PROJECT COMPLETION REPORT

97-5 **"Evaluating the Impact of Kill Permits at Finfish Aquaculture Facilities on Piscivorous Bird Populations in the Northeastern United States"**

Termination Report Period: September 1, 1997 through July 30, 1998

NRAC Total Funding: $44,000 (June 1, 1997 through May 31, 1998)
(No-Cost Ext'n through July 30, 1998)

Principal Investigator: Dr. Bradley F. Blackwell, USDA/APHIS Wildlife Services,
National Wildlife Research Center, Sandusky, OH

Participating Investigators/ Cooperative Agencies: (Cooperating, Non-funded Participants listed at end of report)

Richard A. Dolbeer	USDA/APHIS Wildlife Services	Ohio
Laura A. Tyson	USDA/APHIS Wildlife Services	Ohio

Reason for Termination: Objectives completed.

Project Objectives:

1. Compile from existing records and reports involving northeastern finfish aquaculture facilities in Pennsylvania, New York, and New Jersey the number of: **a)** applications for kill permits received by the USFWS, **b)** kill permits that were issued, and **c)** piscivorous birds (by species) killed annually under these permits. Identify and clarify the criteria under which the USFWS kill permits are approved or denied by the USFWS Law Enforcement Office and by state wildlife agencies.

2. Establish from existing surveys and reports the population status by species of piscivorous birds in Pennsylvania, New York, and New Jersey, compare numbers killed at fish-rearing facilities with estimated total population levels, and determine if there is any correlation between the number of piscivorous birds killed at fish-rearing facilities in the northeast and local or regional population trends of piscivorous birds.

3. Based on data generated in objectives 1-2 and our understanding of avian population dynamics, identify data needs for improving parameter ranges and validation of a matrix model to simulate the effects of various levels of lethal control at aquaculture facilities on respective local and regional piscivorous bird populations.

Anticipated Benefits:

Findings from this research indicate that the number of birds reported killed at aquaculture facilities in the Northeast USA, relative to regional and state population trends, had negligible effects on the population status of the respective species. The direct benefit of these findings to the aquaculture industry is a clear defense against critics of lethal control used as a wildlife management tool in legitimate damage situations. Further, our management recommendations directed to the USFWS will improve the ability of producers to protect their resources by providing the USFWS with methods by which to better monitor piscivorous bird populations, while assisting the aquaculture industry.

Principal Accomplishments:

<u>Objective 1</u>

a. The USFWS received 30 applications for control of piscivorous birds from 10 aquaculture facilities (1 in NY, 3 in NJ, and 6 in PA) during 1985-Septemer 1997.

b. Nine facilities received permits and 26 permits (17 in NJ, 8 in PA, and 1 in NY) were issued.

c. Eight species appeared on permits, but only black-crowned night-herons (*Nycticorax nycticorax*), double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), herring gulls (*Larus argentatus*), ring-billed *gulls (L. delawarensis*), and mallards (*Anas platyrhynchos*) were reported killed. The green-backed heron (*Butorides striatus*) and laughing gull (*L. atricilla*) appeared on permits, but were not reported killed. We note, however, that a final report from 1 facility in NJ (authorized to take 10 great blue herons, 50 gulls, and 50 mallards during 1986) to the USFWS was unavailable.

The reported number of birds killed per species or group ranged from 0-289 (82.7 ± 118.2) for 1985-1997. Facilities in NJ were responsible for over 82% of the reported kills. By state, the total reported number of birds killed per species or group ranged from 0-272 (62.0 ± 92.6) for the 13 years and from 0-55 (15.0 ± 14.8) annually. By permit, the reported number of birds killed per species or group ranged from 0-45 (11.5 ± 10.4).

Four of the 10 facilities were denied permits during the 13 years (1 facility never received a permit). Permits were denied because of failure to respond to USFWS requests to document non-lethal management efforts, obtain state approval to control depredating birds, or include documentation of an environmental assessment. Facilities required to perform environmental assessments were to address the historic and anticipated take under the permit, and impacts on the flyway, regional, and state populations of the target species.

Objective 2

Great blue herons and herring gulls, the species most frequently listed on depredation permits (96% and 61%[gulls], respectively) and reported killed at aquaculture facilities in the 3 states, were well represented locally and regionally. Permit data indicated that the numbers of birds per species or group killed at aquaculture facilities in the northeast USA from 1985-1997 (generally <20 birds annually) represented, on average, less than half the authorized take. Relative to the size of the respective species populations breeding or residing in each of the 3 states and regionally (based on colony censuses, breeding bird atlases, and the Breeding Bird Survey and Audubon Christmas Bird Count databases), this level of reported kill was insignificant.

Objective 3

To identify data needs in modeling piscivorous bird population dynamics, we simulated the annual cycle of the NJ great blue heron population. The great blue heron is listed in NJ as a threatened species. Lethal control was introduced into the model under a "worst case" scenario relative to model assumptions, the total number of birds removed, and the frequency of removals. In 3 simulations we exceeded the recorded authorized take for any year in NJ by removing 30 birds in each scenario, 2 of which involved concentrating removals during the reproductive period. In addition, we removed older birds with higher probabilities of breeding and fledging success. Finally, several facilities reported kills distributed over a period greater than 2 months, a scenario that we simulated.

Each removal of 30 birds forced the population into a slightly negative rate of annual growth (i.e., >-1%). Yet, by reducing the total kill to 24 birds (the highest authorized cumulative take for a piscivorous bird species in a single year in NJ) and distributing the kills across 5 months (similar to facility reports), the population growth rate decreased by 0.6%, but remained positive.

Specific parameters important in modeling populations, and those which should be adjusted in accordance to regional variation, include estimates of the size of breeding populations, age-structure, age-specific fecundity and mortality, population growth rates, and periods of planned and previous removals. Age-specific data are difficult to obtain and can vary regionally. These caveats do not, however, prevent the use of a conservative approach to modeling a population's response to lethal control quotas. Specifically, we suggest caution in interpreting the potential indirect effects of removals on breeding success and survival. Also, detailed reports noting dates and numbers of birds killed (these data were not reported by 9 of 21 facilities with expired permits), along with follow-up census data are critical in evaluating the effects of actual removals on populations and the potential for future depredation problems.

Impacts:

As stated under 'Anticipated Benefits', lethal control of piscivorous birds at aquaculture facilities in the Northeast USA has had negligible effects on species populations.

Economic benefits to the aquaculture industry will be realized through the:

1. continued development, by the USFWS, of a permit database that will improve the efficiency of use of permit data in evaluating potential species-specific population effects of lethal control;
2. justification and defense of the issuance of permits for lethal control on the basis of species population status and dynamics; and
3. use of existing avian population databases and population modeling to standardize the process of determining permit quotas.

Recommended Follow-Up Activities:

The USFWS has instituted the creation of a database to improve the management and accessibility of records pertaining to the permitting process. We suggest that

1. remaining historic records (prior to 1985) be included in the USFWS database such that long-term trends in the authorized and reported kills of depredating birds can be examined relative to population trends; and
2. the USFWS insist on accurate recording by aquaculture facilities of the periods and severity of predation, dates of kills, and the number of birds taken by species.

We also encourage the USFWS to evaluate species quotas prior to the issuance of permits for lethal control. Such an evaluation would incorporate information on the species and period of predation, population size and trend information from independent avian population databases (e.g., nest censuses, the Breeding Bird Survey, Audubon Christmas Bird Counts, and Breeding Bird Atlases), and model simulations of the potential population effects of the removals. Again, specific parameters important in modeling populations, and those which should be adjusted in accordance to regional variation, include estimates of the size of breeding populations, age-structure, age-specific fecundity and mortality, population growth rates, and periods of planned and previous removals.

Given the increasing opposition to lethal control as a wildlife management tool, continued research is needed to develop non-lethal techniques to reduce predation losses at aquaculture facilities, and to evaluate selective lethal control as to its effectiveness in enhancing non-lethal management techniques. However, research involving lethal control and piscivorous bird species, such as the great blue heron, is negatively affected by public opinion. Yet, by conducting research involving selective lethal control with species not considered as charismatic as wading birds (e.g., blackbirds), questions pertinent to the operation of aquaculture facilities can be addressed. The NWRC's Sandusky, Ohio Field Station offers an ideal setting for a controlled study to quantifying the enhancement properties of lethal control to non-lethal management. Four treatments at bird feeding stations located at the Ohio Field Station could be investigated: no harassment or lethal control, non-lethal harassment, lethal control, and a combined use of non-lethal and lethal methods. Findings from such a study could be used as a basis for management of predation at aquaculture facilities.

Publications, Manuscripts, Or Papers Presented:

Lethal control of piscivorous birds at aquaculture facilities in the Northeast USA: effects on populations. Paper presented at the Northeast Association of Wildlife Damage Biologists 1998 annual meeting, 4-5 May, Camp Hill, PA.

Technical Analysis and Summary:

Abstract:

Lethal control of piscivorous birds at aquaculture facilities has raised concerns as to the effects on the distribution and abundance of populations of species identified on depredation permits. We examined the relationship between species-specific numbers of piscivorous birds authorized and killed under U. S. Fish and Wildlife Service (USFWS) permits at aquaculture facilities in New York (NY), New Jersey (NJ), and Pennsylvania (PA), and population trends within the respective states and regionally. The USFWS issued 26 permits to 9 facilities from 1985 through September 1997. Eight species appeared on permits, but only black-crowned night herons (*Nycticorax nycticorax*), double-crested cormorants (*Phalacrocorax auritus*), great blue herons (*Ardea herodias*), herring gulls (*Larus argentatus*), ring-billed *gulls (L. delawarensis*), and mallards (*Anas platyrhynchos*) were reported killed. Over the 13 years, the authorized number of birds to be killed per species or group (e.g. gulls) ranged from 5-800 ($\pm$ SD = 240.0 $\pm$ 299.8), while the reported number of birds killed per species or group ranged from 0-289 (82.7 $\pm$ 118.2). Across states and species, the number of birds authorized to be killed per permit ranged from 2-60 (26.7 $\pm$ 20.3), while reported kills ranged from 0-45 (11.5 $\pm$ 10.4) birds. Herring gulls (N = 272) and great blue herons (N = 163) were the most frequently killed species. The number of birds reported killed, relative to regional and state population trends, is considered to have had negligible effects on the population status of the respective species. Management recommendations include the development of a depredation permit database, evaluation of lethal control as to its effectiveness in enhancing non-lethal management, and evaluation of planned or actual lethal control programs using population modeling.

Key Words:

Aquaculture, depredation permit, great blue heron, herring gull, lethal control, piscivorous birds, population model, population trend.

World-wide aquaculture production is anticipated to reach 20-25 million metric t by 2000, worth $59 Billion U. S., or 40% of world fish production (Price and Nickum 1995). A crucial factor in the growth of the aquaculture industry has been control of mortality during production. In particular, predation by piscivorous birds is viewed as a significant threat to the aquaculture industry (Lagler 1939, Parkhurst et al. 1987, Parkhurst 1994). Avian predation represents not only direct mortality, but also results in injury and stress that can negatively affect fish feeding and growth. In addition, there is concern that avian predators might spread diseases among aquaculture operations (Price and Nickum 1995).

Non-lethal techniques are available to control depredation by piscivorous birds at aquaculture facilities (Mott and Flynt 1995, Mott and Boyd 1995); however, the cost-effectiveness of these methods (e.g., roost dispersal [Mott et al. 1992], exclusion devices at rearing ponds [Mott and Flynt 1995, Mott et al. 1995,]) has been questioned (Trapp et al. 1995). Further, lethal control of problem birds, though intended to enhance the effectiveness of non-lethal methods (Mastrangelo et al. 1997), has raised concerns because of the insufficient understanding of predator-prey relationships, movements, and age-specific survival of the target species (Erwin 1995, Nisbet 1995). Also, questions remain as to the effect of lethal-control programs on distribution and abundance of local, regional, and national populations of species identified on depredation permits (Erwin 1995, Trapp et al. 1995, Belant et al. 1998).

We examined the relationship between species-specific numbers of birds reported killed under permit at aquaculture facilities in NY, NJ, and PA and population trends within the respective states and regionally. Our objectives were to:

1. determine the number of applications for avian depredation permits received by the USFWS for aquaculture facilities in NY, NJ, and PA, the species and number of individuals authorized to be killed, and the species and numbers reported killed,
2. determine the criteria under which the depredation permits were denied,
3. quantify respective state and regional population trends for species identified on depredation permits, and the relative effects on populations of species reported killed,
4. identify data needs for assessing the effects of lethal control at aquaculture facilities on piscivorous bird populations, and
5. make recommendations from a population perspective regarding lethal control of piscivorous birds at aquaculture facilities.

Methods:

Depredation Permits

Records of avian depredation permit applications by aquaculture facilities in NY, NJ, and PA (1985 through September 1997) were provided by the USFWS Migratory Bird Management Office (MBMO), Region 5, Hadley, MA. The records included copies of facility communications to the USFWS documenting predation losses, Migratory Bird Damage Reports, USFWS communications specifying reasons for permit denials, permits with species and number of birds authorized to be killed, and final reports from the facilities documenting species and numbers killed. Permit data prior to 1985 were unavailable because records had been destroyed or were in unmarked bulk storage (D. M. Pence, MBMO, personal communication).

Population Statistics

To determine population levels and breeding distributions for avian species identified on permits, we examined survey data from state and federal natural resource agencies and breeding bird atlases. Breeding bird atlases represent the breeding distribution of avian species within each state over a 5-10 year period (Robbins 1990). Species breeding distributions were mapped relative to a grid of blocks (with the total number variable among states), representing approximately 25 km^2 each.

Species population trends were obtained from the North American Breeding Bird Survey (BBS) (Sauer et al. 1997) and National Audubon Society Christmas Bird Count (CBC) (Sauer et al. 1996) databases. The BBS consists of approximately 3,700 randomly located survey routes (39.4 km each) throughout the continental USA, Canada, and Alaska that are surveyed annually in June (see Peterjohn and Sauer 1993). Each route has 50 stops (at 0.8 km intervals) at which all birds seen within 0.4 km or heard at any distance are tallied during a 3-minute point count (see Robbins et al. 1986). We used breeding population trend (mean % change/year) estimates for 1966-1996 for each state, and for USFWS Region 5 (FWSR5) which extends from Maine through Virginia.

To understand the winter concentration of piscivorous birds in the 3 states, we used the CBC database. The CBC is an annual, early-winter, 1-day survey of birds on approximately 1,700 randomly located circles (24.1 km diameter) throughout the USA and Canada, and in parts of Mexico, Central America, and the Caribbean islands (Butcher and McCulloch 1990, Sauer et al. 1996). Trend (mean % change/year) and mean relative abundance ($\bar{x}$ birds/ 100 party hours) estimates were available for CBCs in each state for 1959 (counts conducted in December 1959 and January 1960)-1988 (Sauer et al. 1996). In addition, we calculated mean relative abundance estimates from raw CBC data for 1989-1996.

Simulated Lethal Control

We evaluated the effects of killing birds at aquaculture facilities by using a simple population model and simulating removals. Because great blue herons appeared frequently on depredation permits (see **Depredation Permits** below) and the species was listed as threatened in NJ (NJ Division of Fish, Game, and Wildlife [NJFGW] Endangered and Non-game Species Program, Northern District Office, Hampton), we chose to model the NJ great blue heron population. First, we estimated the size and age-structure of the population, then simulated the removal of breeding-age birds. Changes in the population were calculated as:

$$N_{(t+1)} = S_i N_{(t)} + P_i F_i N_{(t)} S_f$$

Here, $N_{(t)}$ and $N_{(t+1)}$ represent the population size in year-t and -t + 1. The age-specific (i.e., age-i = 1 to 5+) probability of surviving from year-t to -t + 1 is S_i (Henny 1972), P_i is the age-specific probability of breeding (assumed), F_i is the age-specific fledging success per female (Henny 1972, Butler 1992, Butler et al. 1995), and S_f is fledgling (i.e., age-0) survival (Henny 1972, Butler 1992). We assumed a 50:50 sex ratio for adults and fledglings, a closed population, and that first breeding occurred during the second year (Butler 1992).

To obtain the population age structure, we assumed a founder population of 350 breeding-age adults (200 of age-2, 100 of age-3, and 50 of age-4). Population parameters were adjusted to achieve a stable population after a 20-year simulation, with natural mortality applied after the breeding season. The resulting age-structure and age-specific numbers were used to simulate the annual cycle of the population at weekly intervals, with natural mortality introduced at the end of each week. We assumed that the NJ population comprised 1,744 known breeders, or 872 nesting pairs (B. Hoover, U. S. Geological Survey, Biological Resources Division [BRD], Patuxent Wildlife Research Center [PWRC], Laurel, Maryland [MD], unpublished 1995 census data), on the week of 22 May, 1 week prior to fledging. We then adjusted the population parameters (Table 1) to achieve an annual intrinsic rate of increase, equal to ln ($N_{(t+1)} / N_t$), of 0.69% (Figure 1). The annual rate of growth was equivalent to the BBS population trend for NJ from 1966-1996 (see Sauer et al. 1997). Also, we assumed that eggs were laid from 7-20 Mar., hatching occurred from 3-16 April, and the nestling period (approximately 52 days) extended through 28 May (Butler 1992). Surviving age-0 birds entered the population as fledglings on the weeks of 29 May and 5 June (Figure 1).

Lethal control was introduced as the removal of age-3 and -4 individuals after the introduction of natural mortality (i.e., removals represented additive mortality in the model). We first examined the effects of removing 10 birds (5 of age-3 and 5 of age-4) a week over a 3-week period at 3 times of the year. Birds were removed on the weeks of 8, 15, and 22 May during the nestling period (i.e., the lowest point in the annual cycle), thus effecting a potential nest loss for each breeding-age individual killed. Next, birds were removed on the weeks of 29 May and 5 and 12 June during the fledging period, also effecting a potential nest loss for each breeding-age individual killed. Removals on the weeks of 11, 18, and 25 December occurred during the post-fledging period. We then simulated the combined authorized take (N = 24) and period of reported kills for 3 NJ facilities during 1994. Four birds per week, at 3-week intervals, were removed from 3 July-20 November. After each removal scenario, the intrinsic rate of increase was calculated for the annual cycle.

Results:

Depredation Permits

The MBMO received 30 applications for control of piscivorous birds from 10 aquaculture facilities (1 in NY, 3 in NJ, and 6 in PA) during 1985-Septemer 1997. Nine facilities received permits and 26 permits (17 in NJ, 8 in PA, and 1 in NY) were issued. Four of the 10 facilities were denied permits during the 13 years (1 facility never received a permit). Permits were denied because of failure to respond to USFWS requests to document non-lethal management efforts, obtain state approval to control depredating birds, or include documentation of an environmental assessment. Facilities required to perform environmental assessments were to address the historic and anticipated take under the permit, and impacts on the flyway, regional, and state populations of the target species. We note, however, that an environmental assessment is not a prerequisite under the *Code of Federal Regulations* (Subpart D of Part 21 of Title 50) for receiving a depredation permit.

Great blue herons appeared most frequently (96%) on depredation permits, followed by herring, laughing (*L. atricilla*), and ring-billed gulls (61%). Mallards (23%), black-crowned night-herons (19.2%), green-backed herons (*Butorides striatus*) (4%), and double-crested cormorants (4%) were also represented. We assumed that permits listing "gulls" only included the 3 gull species listed above. The number of species identified per permit ranged from 1-6 (mode = 4).

From 1985-1997, the authorized number of birds to be killed per species or group (e.g., gulls) ranged from 5-800 ($\bar{x}$ $\pm$ SD = 240.0 $\pm$ 299.8). Facilities in NJ were responsible for over 84% of the quota (Table 2). By state, the total authorized number of individuals to be killed per species or group ranged from 4-750 (160.0 $\pm$ 239.7) for the 13 years (Table 2) and from 3-100 (36.9 $\pm$ 29.7) annually (Appendix A). By permit, from 2-60 (26.7 $\pm$ 20.3) birds were authorized to be killed per species or group.

Reported Kills

The reported number of birds killed per species or group ranged from 0-289 (82.7 $\pm$ 118.2) for 1985-1997. Facilities in NJ were responsible for over 82% of the reported kills (Table 2). By state, the total reported number of birds killed per species or group ranged from 0-272 (62.0 $\pm$ 92.6) for the 13 years (Table 2) and from 0-55 (15.0 $\pm$ 14.8) annually (Appendix A). By permit, the reported number of birds killed per species or group ranged from 0-45 (11.5 $\pm$ 10.4). Further, only individuals from 6 of the 8 species appearing on permits were killed (Table 2). We note, however, that a final report from 1 facility in NJ (authorized to take 10 great blue herons, 50 gulls, and 50 mallards during 1986) to the MBMO was unavailable.

A mean of 12.9 ($\pm$ 6.3) great blue herons was killed annually in NJ from 1985-1996, whereas in PA a mean of 15.7 ($\pm$ 9.8) individuals was killed during 1993, 1995, and 1996 (Appendix A). From 1985-1996, facilities in NJ reported an annual mean kill of 30.2 ($\pm$ 18.1) herring gulls. Also, although mallards appeared on permits in NJ for 6 years, only in 1987 were kills reported (Appendix A). From 1993-1996, PA facilities reported an annual mean kill of 4.5 $\pm$ 3.1 black-crowned night-herons. Lastly, double-crested cormorants and ring-billed gulls were killed in PA in 1996 only (Appendix A).

Population Status

Great blue heron

Great blue herons appeared on permits in each of the 3 states (Table 2). Peterson (1988) described the species as fairly common throughout most of upstate NY during the breeding season, and a non-breeding summer visitor to the coastal lowlands. From 1980-1985, great blue herons were observed in 59.5% (n = 3,167) of atlas blocks in NY, with confirmed breeding in 4.0% (n = 212) (Peterson 1988). Recent statewide estimates of the size of the great blue heron breeding population in NY were not available.

In NJ, the great blue heron is predominantly distributed in the north, but expanding south (Walsh et al. 1998). From 1993-1997, the species was recorded in 18.2% (n = 155) of atlas blocks in NJ, and confirmed breeding in 4.8% (n = 41) (Walsh et al. 1998). Estimates of the number of nesting pairs during years when the species was listed on permits (1985-1997) were unavailable. However, an estimate of 872 nesting pairs in 22 colonies was obtained via aerial survey in 1995 (B. Hoover, BRD, PWRC, unpublished data).

The species was observed from 1983-1989 in 46.2% (n = 2,279) of PA atlas blocks, and confirmed as nesting in 2.3% (n = 114) (Schwalbe and Ross 1992). From 1977-1997, 138 great blue heron colonies were located; however all colonies were not searched annually. The most extensive survey was conducted in 1997, covering 73 colonies which contained 1,320 nesting pairs (D. Braunning, PA Game Commission [PGC], Montgomery, unpublished data).

Great blue herons exhibited positive ($P \leq 0.10$) BBS trends in FWSR5 and in each of the three states for the 1966-1996 period, with the exception of NJ (Table 3). Similarly, CBC trends were positive ($P \leq 0.10$) in the three states for 1959-1988 ($P \leq 0.10$), with the exception of NJ (Table 4). Also, the mean relative abundance of great blue herons on CBC circles in the three states during 1989-1996 increased by approximately 12 to 26 birds from the 1959-1988 estimates.

Herring Gull

Herring gulls appeared on depredation permits in NJ and PA only (Table 2). The species was confirmed as nesting in 2.7% (n = 23) of NJ atlas blocks (Walsh et al. 1998). Estimates of the size of the breeding population during permit years (1985-1997) were unavailable; however, 6,828 nests were located in 121 colonies during the 1995 coastal waterbird survey (B. Hoover, BRD, PWRC, unpublished data). The herring gull, generally breeding from NY north (see Bent 1963), was not considered a nesting species in PA, although individuals were observed during surveys of atlas blocks (Brauning 1992).

Breeding Bird Survey trends for the herring gull were not statistically significant in NJ and FWSR5 (Table 3). However, the species exhibited a slightly negative ($P \leq 0.10$) CBC trend in NJ for 1959-1988, while the PA trend was not significant (Table 4). Also, mean relative abundance estimates for herring gulls on CBC circles in NJ and PA increased during 1989-1996, exceeding the 1959-1988 values by over 1,800 and 400 birds, respectively.

Mallard

Mallards appeared on depredation permits in NJ only (Table 2). Individuals were observed in 77.5% (n = 660) of atlas blocks, and confirmed nesting in 55.5% (n = 471) (Walsh et al. 1998). Nest-count data specific to NJ were unavailable, however the mallard breeding population in the northeast USA (i.e., VA, MD, PA, NJ, NY, DE, CT, MA, NH, RI, and VT) averaged 365,000 nesting pairs from 1955-1995; an estimated 397,500 pairs nested in the northeast USA in 1997 (Caithamer and Dubovsky 1997). Further, BBS trends for the species were positive ($P \leq 0.10$) in FWSR5 (Table 3). Also, the CBC trend for 1959-1988 was positive ($P \leq 0.10$), and mean relative abundance estimates for 1989-1996 exceeded the 1959-1988 values by over 700 birds (Table 4).

Black-crowned Night-Heron

Black-crowned night-herons appeared on permits in PA only (Table 2). The species was observed in 3.0% (n = 152) of atlas blocks, and confirmed as nesting in 0.4% (n = 18) (Schutsky 1992). From 1993-1997, years when the species was listed on depredation permits, a mean of 219 $\pm$ 169 nests per year were located in 9 colonies (D. Brauning, PGC, unpublished data). We note, however, that all colonies were not surveyed annually. In addition, population trends for black-crowned night-herons (BBS and CBC) were not significant (Tables 3 and 4).

Ring-billed Gull

Ring-billed gulls were listed on depredation permits in NJ and PA (Table 2). Although the breeding range of the species does not include PA and NJ (see Bent 1963), individuals were observed on PA BBS routes and exhibited a positive ($P \leq 0.10$) trend in FWSR5 during the 1966-1996 period (Table 3). Further, the 1959-1988 CBC trend for the species was positive ($P \leq 0.10$) in NJ. Also, the mean relative abundance estimate in NJ during 1989-1996 increased from the 1959-1988 value by over 1,000 birds (Table 4).

Green-backed Heron

The green-backed heron was listed on a single depredation permit in PA (Table 2). Master (1992) described the species as "Pennsylvania's most abundant and widespread long-legged wader", observed in 40.4 % (n = 1,991) of atlas blocks. However, likely due to its secretive nature, the species was confirmed nesting in only 4.7% (n = 233) of atlas blocks. Nesting data corroborate the difficulty in censusing this species, as only 10 (1983), 5 (1985), and 3 (1989) nests in 2 colonies (only 1 colony represented each year) have been reported (D. Brauning, PGC, unpublished data). Further, the BBS trend for the green-backed heron was not significant in PA, and negative ($P \leq 0.10$) in FWSR5 (Table 3). Also, the species was infrequently observed on PA CBC circles, likely due to its primarily summer residency (Table 4).

Double-crested Cormorant

The double-crested cormorant, like the green-backed heron, was listed on a single depredation permit in PA (Table 2). Though observed during the BBS in PA, the species was not considered nesting (Brauning 1992). We note, however, that 1 nesting pair was discovered in 1996 (D. Brauning, PGC, unpublished data). Likewise, double-crested cormorants were seen infrequently on CBC circles (Table 4). However, in North America, double-crested cormorant populations increased by approximately 2.6% annually in the 1990s. An estimated 85,510 pairs nested from NJ through northeastern Canada in 1994 (Tyson et al. 1998).

Laughing Gull

The laughing gull, identified on a single depredation permit in PA, also represented a potential target species on permits in NJ that listed "gulls" only (Table 2). Although not observed as nesting in PA, the laughing gull was reported as the most common colonial nesting waterbird in NJ (Jenkins et al. 1990). Further, the species was confirmed as nesting in 2.3% (n = 20) of NJ breeding bird atlas blocks (Walsh et al. 1998). In 1995, 39,083 nests were counted in 116 colonies (B. Hoover, BRD, PWRC, unpublished data). Also, although population trends were not significant (Tables 3 and 4), Belant and Dolbeer (1993) reported a mean percent annual increase ranging 5.6-76.2% ($\bar{x}$ = 26.1 $\pm$ 33.6) for 3 nesting-pair counts conducted from the late 1970s through the early 1990s in ME, MA, NY, and NJ.

Simulated Lethal Control

(Great Blue Heron in NJ)

Pre-removal Population. Our estimate of the size of the NJ great blue heron population on 13 March, the beginning of the biological year in the simulation of the annual cycle, was 3,761 birds (Figure 1). This beginning population size was based on the 1995 census of 872 nesting pairs (assumed to be present on 22 May) and our estimate of the age composition and number of non-breeding birds. The stable age-structure for the population on 13 March was 23.5% (N = 883) age-5+, 5.5% (N = 205) age-4, 6.7% (N = 252) age-3, 8.5% (N = 319) age-2, 13.2% (N = 498) age-1, and 42.6% (N = 1,604) age-0 individuals. By the week of 22 May (1 week prior to the recruitment of fledglings into the model population), with an annual rate of increase equal to 0.69%, the population comprised 30.3% (N = 1,066) age-5+, 7.0% (N = 247) age-4, 8.7% (N = 306) age-3, 13.4% (N = 474) age-2, 40.6% (N = 1,430) age-1, and 0 age-0 individuals. The population peaked at 5,424 birds during the second week of fledging (Figure 1).

Removals. Killing 30 breeding-age birds under the three initial removal scenarios resulted in year-end population sizes (i.e., the beginning of the 52nd week in the simulation of the annual cycle) that varied little, although population growth was negative. Specifically, given an intrinsic rate of increase of 0.69% and no removals, the year-end population size was 3,787 birds. Removing birds during incubation produced a year-end population size of 3,745 birds and a rate of growth of -0.42%. Removals during the fledging period effected a year-end population size of 3,747 birds, with a rate of growth of -0.36%. The removal of herons during December resulted in a year-end population size of 3,758 birds and a rate of growth of -0.09%. However, by distributing the removal of 4 birds per week at 3-week intervals (*N* = 24) from 3 July-20 November, the population dropped to 3,764 individuals and a growth rate of 0.09%.

Discussion:

Avian populations that conflict with humans have increased in North America in recent years (Blokpoel and Tessier 1986, Dolbeer and Bernhardt 1986, Belant 1997, Tyson et al. 1998). However, species of avian piscivores perceived as a predation threat by the aquaculture industry are protected within the United States by the Migratory Bird Treaty Act of 1918 (16 U. S. C. 703-711). In addition, because information on the ecology of these species is often incomplete (see Erwin 1995, Nisbet 1995), no management option to reduce predation losses has been more controversial than lethal control. Dolbeer (1998) noted that to justify and defend lethal or reproductive control programs to solve vertebrate pest problems, a sound understanding of the population status and dynamics of the problem species is necessary. Currently, regulations pertaining to the issuance of permits to control depredating birds (*Code of Federal Regulations*, Part 21 of Title 50) dictate that no federally designated threatened or endangered species can appear on a depredation permit, nor can the proposed action violate respective state ordinances.

We found that no species appearing on depredation permits in NY, NJ, and PA (1985-1997) was listed on state or federal threatened or endangered lists, with the exception of the great blue heron which was listed as threatened in NJ. Further, great blue herons and herring gulls, the species most frequently listed on depredation permits and reported killed at aquaculture facilities in the 3 states, were well represented locally and regionally. In addition, permit data indicated that the numbers of birds per species or group killed at aquaculture facilities in the northeast USA from 1985-1997 (generally <20 birds annually) represented, on average, less than half the authorized take. Relative to the size of the respective species populations breeding or residing in each of the 3 states and regionally, this level of reported kill was insignificant.

Currently, however, the primary factor preventing the listing of an avian piscivor on depredation permits is federal designation as threatened or endangered (see *Code of Federal Regulations*, Part 21 of Title 50). Thus, a species population that is declining, but not protected, could experience adverse population effects from cumulative kills. By projecting a population response to proposed or implemented management decisions, managers can provide a scientific foundation for evaluating the effects of lethal control (see BJdard et al. 1995, Wanless et al. 1996, Dolbeer 1998). In simulating lethal control of the NJ great blue heron population, we assumed a "worst case" scenario relative to model assumptions, the total number of birds removed, and the frequency of removals.

First, we assumed that the population was closed, thus no adults from outside of NJ were recruited into the breeding population. Also, simulated removals were assumed to represent additive mortality. Further, in 3 simulations we exceeded the recorded authorized take for any year in NJ by removing 30 birds in each scenario, 2 of which involved concentrating removals during the reproductive period. In addition, we removed older birds with higher probabilities of breeding and fledging success, whereas birds of age-1 or -2 are potential predators (Sciascia 1984, T. T. Tomsa, U. S. Department of Agriculture, Wildlife Services, WS, Harrisburg, PA). Finally, several facilities reported kills distributed over a period greater than 2 months, a scenario that we simulated.

As expected, we observed a greater effect on population growth when birds were removed prior to the fledging period, at the lowest point in the annual cycle (Figure 1). Also, the removal of breeding-age birds, prior to calculating fledgling output (via equation 1), simulated the indirect effect of nest loss when a member of a breeding pair is killed. Subsequent removals during the post-fledging period, in combination with natural mortality, resulted in a year-end population size that differed from the scenario of no removals by only 29 birds. However, each removal of 30 birds forced the population into a slightly negative rate of growth (i.e., >-1%). Yet, by reducing the total kill to 24 birds and distributing the kills across 5 months (similar to facility reports), the population growth rate decreased by 0.6%, but remained positive.

We note that, as with any model, the simulation of population growth is only as reliable as the data used to define the parameters. Further, the actual effects of lethal control on a population may be exacerbated by other factors (e.g., predation and nest abandonment). For example, in assessing the effects of a planned cull of double-crested cormorants in the St. Lawrence River system, QuJbec, BJdard et al. (1995) reported a breeding population level after removals that was only 55% of the number predicted from deterministic modeling. By 1993 the estuarine population was 35% of model estimates (BJdard et al. 1998). The cause for the discrepancy between the predicted and realized population level was due, in part, to a greater vulnerability of males to shooting. The resulting unbalanced sex ratio combined with fidelity to the breeding territory likely decreased mating opportunities for females (BJdard et al. 1998). Thus, a conservative approach is necessary in evaluating model results that represent the effects of a planned control program, particularly potential indirect effects on breeding success and survival. Moreover, detailed reports noting dates and numbers of birds killed (these data were not reported by 9 of 21 facilities with expired permits), along with follow-up census data are critical in evaluating the effects of actual removals on populations and the potential for future depredation problems.

Management Implications

The process of evaluating the effects of lethal control on piscivorous bird populations can be improved. Importantly, the USFWS has instituted the creation of a database to improve the management and accessibility of records pertaining to the permitting process (D. M. Pence, MBMO, personal communication). We suggest that remaining historic records (prior to 1985) be included in the USFWS database such that long-term trends in the authorized and reported kills of depredating birds can be examined relative to population trends. Also, we encourage the USFWS to insist on accurate recording by aquaculture facilities of the periods and severity of predation, dates of kills, and the number of birds taken by species. Further, we concur with Trapp et al. (1995) as to the need for continued research into non-lethal techniques to reduce predation losses at aquaculture facilities. In addition, lethal control should be evaluated as to its effectiveness in enhancing non-lethal management techniques.

Finally, we encourage the evaluation of species quotas prior to the issuance of permits. Such an evaluation would incorporate information on the species and period of predation, population size and trend information from independent avian population databases (e.g., nest censuses, breeding bird atlases, the BBS, and CBC), and model simulations of the potential population effects of the removals. Specific parameters important in modeling populations, and those which should be adjusted in accordance to regional variation, include estimates of the size of breeding populations, age-structure, age-specific fecundity and mortality, population growth rates, and periods of planned and previous removals. Improving our understanding of the ecology of piscivorous birds and making efficient use of permit and population data will enable better management of both predation losses at aquaculture facilities and the species populations involved.

Acknowledgements

The work reported in this publication was supported in part by the Northeastern Regional Aquaculture

Center at the University of Massachusetts Dartmouth, through grant No. 96-38500-3032 from the Cooperative State Research, Education, and Extension Service of the U. S. Department of Agriculture.

We thank J. L. Belant, D. W. Brauning, J. L. Bucknall, R. B. Chipman, J. L. Dyer, N. N. Flemming, B. Hoover, C. D. Jenkins, A. J. Montoney, D. M. Pence, B. G. Peterjohn, J. Serie, L. A. Sommers, T. T. Tomsa, and J. Walsh for providing advice and assistance in data collection. J. L. Bucknall, M. E. Tobin, and S. E. Wright were helpful in providing reviews of the manuscript.

Literature Cited:

Bédard, J., A. Nadeau, and M. Lepage. 1995. Double-crested cormorant culling in the St. Lawrence River Estuary. Pages 78-85 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Publication 1).

Bédard, J., A. Nadeau, and M. Lepage 1998. Double-crested cormorant culling in the St. Lawrence River Estuary: results of a five-year program. M. E. Tobin, editor. Symposium on the double-crested cormorant: population status and management issues in the Midwest. U. S. Department of Agriculture Technical Bulletin. In press.

Belant, J. L. 1997. Gulls in urban environments: landscape-level management to reduce conflict. Landscape and Urban Planning 38:245-258.

Belant, J. L. and R.A. Dolbeer. 1993. Migration and dispersal of laughing gulls in the United States. Journal of Field Ornithology 64:557-565.

Belant, R.A., L.A. Tyson. and P. M. Mastrangelo. 1998. Effects of lethal control at aquaculture facilities on populations of piscivorous birds. Wildlife Society Bulletin 26: In press.

Bent, A. C. 1963. Life histories of North American gulls and terns. Dover Publications, Inc. New York, New York, USA.

Blokpoel, H., and G. D. Tessier. 1986. The ring-billed gull in Ontario: a review of a new problem species. Canadian Wildlife Service, Occasional Paper 57.

Brauning, D. W., editor. 1992. Atlas of breeding birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA, USA.

Butcher, G. S., and C. E. McCulloch. 1990. Influence of observer effort on the number of individual birds recorded on Christmas Bird Counts. Pages 120-129 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U. S. Fish and Wildlife Service Biological Report 90(1).

Butler, R. W. 1992. Great blue heron. No. 25 *in* A. Poole, P. Stettenheim, and K. Kaufman, editors. The birds of North America. The Academy of Natural Science: Philadelphia, Pennsylvania, USA; The American Ornithologist's Union: Washington, D. C., USA.

Butler, R. W , P.E. Whitehead., A. M. Breault, and I. E. Moul. 1995. Colony effects on fledging success of great blue herons (*Ardea herodias*) in British Columbia. Colonial Waterbirds 18:159-165.

Caithamer, D. F., and J. A. Dubovsky. 1997. Waterfowl population status, 1997. U. S. Fish and Wildlife Service, Office of Migratory Bird Management, Branch of Surveys and Assessment.

Dolbeer, R. A. 1998. Population dynamics: the foundation of wildlife damage management for the 21st Century. Proceedings of the Vertebrate Pest Conference 18. In press.

Dolbeer, R.A. and G.E. Bernhardt. 1986. Early-winter population trends of gulls on western Lake Erie, 1950-84. American Birds 40:1096-1102.

Erwin, R. M. 1995. The ecology of cormorants: some research needs and recommendations. Pages 240-246 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Publication 1).

Henny, C. J. 1972. An analysis of the population dynamics of selected avian species with special reference to changes during the modern pesticide era. U. S. Fish and Wildlife Service Wildlife Research Report 1, Washington, D. C.

Jenkins, C. D., Jr., L. J. Niles, and J. Wessel. 1990. Survey of colonial nesting waterbirds on the Atlantic coast of New Jersey-1989. Unpublished report by the Endangered Species Program, New Jersey Department of Environmental Protection, Division of Fish, Game and Wildlife, Trenton, NJ, USA.

Lagler, K. F. 1939. The control of fish predators at hatcheries and rearing stations. Journal of Wildlife Management 3:169-179.

Master, T. L. 1992. Green-backed heron. Pages 58-59 *in* D. W. Brauning, editor. Atlas of breeding birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, PA, USA.

Mastrangelo, P., C. Sloan, and K. Bruce. 1997. Incorporating depredation permits into integrated damage management plans for aquaculture facilities. Proceedings of the Eastern Wildlife Damage Management Conference 7:36-43.

Mott, D. F., K. J. Andrews, and G. A. Littauer. 1992. An evaluation of roost dispersal for reducing cormorant activity on catfish ponds. Proceedings of the Eastern Wildlife Damage Control Conference 5:205-211.

Mott, D. F and F.L. Boyd. 1995. A review of techniques for preventing cormorant depredations at aquaculture facilities in the southeastern United States. Pages 176-180 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Publication 1).

Mott, D. F and R.D. Flynt, 1995. Evaluation of an electric fence system for excluding wading birds at catfish ponds. Progressive Fish Culturist 57:88-90.

Mott, D.F., R.D. Flynt and J. O. King. 1995. An evaluation of floating ropes for reducing cormorant damage at catfish ponds. Proceedings of the Eastern Wildlife Damage Control Conference 6:93-97.

Nisbet, I. C. T. 1995. Biology, conservation and management of the double-crested cormorant: symposium summary and overview. Pages 247-252 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Pub. 1).

Parkhurst, J. A. 1994. An overview of avian predation and management techniques at fish-rearing facilties. Proceedings of the 16th Vertebrate Pest Conference.

Parkhurst, J. A, R.P. Brooks and D. E. Arnold. 1987. A survey of wildlife depredation and control techniques at fish-rearing facilities. Wildlife Society Bulletin 15:386-394.

Peterjohn, B. G., and J. R. Sauer. 1993. North American Breeding Bird Survey annual summary 1990-1991. Bird Populations 1:52-67.

Peterson, D. M. 1988. Great blue heron. Pages 36-37 *in* R. F. Andrle and J. R. Carroll, editors. The atlas of breeding birds in New York State. Cornell University Press, Ithaca, NY, USA.

Price, I. M., and J. G. Nickum. 1995. Aquaculture and birds: The context for controversy. Pp. 33-45 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Publication 1).

Robbins, C. S. 1990. Use of breeding bird atlases to monitor population change. Pages 19-22 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U. S. Fish and Wildlife Service Biological Report 90(1).

Robbins, C. S., D. Bystrak and P. H. Geissler. 1986. The Breeding Bird Survey: its first fifteen years, 1965-1979. U.S. Fish and Wildlife Service Resource Publication 157.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, and B. G. Peterjohn. 1997. The North American Breeding Bird Survey Results and Analysis. Version 96.3. Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Sauer, J. R., S. Schwartz and B. Hoover. 1996. The Christmas Bird Count Home Page. Version 95.1. Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schutsky, R. M. 1992. Black-crowned night-heron. Pages 60-61 *in* D. W. Brauning, editor. Atlas of breeding birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, Pennsylvania, USA.

Schwalbe, P. W., R. M. Ross. 1992. Great blue heron. Pages 50-51 *in* D. W. Brauning, editor. Atlas of breeding birds in Pennsylvania. University of Pittsburgh Press, Pittsburgh, Pennsylvania, USA.

Sciascia, J. C. 1984. Aspects of great blue heron utilization of a New Jersey Fish Hatchery. New Jersey Fish and Game Wildlife Publication, Trenton, New Jersey, USA.

Trapp, J. L., T. J. Dwyer, J. J. Doggett, and J. G. Nickum. 1995. Management responsibilities and policies for cormorants: United States Fish and Wildlife Service. Pages 226-230 *in* D. N. Nettleship and D. C. Duffy, editors. The double-crested cormorant: biology, conservation and management. Colonial Waterbirds 18 (Special Publication 1).

Tyson, L. A., J. L. Belant, F. J. Cuthbert, and D. V. C. Weseloh. 1998. Nesting populations of double-crested cormorants in the United States and Canada. M. E. Tobin, editor. Symposium on the double-crested cormorant: population status and management issues in the Midwest. U. S. Department of Agriculture Technical Bulletin. In press.

Walsh, J., V. Elia, R. Kane, and T. Halliwell. 1998. Birds of New Jersey. New Jersey Audubon Society, Cape May Court House, New Jersey, USA. In press.

Wanless, S., M. P. Harris, J. Calladine, and P. Rothery. 1996. Modeling responses of herring gull and lesser black-backed gull populations to reduction of reproductive output: implications for control measures. Journal of Applied Ecology 33:1420-1432.

Please Note: Figure 1 available from NRAC: The annual cycle, upper line (u), of the New Jersey great blue heron population (all age classes) increasing at an intrinsic rate of 0.69%/year. The lower line (s) indicates the size of the breeding population, based on a 1995 census of 872 nesting pairs (B. Hoover, BRD, PWRC, unpublished data), assumed present 22 May.

Table 1. Parameters used to project the dynamics of the New Jersey great blue heron population over an annual cycle at an intrinsic rate of increase of 0.69%/year[a]

Parameter	Value
Age-0 survival[a]	0.97861
Age-1 survival[a]	0.99289
Age-2 survival[a]	0.99580
Age-3 to -5+ survival[a]	0.99798
Age-2 probability of breeding	0.30
Age-3 to -5+ probability of breeding	0.99
Age-2 fledging success (n/female)	1.65
Age-3 to -5+ fledging success (n/female)	2.3

[a] Based on the Breeding Bird Survey mean annual rate of increase for the New Jersey great blue heron population, 1966-1996 (Sauer et al. 1997).

[b] Probability of survival is expressed as a weekly (N = 52) value.

Table 2. Piscivorous birds authorized to be killed and reported killed at aquaculture facilities in New York (NY), New Jersey (NJ), and Pennsylvania (PA), 1985-1997. See Appendix A for annual summary.

		Number of birds		
Species[a]	State	Authorized take	Reported kill	Reported kill as % of authorized take
BCNH	PA	65	18	28
GBHE	NY	4	P[b]	P[b]
	NJ	144	116	80
	PA[c]	97	47	48
GNBH	PA[c]	25	0	0
DCCO	PA	5	5	100
GULL	NJ[d]	750	272	36
	PA[e]	50	17	34
MALL	NJ	300	21	7
All species	NY	4	P[b]	P[b]
	NJ	1,194	409	34
	PA[c]	217	87	40

[a] Black-crowned night-heron (BCNH), great blue heron (GBHE), green-backed heron (GNBH), double-crested cormorant (DCCO), herring, laughing, and ring-billed gulls (GULL), and mallard (MALL).

[b] P = final report from aquaculture facility is pending.

[c] Permit allowed 25 birds only, in any combination of GBHE and GNBH.

[d] Only HERG reported killed, but 27 gulls were not identified to species.

[e] Only RBGU reported killed.

Table 3. North American Breeding Bird Survey trends (1966-1996) by state and U. S. Fish and Wildlife Service Region 5 (FWSR5) for birds listed on depredation permits at aquaculture facilities in New York (NY), New Jersey (NJ), and Pennsylvania (PA), 1985-1997.

			% Change/year		
Species[a]	Area	Routes	Mean	*P*[b]	SE
BCNH	PA	5	13.0		2.0
	FWSR5	31	-1.4		0.2
DCCO[c]	FWSR5	47	4.3		0.5
GBHE	NY	88	3.1	***	0.1
	NJ	33	0.7		0.3
	PA	61	4.5	***	0.1
	FWSR5	337	5.1	***	<0.1
GNBH	PA	84	-1.5		0.1
	FWSR5	410	-1.4	***	<0.1
HERG[c]	NJ	8	-4.3		5.7
	FWSR5	108	-0.3		0.1
LAGU[c]	NJ	12	-2.8		4.2
	FWSR5	51	3.4		0.4
RBGU[d]	PA	3	15.5		5.0
	FWR%	81	10.3	***	0.3
MALL	NJ	24	3.5		1.4
	FWSR5	385	10.9	***	0.2

[a]Black-crowned night-heron (BCNH), great blue heron (GBHE), green-backed heron (GNBH), double crested cormorant (DCCO), herring gull (HERG), laughing gull (LAGU), ring-billed gull (RBGU), and mallard (MALL).

[b]Significance level: * = 0.10 > P > 0.05, ** = 0.05 > P > 0.01, *** = P < 0.01.

[c]Species was not observed on PA routes.

[d]Species was not observed on NJ routes.

Table 4. Audubon Christmas Bird Count (CBC) population trends (1959-1988) and relative abundance (RA)[a] estimates (1989-1996) for birds listed on depredation permits at aquaculture facilities in New York (NY), New Jersey (NJ), and Pennsylvania (PA), 1985-1997.

		1959-1988				1989-1996	
Species[b]	State	Mean	P[c]	N[d]	RA	N[d]	RA
BCNH	PA			67	0.0	67	0.1
DCCO	PA			67	0.0	67	1.0
GBHE	NY	2.0	***	74	0.2	30	12.0
	NJ	1.5		29	1.6	70	27.3
	PA	4.9	***	67	0.5	67	11.9
GNBH	PA			67	0.0	67	<0.1
HERG	NJ	-0.7	*	31	245.1	70	2,120.8
	PA	1.9		51	271.8	67	730.8
LAGU	NJ			30	0.0	70	0.5
RBGU	NJ	6.5	***	30	40.6	70	1,400.4
	PA	6.1		50	829.6	67	1,065.3
MALL	NJ	4.1	***	30	51.4	70	767.4

[a] Relative abundance = ($\bar{x}$ birds/100 party hours).

[b] Black-crowned night-heron (BCNH), great blue heron (GBHE), green-backed heron (GNBH), double-crested cormorant (DCCO), herring gull (HERG), laughing gull (LAGU), ring-billed gull (RBGU), and mallard

[c] Significance level: * = 0.10 > P > 0.05, ** = 0.05 > P > 0.01, *** = P < 0.01.

[d] Number of CBC circles (24.1 km diameter) surveyed.

Appendix A.

Annual summary of piscivorous birds authorized to be killed and reported killed at aquaculture facilities in New York (NY), New Jersey (NJ), and Pennsylvania (PA), 1985-1997.

State	Year	Species[a]	Number of birds: Authorized take	Number of birds: Reported[b] killed	Reported kill as % of authorized take
NJ	1985	GBHE	5	5	100
		GULL[c]	50	15	30
	1986	GBHE	20	4	20
		GULL[c]	100	8	8
		MALL	50	0	0
	1987	GBHE	10	10	100
		GULL[c]	50	16	32
		MALL	50	21	42
	1989	GBHE	10	10	100
		GULL[c]	50	17	34
	1990	GBHE	20	20	100
		GULL[c]	100	22	22
		MALL	50	0	0
NJ	1991	GBHE	20	18	90
		GULL[c]	100	55	55
		MALL	50	0	0
NJ	1992	GBHE	20	20	100
		GULL[c, d]	100	48	48
		MALL	50	0	0
NJ	1993	GBHE	12	11	92
		GULL[c]	50	40	80

PA	1993	BCNH	25	7	28
		GBHE	10	10	100
NJ	1994	GBHE	24	18	75
		GULL[c, e]	90	51	57
		MALL	50	0	0
PA	1994	BCNH	10	0	0
	1995	BCNH	10	6	60
		GBHE	10	10	100
	1996	BCNH	10	5	50
		GBHE[f]	35	27	77
		DCCO	5	5	100
		GNBH[f]	25	0	0
		GULL[g]	50	17	34
NY	1997	GBHE[h]	4	P	
NJ	1997	GBHE	3	P[h]	
		GULL	60	P[h]	
PA	1997	GBHE	42	P[h]	
		BCNH	10	P[h]	

[a] Black-crowned night-heron (BCNH), great blue heron (GBHE), green-backed heron (GNBH), double-crested cormorant (DCCO), herring, laughing, and ring-billed gulls (GULL), and mallard (MALL).

[b] One final report for a PA permit listing GBHE, MALL, and GULL (1986) was not recovered.

[c] Only HERG reported killed.

[d] Thirteen gulls not identified to species.

[e] Fourteen gulls not identified to species.

[f] Permit included 25 birds in any combination of GBHE and GNBH.)

[g] Only RBGU reported killed.

[h] Final report from the aquaculture facility to the U. S. Fish and Wildlife Service Migratory Bird Management Office is pending.