Appendix C

Demographic Parameters for Calculation of Lost Bird-Years

TABLE 1: Potential Proxy Species for Bird Injury Calculations

Bird Category	Species Suffering Mortality from Stuyvesant Spill	Potential Source of Demographic Parameters
Grebes	Western Grebe Eared Grebe Pie-billed Grebe Unknown Grebe	*North Cape* Grebe
Loons	Common Loon Red-throated Loon	*North Cape* Loon
Non-Marbled Murrelet Alcids	Tufted Puffin Rhinocerous Auklet Cassin's Auklet Pigeon Gillemot Common Murre	Common Mure
Gulls	Glaucous-winged Gull Western Gull California Gull Ring-billed Gull Sabine's Gull Unknown Gull	Western Gull
Procellarids	Laysan Albatross Northern Fulmar Pink-footed Shearwater Sooty Shearwater Buller's Shearwater	Northern Fulmar
Cormorants	Double-crested Cormorant Brandt's Cormorant Pelagic Cormorant Unknown Cormorant	Double-crested Cormorant
Pelicans	Brown Pelican	Brown Pelican
Waterfowl and Wetland birds	White-winged Scoter Surf Scoter Greater White-fronted Goose Canada Goose Caspian Tern Common Tern Great Egret American Coot Red Phalarope Red-necked Phalarope	*North Cape* Scoter

In the past, Trustees have compiled demographic information and calibrated injury models for various bird families. Several are listed in Table 1 next to species with documented mortality from the Stuyvesant spill. The demographic parameters for each specie group/family presented below have been calibrated to be consistent with a population that is roughly stationary in numbers (i.e., non-declining or non-increasing). The extent to which this sort of calibration is reasonable depends on both the specie being considered and the application of the modeling.

General Grebe

The North Cape REA (Sperduto et al, 1999) calculates injury to grebes by averaging demographic estimates for a variety of grebe species. The following set of roughly stationary demographic parameters is based upon their analysis:

- *Age of First Breeding: 2* Years Old
- *Female Offspring per Adult Female (Annual):* 0.91
- *Survivorship (From fledge to one year of age): 60*%
- *Annual Survivorship (Age 1+): 64*.7%
- *Maximum Age:* 24 Years Old

The only difference between these parameters and those used by Sperduto et al (1999) is that annual survivorship beyond the first year has been increased 2.7%. This calibrates the life history to a population that maintains an approximately constant population size.

General Loon

The North Cape REA (Sperduto et al, 1999) calculates injuries to loons based upon common loon demographics. The following set of roughly stationary demographic parameters is based upon their analysis:

- *Age of First Breeding:* 5 Years Old
- *Female Offspring per Female (Annual):* 0.27
- *Survivorship (From fledge to one year of age):* 76%
- *Survivorship (Age 1+):* 88.5%
- *Maximum Age:* 24 Years Old

The only difference between these parameters and those used by Sperduto et al (1999) is that annual survivorship beyond the first year has been increased 0.5%. As with the grebe calibration, this adjusts the implied loon life history to maintain an approximately constant population size.

Western Gull

Nur et al (1994) create a population model for western gull at the Farallon Islands. The following parameters draw from their analysis:

- *Age of First Breeding:* 3 Years Old
- *Male Offspring per Male (Age 3):* 0.012
- *Male Offspring per Male (Age 4):* 0.152
- *Male Offspring per Male (Age 5):* 0.457
- *Male Offspring per Male (Age 6):* 0.660
- *Male Offspring per Male (Age 7):* 0.695
- *Male Offspring per Male (Age 8):* 0.765
- *Male Offspring per Male (Age 9):* 0.785
- *Male Offspring per Male (Age 10):* 0.750
- *Male Offspring per Male (Age 11):* 0.710

- *Male Offspring per Male (Age 12 and 13):* 0.725
- *Male Offspring per Male (Age 14):* 0.705
- *Male Offspring per Male (Age 15):* 0.660
- *Male Offspring per Male (Age 16+):* 0.610
- *Survivorship (From fledge to one year of age):* 60%
- *Annual Survivorship (Age 1-2):* 75%
- *Annual Survivorship (Age 2-3): 82%*
- *Annual Survivorship (Age 3-4 to 6-7): 84%*
- *Annual Survivorship (Age 7-8 and 8-9): 83%*
- *Annual Survivorship (Age 9-10 and 10-11): 82%*
- *Annual Survivorship (Age 11-12): 81%*
- *Annual Survivorship (Age 12-13 to 14-15): 80%*
- *Annual Survivorship (Age 15-16 and 16-17): 78%*
- *Annual Survivorship (Age 17-18):* 75%
- *Annual Survivorship (Age 18-19): 67%*
- *Annual Survivorship (Age 19-20): 57%*
- *Annual Survivorship (Age 20-21): 50%*
- *Maximum Age:* 21 Years Old

The Nur et al (1994) model tracks males in the population (assuming a 1:1 sex ratio).[1] The difference between the above parameters and those used by Nur et al (1994) is that the survivorship from fledge to one year of age has been increased 4.5% to calibrate the model to approximate stationarity. This 60% survivorship from fledge to Age 1 is still within the range considered by Nur et al (1994).

Northern Fulmar

Northern fulmar may be longer lived than other procellarids injured by the spill. Using northern fulmar as a proxy for procellarid injury calculation may overestimate bird-year loss for the entire procellarid family (depending on the demographics of the other birds that died). Since we have yet to evaluate the life histories of other procellarids injured in the Stuyvesant spill, we present calibrated parameters for northern fulmar demographics. This is in the interest of providing a timely response to Entrix.

The following northern fulmar demographic parameters have been calibrated to imply a roughly constant population size:

- *Age of First Breeding:* 5 Years Old
- *Female Offspring per Female (Age 5): 0.013*
- *Female Offspring per Female (Age 6): 0.026*
- *Female Offspring per Female (Age 7): 0.039*
- *Female Offspring per Female (Age 8): 0.053*
- *Female Offspring per Female (Age 9): 0.066*
- *Female Offspring per Female (Age 10): 0.079*
- *Female Offspring per Female (Age 11): 0.092*
- *Female Offspring per Female (Age 12): 0.105*
- *Female Offspring per Female (Age 13): 0.118*

[1] Male western gulls are perceived to be the limiting factor in western gull population growth (Nur et al 1994, Pierotti and Annet 1995). During the 1970s, some western gull populations displayed male-female sex ratios close to 2:3, presumably due to the feminization of male embryos from DDT (Pierotti and Annet 1995). Since that time sex ratios have returned to "near equity" (Pierotti and Annet 1995).

- *Female Offspring per Female (Age 14): 0.131*
- *Female Offspring per Female (Age 15): 0.144*
- *Female Offspring per Female (Age 16): 0.158*
- *Female Offspring per Female (Age 17): 0.171*
- *Female Offspring per Female (Age 18): 0.184*
- *Female Offspring per Female (Age 19): 0.197*
- *Female Offspring per Female (Age 20+): 0.21*
- *Annual Survivorship (Age 69-70):* 6.9%
- *Annual Survivorship (Age 68-69):* 16.9%
- *Annual Survivorship (Age 67-68):* 26.9%
- *Annual Survivorship (Age 66-67):* 36.9%
- *Annual Survivorship (Age 65-66):* 46.9%
- *Annual Survivorship (Age 64-65):* 56.9%
- *Annual Survivorship (Age 63-64):* 66.9%
- *Annual Survivorship (Age 62-63):* 76.9%
- *Annual Survivorship (Age 61-62):* 86.9%
- *Annual Survivorship (Age 5-6 to 60-61):* 96.9%
- *Annual Survivorship (Age 4-5):* 89.6%
- *Annual Survivorship (Age 3-4):* 82.4%
- *Annual Survivorship (Age 2-3):* 75.1%
- *Annual Survivorship (Age 1-2):* 67.9%
- *Survivorship (From fledge to one year of age):* 60.6%
- *Maximum Age:* 70 Years

A review by Hatch and Nettleship (1998) provides the basis for these choices. Their summary includes the following information specific to deriving demographic model parameters specific to northern fulmar:[2]

- *Age of First Breeding:* Dunnet (1992) notes first evidence of breeding northern fulmars at five years of age.
- *Female Offspring per Female (Ages 20+):* Hatch and Nettleship (1998) present unpublished data by Nettleship that show the proportion of fulmar pairs that produce a fledgling ranged from 37.2 - 46.9% in three "good" years, and 5.4 % in one "bad" year. If we assume (1) the productivity is at the midpoint of the range in good years (0.4205) and (2) a one-to-one sex ratio, then the full productivity of northern fulmars is (.4205)(.5) = 0.21025,
- *Female Offspring per Female (Age 5-19):* Dunnet (1992) finds evidence that first breeding in northern fulmars occurs when the birds are between five and twenty years of age. We assume that the productive capacity of northern fulmar increases linearly such that it is 6.25% in Year 5, 12.5% in Year 6, etc. until 100% are breeding in Year 20.
- *Annual Survivorship (Age 5-6 to 60-61):* Hatch (1987b) estimates average annual survival rates of northern fulmar at 96.9%.
- *Maximum Age:* With a constant 96.9% adult survivorship it is reasonable for some northern fulmar to live a very long time (greater than 80 years). Evidence of there long-lived life history was found in Scotland where several birds banded in 1951 were still breeding in 1990 at ages likely to be greater than 50 years old (Dunnet 1991). For the purpose of this analysis, we chose a maximum age of 70. Because of our belief that the adult survivorship will decline as a bird reaches the older age classes, we assume that,

[2] The below citations are cited as referenced in Hatch and Nettleship (1998). They are not cited as primary sources.

starting at Age 61, survivorship decreases 10% per year until it reaches zero at 70 years old.

To calibrate the model, we assumed that the survivorship from Ages 0-1 to 4-5 increased linearly each year such that 96.9% adult survivorship was achieved at Age 5-6. We then calibrated Age 0-1 survivorship so that the sequence was consistent with a population maintaining a constant population size.

Double-Crested Cormorant

The following double-crested cormorant demographic parameters have been calibrated to imply a roughly constant population size:

- *Female Offspring per Female (Age 1):* 0.028
- *Female Offspring per Female (Age 2):* 0.12
- *Female Offspring per Female (Age 3):* 0.58
- *Female Offspring per Female (Age 4+):* 0.54
- *Survivorship (From fledge to one year of age):* 48%
- *Annual Survivorship (Age 1-2):* 74%
- *Annual Survivorship (Age 2+):* 83.2%
- *Maximum Age:* 24 Years

A review by Hatch and Weseloh (1999) provides the basis for these parameter choices.[3] Their summary includes the following information specific to deriving demographic model parameters specific to double-crested cormorants:

- *Female Fledges per Female (Age 1).* Observations by van der Veen (1973) suggest that 4.7% of females first bred at Age 1. Hatch and Weseloh's (1999) summary of numerous studies suggest that each double-crested cormorant nest produces between 1.2-2.4 fledges per nest. If we assume the low end of that range (which we use to calibrate demographic information) and a one-to-one sex ratio, then each Age 1 female produces (.047)(1.2)(.50) = 0.028 fledging females on average.
- *Female Fledges per Female (Age 2).* Observations by van der Veen (1973) suggest that 16.5% of females first breed at Age 2. If we assume that 90% of past breeders nest, a one-to-one sex ratio, and 1.2 fledges per nest, then Age 2 each female produces (.165)(1.2)(.50) + (.047)(1.2)(.50)(.9) = 0.12 fledging females on average.
- *Female Fledges per Female (Age 3).* Observations by van der Veen (1973) suggest that 78.8% of females first breed at Age 3. If we assume that 90% of past breeders nest, a one-to-one sex ratio and 1.2 fledges per nest, than each Age 3 female produces (.788)(1.2)(.50) + (.212)(1.2)(.50)(.9) = 0.59 fledging female on average.
- *Female Fledges per Female (Age 4+).* Observations by van der Veen (1973) suggest that all Age 4 and later females have already breed once. If we assume that 90% of past breeders nest, a one-to-one sex ratio and 1.2 fledges per nest, then each Age 4+ female produces (1.2)(.50)(.9) = 0.54 fledging female on average.
- *Survivorship (From fledge to one year of age).* van der Veen (1973) estimates Age 0 survival at 48%.

[3] The below citations are cited as referenced in Hatch and Weseloh (1999). They are not cited as primary sources.

- *Annual Survivorship (Age 1).* van der Veen (1973) estimates Age 1 survival at 74%.
- *Annual Survivorship (Age 2+).* van der Veen (1973) estimates Age 1 survival at 85%. We chose the slightly lower value of 83.2% to calibrate the model to a population that was maintaining constant numbers over time.
- *Maximum Age.* Klimkiewicz and Futcher (1989) note that the oldest banded bird in 5,589 encounters was 17 years 9 months old. We choose a maximum age of 24 because that is the oldest age that at least 1% of the cormorants will reach given the demographic assumptions presented above.

Overall, choosing low range values for (1) *Age 2+ Survivorship* and (2) *Fledges per Nest* calibrates the model.

Brown Pelicans
Demographic information on brown pelicans was compiled by the California Office of Environmental Health Hazard Assessment and summarized in the Cal/Ecotox online database (http://www.oehha.org/cal_ecotox/default.htm). The Cal/Ecotox database (and the research papers cited therein) provides the primary data source for the below potential parameter choices:

- *Age of First Breeding:* 3 Years Old
- *Female Offspring per Adult Female:* 0.33
- *Annual Survivorship (Age 3+):* 88%
- *Annual Survivorship (Age 2-3):* 80%
- *Annual Survivorship (Age 1-2):* 72%
- *Survivorship (From fledge to one year of age):* 64%
- *Maximum Age:* 34 Years

These are based upon the following citations from the Cal/Ecotox database.[4]

- *Age of First Breeding:* Lovett and Joanen (1974) note that the age of first nesting is at three years old.
- *Female Offspring per Adult Female:* Anderson et al. (1982) examine six years of data and find 0.18-0.88 fledglings per nest on West Anacapa Island (California) and 0.23-1.20 fledglings per nest on Isla Coronado Norte (California). If we assume (1) a midpoint of the overall 0.18-1.20 fledglings per nest range (0.69), (2) a one-to-one sex ratio, and (3) 95% adults breeding each year, then we get (0.69)(0.5)(.95) = 0.33 female offspring per adult female.
- *Annual Survivorship (Age 3+):* Anderson et al. (1996) find that sixteen of seventeen brown pelicans (94%) from 1986 and 1990 survived 180 days. If we extrapolate to a full year, we find that this is equivalent to approximately an 88% annual adult survival rate.

To calibrate the model, we assumed that the survivorship from Ages 0-2 increased linearly each year such that 88% adult survivorship was achieved at Age 3. We then calibrated Age 0 survivorship so that the sequence of Age 0 to Age 3 survivorship rates is consistent with a population maintaining a constant population size. We choose a maximum age of 34 because that is the oldest age that at least 1% of the brown pelicans would reach given the survivorship assumptions presented above.

[4] The below citations are cited as referenced in the Cal/Ecotox database. They are not cited as primary sources.

Common Murre
Nur et al (1994) created a common murre demographic model for the Farallon Islands. The following parameters are based upon their work, but have been calibrated to imply a roughly constant population size:

- *Age of First Breeding:* 5 Years Old
- *Female Offspring per Female (Age 5):* 0.126
- *Female Offspring per Female (Age 6):* 0.310
- *Female Offspring per Female (Age 7):* 0.405
- *Female Offspring per Female (Age 8+):* 0.420
- *Survivorship (From fledge to one year of age):* 40%
- *Annual Survivorship (Age 1-2):* 80%
- *Annual Survivorship (Age 2-3):* 87%
- *Annual Survivorship (Age 3+):* 91.6%
- *Maximum Age:* 35 Years

The difference between these parameters and those used by Nur et al (1994) is that annual survivorship beyond the first year has been decreased 1.7%.

General Scoter
The Noth Cape REA (Sperduto et al, 1999) calculates injury to scoters by combining demographic information for both surf scoters and black scoters. For the purpose of settlement, we suggest drawing on their parameters for calculating injuries for waterfowl/wetland birds. Specifically:

- *Age of First Breeding: 2* Years Old
- *Female Offspring per Adult Female (Annual): 1.2025*
- *Survivorship (From fledge to one year of age): 37*%
- *Annual Survivorship (Age 1+): 69.375*%
- *Maximum Age:* 15 Years Old

The difference between these parameters and those used by Sperduto et al (1999) is that fecundity and survivorship parameters have been decreased by 7.5% of the *North Cape REA* values (1.3, 40%, 75%) to calibrate the life history parameters to be consistent with a constant population size.

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