34 | 12 | 29 | 10 | 5 | 2 | 2 | 1 |
| | 5 | 36 | 43 | 382 | 337 | 489 | 164 | 5 | 6 | 29 | 10 | 25 | 8 | 5 | 2 | 2 | 1 |
| | 6 | 21 | 23 | 293 | 252 | 422 | 137 | 3 | 3 | 25 | 8 | 22 | 7 | 4 | 1 | 2 | 1 |
| | 7 | 12 | 12 | 225 | 187 | 363 | 115 | 2 | 2 | 22 | 7 | 19 | 6 | 3 | 1 | 1 | 0 |
| | 8 | - | - | 173 | 140 | 312 | 96 | - | - | 19 | 6 | 16 | 5 | 3 | 1 | 1 | 0 |
| | 9 | - | - | 133 | 104 | 268 | 80 | - | - | 16 | 5 | 14 | 4 | 2 | 1 | 1 | 0 |
| | **Total** | | **1,187** | | **3,369** | | **1,543** | | **163** | | **92** | | **79** | | **14** | | **6** |
| **Reproductive Failure** | **Year** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** | **Oiled/ Surv.** | **Lost Prod.** |
| | 0 | 611 | - | 2,518 | - | 1,342 | - | 26 | - | 8 | - | 0 | - | 14 | - | 1 | - |
| | 1 | - | 577 | - | 1,171 | - | 331 | - | 24 | - | 2 | - | 0 | - | 3 | - | 0 |
| | **Total** | | **577** | | **1,171** | | **331** | | **24** | | | | | | **3** | | |
| | **Grand Total** | | **1,764** | | **4,540** | | **1,875** | | **187** | **2** | **94** | **0** | **79** | | **17** | **0** | **6** |

## 8.0 INJURY ASSESSMENT OF OTHER BIRDS AND WILDLIFE

Other birds and wildlife that were potentially affected by the spill were aquatic mammals and bald eagle. Injury to aquatic mammals (muskrat [*Ondatra zibethicus*] and otters [*Lutra canadensis*]) was assessed using two methods: 1) aerial counts of huts in oiled and unoiled areas; and 2) telephone surveys of trappers with trapping rights in the impacted areas. Based on the trapper phone survey and the limited number of houses observed in the two most northern marshes (Lukens and Hamburg Cove), it was determined that the impact of the *M/T Athos I* oil spill on aquatic mammals in Delaware and possibly the Estuary as a whole was probably minimal. See Appendix B for a more detailed report on the assessment methods and results.

There are five bald eagle nesting territories in the region affected by the *M/V Athos I* oil spill, between Petty Island and Salem, New Jersey. In the period after the oil spill, 28 November 2004 through 6 January 2005, at least one bald eagle in each of the five territories was observed with oil, as was one migrant eagle. The oiling of the four nesting eagles was “trace” and the one migrant eagle had “light” oiling. Since they spend so little time on the water, they would not be susceptible to death by hypothermia. All of the nesting adults survived and no impacts to nesting success were attributable to the spill. In studies of bald eagle productivity following the *T/V Exxon Valdez* oil spill in Alaska, Bernatowicz et al. (1996) found lower nesting success in 1989, the year of the spill, only in western Prince William Sound; more distant oiled areas outside the sound had reproductive success that appeared normal. By 1990, reproductive success for bald eagles was normal in all oiled areas, compared to unoiled areas. Based on available field and literature data, injuries to bald eagles were probably minimal. See Appendix C for a more detailed report on the assessment methods and results.

## 9.0 TOTAL INJURY ESTIMATION

Total injury to birds from the *M/T Athos I* oil spill is estimated by combining direct injury due to mortality, as in Table 9, with indirect injury due to production foregone, as in Table 11. Table 12 summarizes total estimated injury to birds, in individuals, from the spill by guild and injury category. The total estimated bird injury from the *M/T Athos I* oil spill is 11,869 individuals (adults and fledged young).

**TABLE 12.** Total (direct and indirect) bird injury from the *M/T Athos I* oil spill by guild.

| Guild | Direct Injury (Adults) | Discounted Indirect Injury (Fledged Young) | | TOTAL (Adults and Fledged Young) |
|---|---|---|---|---|
| | Died | Lost Prod. (Mortality) | Lost Prod. (Repr. Failure) | |
| Dabbling ducks | 605 | 1,187 | 577 | 2,369 |
| Diving ducks | 82 | 163 | 24 | 269 |
| Diving birds | 64 | 92 | 2 | 158 |
| Gulls | 1,072 | 1,543 | 331 | 2,946 |
| Shorebirds | 55 | 79 | 0 | 134 |
| Wading birds | 10 | 14 | 3 | 27 |
| Swans/geese | 1,416 | 3,369 | 1,171 | 5,956 |
| Kingfishers | 4 | 6 | 0 | 10 |
| **Total** | **3,308** | **6,453** | **2,108** | **11,869** |

## 10.0 UNCERTAINTY ANALYSIS

The volume of data that exists to quantify bird and wildlife injury for the *M/T Athos I* oil spill is significant, and these data are of relatively high quality as compared with other oil spills. The Trustees have attempted to make best use of these data as supplemented with reasonable assumptions, but it is important to acknowledge uncertainties in this analysis.

1) **Extrapolation from aerial surveys to impacted population**: Detectability was estimated from professional opinion. All the observers, however, are experienced in conducting aerial surveys. Also, the most populous guilds have high estimated detectability which are equal to or higher than quantitatively estimated detectabilities reported in literature for similar surveys. In total, it was estimated that approximately 85-90% of total birds present in the areas surveyed were counted –a conservative estimate of survey efficiency. Between 55 and 65% of total habitat area was surveyed in each time period, and it was estimated that approximately 65% of the birds present in marsh complexes were counted during aerial surveys– again, a conservative estimate. It was assumed that individuals sighted at one location were not those sighted at another location during a particular survey.

2) **Extrapolation from ground surveys to overall degrees of oiling:** The extrapolation of the ground survey data to the entire population of potentially oiled birds was based upon a large and fairly high quality dataset. The average across-guild, across time period oiling rate for all birds was 4 percent – a conservative rate of oiling. It was assumed that the degree of oiling did not affect probability of observation. Usually, oiled or sickened birds tend to be secretive and, therefore, more difficult to observe. As such, this assumption builds a degree of conservatism into oiling mortality estimates. Also, an observer never sees all sides of all birds.

3) **Non-recovered bird outcome estimates by degree of oiling:** The estimation of outcomes by degree of oiling was based on best available published laboratory and field data, as well as extensive practical experience. Considering the degree of oiling descriptors for oiled birds (e.g., "lightly" oiled birds had 6-20 percent of their body coated with oil, and "trace" oiling was up to 5 percent coverage), the harsh weather conditions at the time of the spill, and the migratory status of many species that were affected, the outcome estimates presented here are fairly conservative. We did not make the frequent assumption that "an oiled bird is a dead bird," but made considerable effort to account for the life history of different species guilds to allow for survival of large or hardy species.

4) **Rehabilitated and released bird outcome estimates:** The estimation of outcomes for rehabilitated and released birds was based upon literature and the extensive experience of leading rehabilitation scientists who worked on this spill (Heidi Stout, Tri-State Bird Rescue and Rehabilitation). We were conservative in estimating sublethal impacts of exposure. For example, Anderson (1996) reports that oiled and rehabilitated pelicans did not attempt to breed for two seasons following exposure.

Here, only a single season of reproductive failure for rehabilitated birds was estimated oiling – a conservative estimate of impact.

5) **Age-structured models:** The demographic parameters used as input to this model were derived from the best available USFWS data averaged for last 5 years for waterfowl. For gulls, these values were derived from the best available literature studies. These parameters fit in the center of the range of parameters reported in the literature and agree with the overall understanding of the population structure of that species.

6) **Production foregone:** The estimation of production forgone accounts for a single lost generation produced by birds killed by the oil spill. It is important to note that density-dependent population dynamics (the theory that compensatory mechanisms will result in higher production by remaining individuals after the removal of some individuals by a population injury) are currently in debate and differ by species. Hampton and Zafonte (2003) concluded that many bird populations are not density dependent at the scale of injury from oil spills, and that lost production should be calculated for perpetuity to the limits of the annual discounting process. We considered only production lost from the first generation of offspring from those individuals killed, and for only one third the maximum lifespan of each model species.

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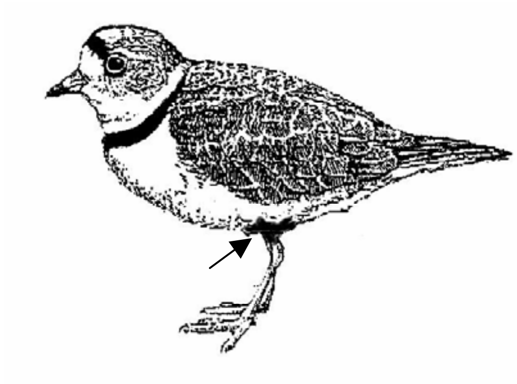
# APPENDIX A

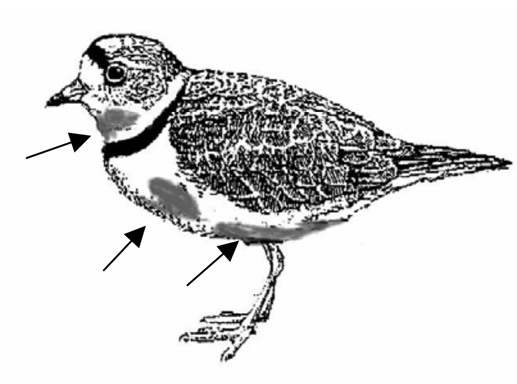
## Field Guide Used to Assist in Estimating Percent Oil on Birds

## TRACE



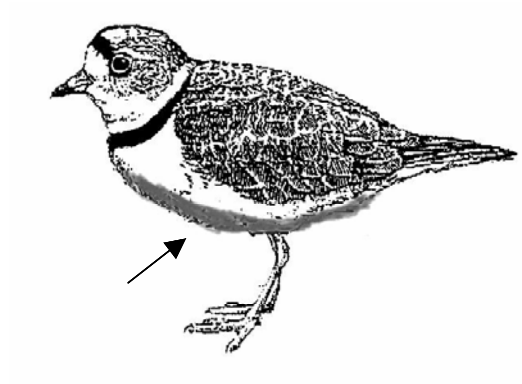
Note < 5% oiling, i.e, light soiling around the top of leg(s).

## LIGHT (below)

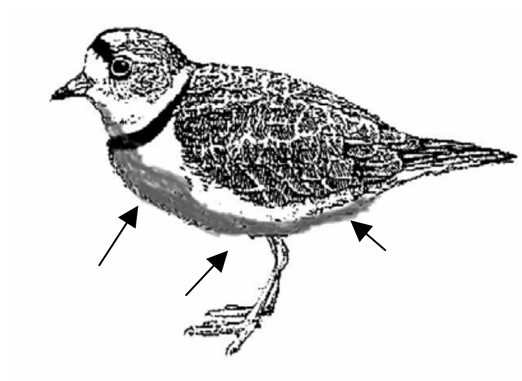


6-20% An example of light oiling may also appear as light colored spots on the face **or** breast **or** belly, **or** parts of the body.

## MODERATE

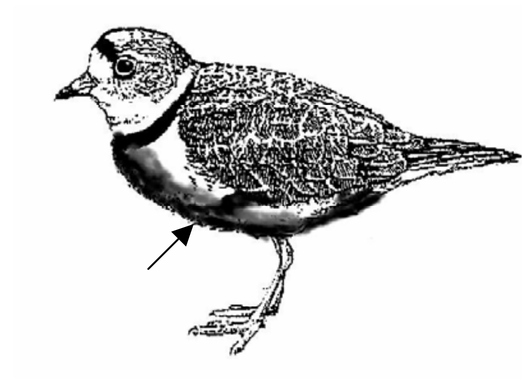


Note that the whole belly is covered with moderately darker oil

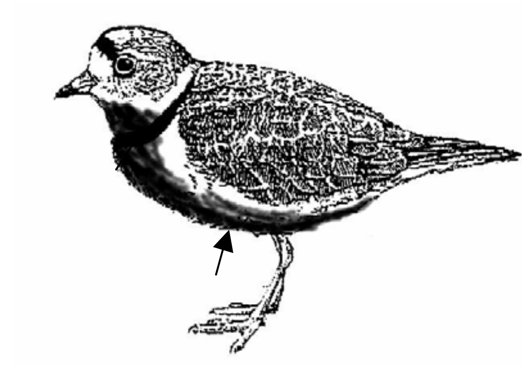


Another example of moderate oiling showing most of the breast, belly and vent covered with oil.

## HEAVY



Note that the breast and belly are covered with a very dark layer of oil.



Here, a heavy dark layer of oil is seen on the face, breast, and belly.

# APPENDIX B

## Calculations for Estimating Bird Populations

The majority of calculations used to estimate bird populations for this report were carried out in MS Excel spreadsheets. The size and complexity of these spreadsheets precludes their inclusion as tables in the hardcopy version of this report. See the accompanying digital file for a simplified version of these calculations. These calculations compute estimated populations for each guild, in each survey segment, for two time periods according to the methods described in this report, and include application of detectability adjustments, marsh sample extrapolation, and supplemental counts.

# APPENDIX C

## Injury Assessment of Aquatic Mammals Associated with the 26 November 2004 *T/V Athos I* Oil Spill

# Injury Assessment of Aquatic Mammals Associated with the 26 November 2004 *T/V Athos I* Oil Spill

**By Robert Hossler, Fish and Wildlife Regional Manager**
**Delaware Division of Fish and Wildlife**

In an effort to assess the injury to aquatic mammals (muskrat [*Ondatra zibethicus*] and otters {*Lutra canadensis*]) attributed to the 26 November 2005 *T/VAthos I* Delaware River oil spill, two assessment methods were employed. First an aerial survey of muskrat houses in potentially impacted marshes was undertaken on 4 March 2005. This aerial survey consisted of utilizing a helicopter to count houses within three tidal marsh systems along the Delaware River in New Castle County, Delaware (see attached figures). Since the houses were constructed prior to the oil spill and are frequently used as an index of muskrat population density, a comparison between a 2005 and a 2006 aerial house count could indicated whether a population decrease occurred that could be attributable to the oil spill. The second assessment method involved contacting local trappers utilizing these areas through late January-early March to see if they observed decreased muskrat or otter numbers or any indication of oiled furbearers. These two assessment techniques were to be used in tandem. The trapper survey was to be used to assess if an injury to the aquatic mammal resources existed and the aerial survey was designed to help quantify any potential injury.

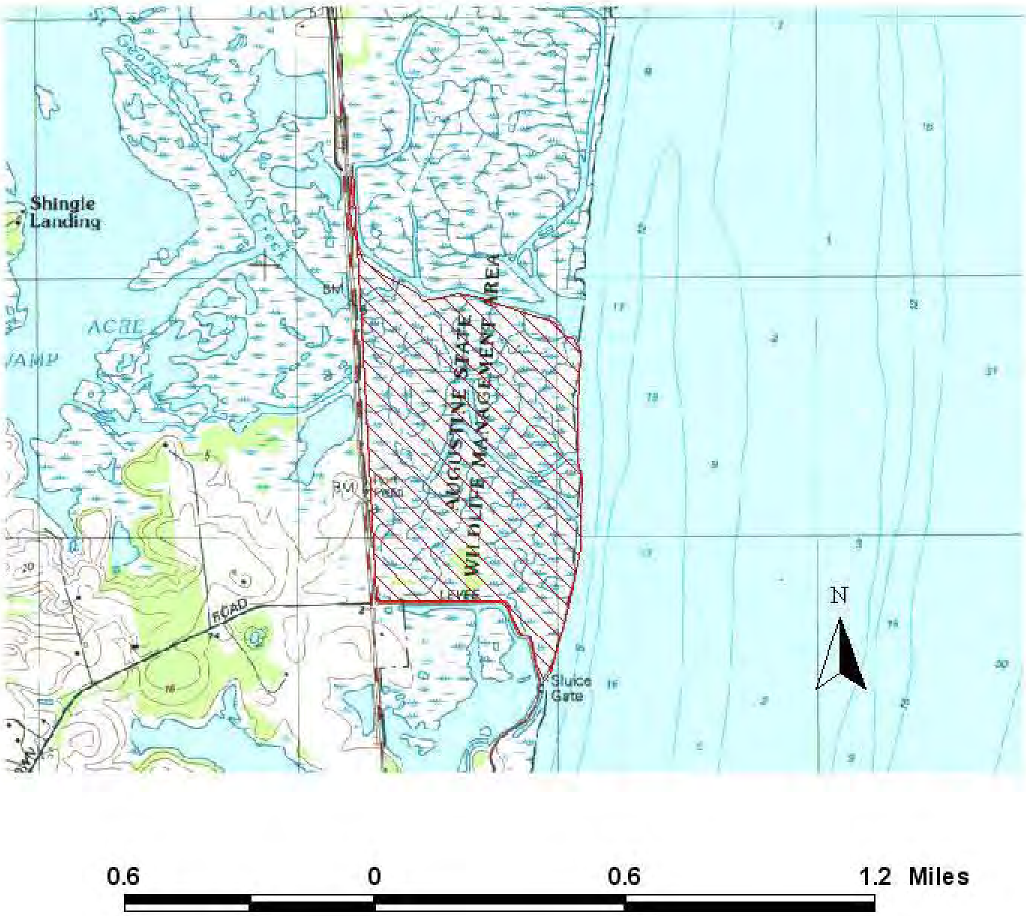
Aerial surveys of muskrat houses are best conducted when snow cover exists. Conditions on 4 March 2005 were good to ideal with 3 inches of patchy snow still visible on houses but not widespread across the marsh plain. The only limiting factor associated with the survey was that the pilot was new and flight lines could have been lower. The three marshes (Lukens [67 acres], Hamburg Cove [166 acres] and Lang [245 acres)] were selected because they were the northern most mashes in Delaware that exceeded 50 acres in size (see figures attached to this report for the survey areas). The house counts and density were as follows: Lukens Marsh – 4 houses (0.15/ha), Hamburg Cove Marsh – 16 houses (0.24/ha), and Lang Marsh (south) – 66 houses (0.67/ha). The finalized SCAT data for the Lukens and Hamburg Cove Marshes indicted that these areas received “no or minimum oiling”, whereas the Lang Marsh received “light oiling”.

Trapping opportunities on state wildlife areas in Delaware are issued though a completive bid system. All successful bidders are also required to report to the Delaware Division of Fish and Wildlife (Division) the number of animals they harvested. In March of 2005, the six trappers who received trapping rights in areas impacted by the *T/VAthos* spill were contacted by phone. All individuals indicated that they did not notice any muskrat population effects attributable to the oil spill. Additionally they did not notice any oiling on harvested furs. Trappers in Delaware and the Mid-Atlantic region as a whole are a small and tight group that frequently exchanges information. Because all of the state wildlife areas were south of the C&D Canal and, therefore, distant from some of the more heavily oiled shorelines located to the north, these individuals were also asked if they had heard of oiling fur or reduced harvests reports from fellow trappers who might have been trapping more northern areas. All the contacted trappers indicated that they had not heard any such reports. This information was consistent with that obtained from New

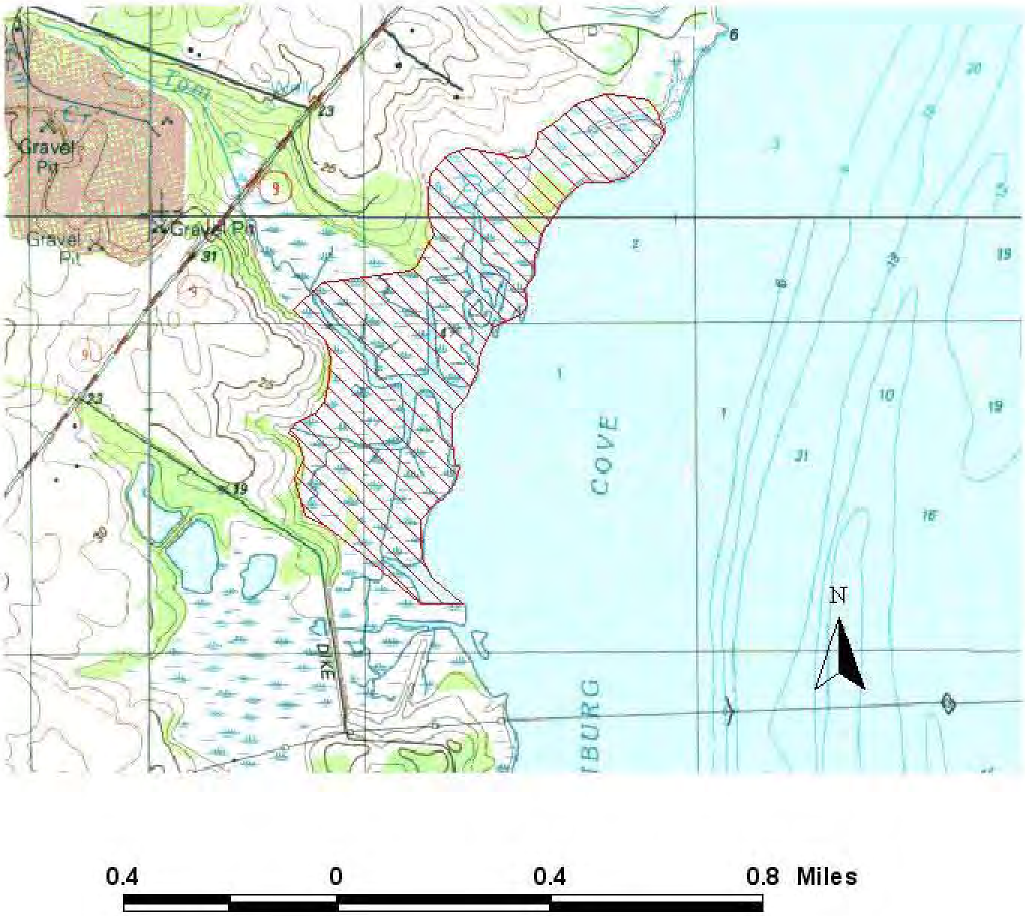
Jersey concerning their otter and muskrat trappers who also did not find any oiled pelts or documented population reductions (David Bean, NJDEP, personal communication).

Based on the trapper phone survey and the limited number of houses observed in the two most northern marshes (Lukens and Hamburg Cove), it is the Division's opinion that the impact of the *T/VAthos* oil spill on aquatic mammals in Delaware and possibly the Estuary as a whole was probably minimal. Therefore additional aerial surveys in 2006 would probably not yield much additional information pertaining to quantifiable injury especially since there can be substantial annual variation in muskrat house numbers within an area attributable to other factors (predation, trapping pressure, drought etc.). Finally it is the Division's opinion that any future potential restoration efforts designed to mitigate other wildlife and habitat injuries associated with the oil spill will undoubtedly also compensate for this minimal impact on aquatic mammals.

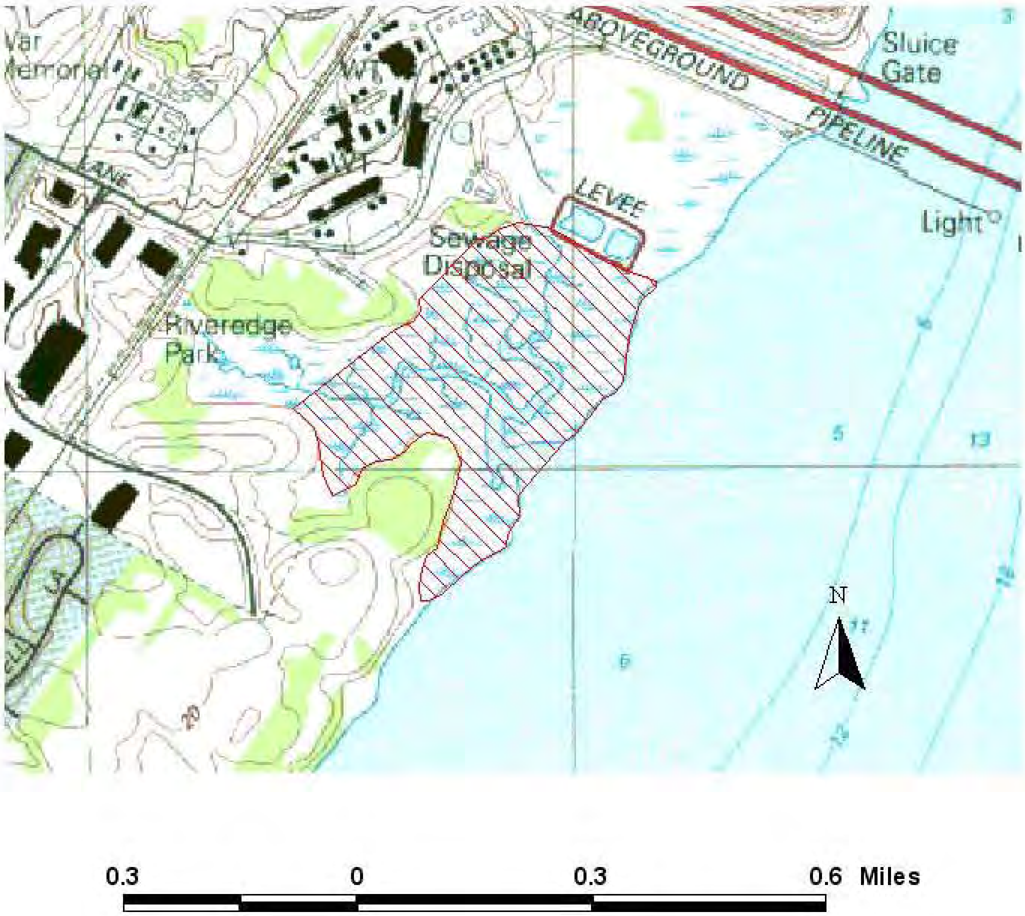
**Muskrat Survey - Lang Marsh 2005**
**Athos 1 Oil Spill**



**Muskrat Survey - Hamburg Cove 2005**
**Athos 1 Oil Spill**



## Muskrat Survey - Lukens Marsh 2005
## Athos 1 Oil Spill



# APPENDIX D

## Injury Assessment of Bald Eagles Associated with the 26 November 2004 *T/V Athos I* Oil Spill

# Bald Eagle Injury Assessment

**Kathleen E. Clark and Larry Niles**
**Endangered and Nongame Species Program**
**NJDEP Division of Fish and Wildlife**

## Summary of bald eagle oiling in New Jersey

There are five bald eagle nesting territories in the region affected by the Athos oil spill, between Pettys Island and Salem, New Jersey. In the period after the Athos oil spill, 28 November 2004 through 6 January 2005, at least one bald eagle in each of the five territories was observed with oil, as was one migrant eagle. The details of these observations are listed below by nest territory. The degree of oiling is estimated, because the dark oil could generally not be seen on the dark body plumage of bald eagles. In general, oiling was observable only on the white head, white tail and/or yellow legs.

<u>Pettys Island area</u>: 1 adult with oil observed on 12/3, 12/4, and 12/16. Oiling was observed on the ventral tail on all three occasions, suggesting it was one individual affected. A second adult eagle was observed on four other dates and described as clean.

<u>Mantua Creek area</u>: One adult with oil was observed on 11/29 and 12/7. Later, on 12/18 a pair was observed at their nest and both birds were described as clean.

<u>Mond’s Island area</u>: This pair was observed on 12/2 and 12/10 when both birds were described as clean. On 12/14, however, the pair was observed at the nest, and the female had oil on the back of her head and on the legs. No subsequent sightings were made through mid-January.

<u>Supawna Meadows NWR</u>: Few observations of this pair were available, but on 12/2 the pair was sighted at the nest and both birds were described as clean. On 1/2, however, one bird was observed to be lightly oiled, and was again on 1/6. On 1/12, both birds were described as clean.

<u>Mannington Meadows</u>: The birds of this pair were not sighted until 12/26, when one bird was described as lightly oiled. Subsequent observations indicated both birds were clean.

One migrating bald eagle was observed to be oiled on the upper neck and tail when seen on the Delaware Bay beach of Villas, NJ on 12/6. It was not seen again after that date, and was presumed to have been oiled in the Camden area before heading south through Cape May County.

ENSP staff supervised observations in all of these eagle nest areas, in addition to the wildlife surveys conducted in the primary spill areas of the Delaware River and tributaries from Cooper River to Oldman’s Creek. Beginning on 12/2, staff directed the placement of deer carcasses in all five eagle nest territories to provide alternatives to oiled wildlife for foraging eagles. Eagles were not observed feeding on the deer carcasses, but that would have been the first step to any attempt to capture oiled eagles for treatment. ENSP staff did not attempt to make any captures of eagles, nor did we confirm any bald eagle mortality associated with the Athos oil spill.

**Expected impacts of injuries**

The Athos oiling of bald eagles occurred in early winter, a time when oiling could cause hypothermic conditions in birds. Eagles, like all birds, depend on feather integrity to help maintain their body temperature. Oiling compromises feathers and thus eagles' ability to maintain body temperature. In November and December, such conditions could have contributed to lower survival of affected individuals.

In the Athos oil spill, there were hundreds of Canada geese and gulls oiled, many of which became more vulnerable to predation by eagles as a result. Capturing and feeding on wildlife oiled by *Athos* oil may explain the appearance of oil on eagles' white heads and tails. Thus eagles likely ingested oil in the course of eating oiled wildlife, as well as through preening their own feathers to clean them. The Athos oil was relatively low in toxicity, but the physical aspect of the oil could have caused impaired digestion. There is research showing that hydrocarbons in this type of oil cause changes in they hypothalamus leading to physiological stress. In mallards dosed with a similar type of oil this resulted in decreased pair bonding and inattention to the nest and eggs (L. Miller, pers. commun.).

**Nest success of eagles in 2006**

On the surface, nest success of bald eagles in the five territories affected by the spill was not substantially different in 2005 than 2004. Three of the five nesting pairs were already reproductively impaired due to environmental conditions of the Delaware River and several of its tributaries. However, we suspect that the spill and cleanup operations may have had a negative influence on the eagles' behavior as nesting season began in January.

- Pettys Island area: This pair nested in 2003 and 2004, producing eggs that failed to hatch successfully. In 2004 they raised a foster eaglet provided by NJDFW. In 2005 they moved their nest to a new site and laid one egg that failed to hatch. This pair may have moved their nest site in reaction to the spill-related activity around the island and the Delaware River. It is just as likely, however, that they moved due to disturbance around their original nest site in the 2004 nesting season.
- Mond's Island area: This pair has failed to hatch their own eggs for 14 of the last 15 years. In 2005 they did not lay any eggs, unlike the previous 15 years. This may be a result of a new female in the pair, arriving too late to establish a pair bond and attempt to nest. We must consider, however, that the oil affected their ability to form a pair bond effectively, resulting in at least one lost nesting season.
- Mannington Meadow: This pair did not nest in the same location as seven previous years. They moved but the new nest site could not be found by observers, thus if they nested in 2005 it was not recorded. Their previous nest success rate was below average but they raised three young in the previous four years. Because cleanup operations did not affect the Mannington Meadow territory, we do not consider that as a reason for the move. However, the fact that one of these birds was oiled, then their nesting behavior changed,

leaves the possibility that this bird's oiling played a part in their abandonment of their traditional nest location.

- Supawna Meadows NWR: This pair nested in the same location as 2004, and they raised one young successfully. This represents normal production for this pair.
- Mantua Creek area: This pair successfully raised two young in 2005, similar to its productivity in 2004 (2 young) and 2003 (2 young). There were no changes observed to indicate deleterious effects of the spill.

**Conclusions**

We determined that five resident, breeding bald eagles and one migrant bald eagle became oiled during the Athos spill event. The oiling of the five eagles carried the risk of reducing the survival of New Jersey's resident breeding population of bald eagles, particularly in the region of the Delaware River where eagles' health may already be impaired. It is likely that in this region this oil spill was additive in its effects on long term viability of individual eagles and their physical habitat.

We cannot link this oil spill with mortality of individual birds, but we do suggest that it contributed to lost potential productivity due to the failure of one pair to nest, and the possible failure of a second pair to nest, in 2005. In the first case (Mond's Island) the new female mate had a higher chance for successful nesting as a new bird that may not have accumulated embryotoxic contaminants; impaired pair bonding would have eliminated 2005 as a nesting season. In the second case (Mannington) the pair did not nest at the site where they had for seven years, and were not found despite a search of the area; their possible failure to nest is a loss for the area's population.

In addition, this spill added to the impaired condition of this area of the Delaware River and eagle habitat in the tributaries of Big Timber Creek, Woodbury Creek, and possibly others downstream. These impacts may impede habitat and water quality recovery for eagles and for eagle prey (fish and waterfowl) for years to come.

The single migrant bald eagle was moderately oiled and is more likely to have died of its oiling. It was in the process of migrating, when it must compete for food and roosting space in areas with which it is unfamiliar, as well as expend energy in migrating flight. Because of adult eagle's coloring, oil could only be identified on the white heads and tails and yellow legs; oiling on their brown bodies would not have been observable. This migrant bird was clearly oiled on both head and tail, and thus may have actually been in the "heavy oil" category. This bird may have been a New York or New England resident migrating through New Jersey. We cannot determine the injury to this bird with any certainty.

In conclusion, we do not have sufficient evidence to state the injuries to bald eagles caused by their exposure to Athos oil. The evidence is insufficient to pursue this matter further.