4
Bird Predation

INTRODUCTION

Birds are responsible for sometimes serious production losses for aquaculturalists. Estimates of losses to predators at aquaculture facilities vary from as low as 8 percent to as high as 75 percent of total fish production (33). In dollar amounts this translates to annual economic losses of $49 to $4,120 per trout raceway in central Pennsylvania (108); $20,000 in a two-week period for baitfish in Arkansas (65); and up to $3.3 million per year on catfish farms in the Mississippi Delta (15,133).[1]

An unprotected aquacultural operation presents a textbook example of an optimal foraging situation for predators because of the high prey density and the potential for a high foraging success rate (107). At least 65 bird species have been identified as predators of aquacultural crops in the United States (107) (box 4-1). Numbers and types of avian predators vary depending on facility type, cultured species, and management techniques. Common bird predators at aquaculture facilities include double-crested cormorants, great blue herons, great egrets, snowy egrets, little blue herons, black-crowned night herons, ring-billed gulls, and belted kingfishers (107).

A widely applicable solution to bird predation problems in aquaculture has not yet been discovered and one is not likely to arise in the near future. Aquaculture today is so diverse that it is unrealistic to expect one methodology to manage predators effectively in all types of facilities. The most effective approach to deterring bird predators to date is to use a variety of non-lethal techniques, changed often and perhaps supplemented with periodic lethal control with a proper permit.

CONGRESSIONAL INTEREST

Most of the bird predators at aquaculture facilities are protected by the Migratory Bird Treaty Act of 1918. Federal agencies are involved in developing non-lethal methods to control predators exploiting agricultural crops and for issuing permits, when warranted, to kill the predators. The Fish and Wildlife Service works with the U.S. Department of Agriculture, Animal and Plant Health Inspection Service/Animal Damage Control to ensure permits are warranted and issued in a timely fashion. USDA's Office of Animal Damage Control also develops and implements depredation control measures.

Congressional interest in the problem of bird predation in aquaculture stems from its oversight of the federal agencies charged with enforcing depredation permits and developing predator control methods. One example of a potential Congressional role regarding bird predation and aquaculture includes creating a certification program to curb predation problems. Congress could require the U.S. Fish and Wildlife Service to certify aquaculture facilities with a predator-check permit. The predator-check permit could ensure that every new aquaculture facility consider the potential for predation problems during the original siting and approval process. The certifi-

[1] The $3.3 million figure did not include the cost to harass birds or to protect cultured stocks, estimated at $2.1 million per year. Thus, the total annual loss of catfish to cormorants in the Mississippi Delta was estimated at $5.4 million (133).

BOX 4-1: Mammal Predation and Aquaculture

At least 15 mammal species have been identified as predators at aquaculture facilities including seals, sea lions, muskrats, mink, river otters, Norway rats, raccoons, feral cats, bears, and skunks (107).

Unlike the situation for birds, a systematic attempt is not made at the national level to monitor population trends of most freshwater and terrestrial mammals over large regions of the country. The task of monitoring and setting policy for many freshwater and terrestrial mammals resides with the natural resources agency in each state and may be regulated through open seasons, a permit system, and bag limits. Producers experiencing damage from regulated species, such as game species or furbearers, are encouraged to manage the offending species during established regulated seasons.

Where damage is severe and where non-lethal methods have not provided satisfactory control, the state game warden may issue a damage kill permit. A damage kill permit will describe the species and number of individuals allowed to be taken and the time period within which this take shall occur. In most cases, the carcasses of the animals taken while under the provisions of the permit must be turned over to the warden and an annual report that summarizes the take made by the permitee must be filed with the state wildlife agency (107).

The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) have jurisdiction over management decisions relating to federally listed endangered or threatened mammals and all marine mammals. Marine mammal species protected under the Marine Mammal Protection Act of 1972 (MMPA) and/or the Endangered Species Act of 1973 (ESA) may have sufficient data available to monitor population trends. According to NMFS, this office has published information on all marine mammal stocks in U.S. waters, completed stock assessments for marine mammal populations that interact with fisheries, and detailed information on pinniped populations for which there have been documented interactions with aquaculture (including harbor seals, gray seals, California sea lions, and Steller sea lions) (99).

Amendments to MMPA in 1994 required a study of marine mammal interactions with salmonid fisheries in the west (due October 1, 1995) and an examination of interactions between pinnipeds and aquaculture in the Gulf of Maine (due April 30, 1996) (20,99). These studies may provide suggestions for future aquaculture/marine mammal interaction programs.

SOURCE: Office of Technology Assessment, 1995.

cation program could rely on advice at the pre-permit stage from engineers, ornithologists, and others familiar with predation problems. Permit processors could ensure that potential new aquafarmers are aware of sources and availability of good advice and management techniques to prevent problems before starting the culture operation. Finally, the permit could require the industry to use facility construction that takes advantage of the best available and most economical technologies for excluding predators.[2]

Providing compensation for losses incurred at aquaculture facilities from predators frequently is espoused as a solution to predation problems. In response to this proposed solution, Congress might require compensation be given to all aquaculture facilities that experience a specified level of economic damage due to

[2]The Scottish Salmon Growers Association (SSGA) adopted a Code of Practice relating to predators (22). This code specifies that new farms not be established close to known concentrations of predators; that adequate preventative measures be incorporated into all farms at the planning stage, and be regularly reviewed in the light of future research; and that it is the responsibility of salmon farm management to ensure proper procedures are adopted to reduce the impact of predators on farmstock. The SSGA plays an important role in the dissemination of information and research to improve the exclusion of predators from primarily salmon farms by non-destructive means. While the United States aquaculture industry includes production of diverse products, not limited to salmon, the SSGA Code of Practice might be used as a model for the National Aquaculture Association to use in establishing a similar predation-prevention program in the United States.

predators. However, there are faults with this approach. Compensation without a requirement to correct or limit the root cause of the problem would not prevent repeated future damage. Additionally, there must be a funding source to pay for compensation claims. Existing compensation programs for wildlife damage are funded primarily by fees imposed as a part of obtaining a hunting or trapping license (107). This could be viewed as penalizing the sporting public while others who benefit from wildlife are not assessed a similar penalty. Limited funds may lead to "first come, first serve" payments, with the possibility of individuals who experience late season damage being turned away for lack of funds.

Suggestions have been made that all aquaculturists pay a fee in return for the privilege of participating in the industry. These monies would be used to fund compensation for losses to predators and for research on control methods. Another suggestion for Congress is to provide incentives such as low interest loans or tax credits to those who retrofit existing facilities to exclude predators.

ISSUE IDENTIFICATION

Issue: Conflicts of Interest in Addressing Bird Predation Problems

Industry representatives, environmental groups, and consumers have conflicting viewpoints and concerns about wildlife predation at aquaculture facilities. Industry representatives complain of excessive economic losses caused by predators; of delays in acquiring depredation permits; and of failure by the U.S. government to compensate the industry for losses from predation. Environmental groups are concerned about unwillingness of some producers to rely solely on non-lethal methods of control and about real or perceived abuses of depredation permits. Consumer interest in predation problems may be spurred if prices of aquacultural products increase as producers factor in costs of mitigating predation problems.

Issue: Lack of Data Documenting Problems and Solutions

The general lack of reliable, easily accessible scientific data on the true extent of the physical and economic impacts of bird predators on aquaculture impedes progress toward resolving conflicts among stakeholders (107). Anecdotal accounts and extrapolations of data from small studies to broad, industry-wide application tend to dominate the information available on predation problems. To make reasonable approximations of economic impact of predators even on a single aquaculture facility, reliable data are required on number of predators, size and number of prey taken, and how long the predators fed.

To address predation problems with an accurate information base, the aquaculture industry must be willing to quantify and compare economic losses from predation with losses from other sources of mortality such as disease and weather (108,112). In some aquacultural facilities, the impact of predation might be insignificant relative to other problems, yet, managers may continue to devote capital toward deterrent options that may not be cost effective.

Few scientific studies have specifically examined the potential cause and effect relationship between aquaculture and bird populations (107). Even fewer studies have linked population increases or decreases or changes in behavior of wildlife directly to the development of aquacultural operations. Thus, although there is much speculation about the potential effects of these facilities on bird numbers and distributions (e.g., 92,93), hard evidence documenting effects of aquaculture facilities on wildlife populations generally is lacking. Like most wild animals, however, birds optimize and will adapt appropriately to opportunistic situations (box 4-2) (114).

Not only are data lacking on causal relationships between bird population changes and aquaculture facilities, but also on national or regional population trends for birds. Detailed information usually is available only for selected species in restricted locales. Lack of reliable data makes it difficult to determine whether a trend exists for a particular species or group of species over large areas such as states, regions, or the nation (107).

BOX 4-2: Short-Stopping Double-Crested Cormorants and Fish Farms

Fish farmers and others have speculated that the increase in number of wintering double-crested cormorants in the Mississippi Delta is due in part to the phenomenon of "short-stopping" of southward migrating birds attracted by the burgeoning aquaculture industry (133). Short-stopping refers to the premature termination of southern migratory movement well short of the normal wintering grounds in response to a particular stimulus, usually abundant food.

Verification of such hypotheses with hard scientific evidence, such as recovery of marked individuals or radio telemetry data, has not been made (107). Strong circumstantial evidence, however, seems to support the short-stopping speculation. Evidence shows the number of roosts and individual wintering cormorants in the Mississippi Delta area has increased since 1987 (133). It is not clear whether this represents short-stopping or simply increases in seasonal local populations.

It has been further speculated that some cormorants may eventually forego migrating altogether and establish a resident population in the Mississippi Delta (133). Other typically migratory species remaining longer in wintering or breeding areas or becoming year-round residents now present wildlife damage problems in certain areas (24,151). However, in the case of the double-crested cormorant, although many spend the winter in the Mississippi Delta in response apparently to the vast acreage of catfish ponds, the great majority still winters in coastal waters of the Gulf of Mexico (137).

SOURCE: Office of Technology Assessment, 1995.

Issue: Use of Lethal Methods to Control Avian Predators

Considerable debate surrounds the purpose, need, and effectiveness of lethal methods. If nothing is done to make a foraging site unattractive, avian predators removed via lethal methods are replaced quickly by other individuals of the same or different species (34). Rapid replacement of one predator by another suggests that elimination of individual birds may not be an effective solution to reducing bird abundance at fish farms. In fact, it has been claimed that no scientific data exist to show that removal, relocation, or elimination of individual bird predators has any long-lasting effect on reducing bird predator abundance at fish farms, nor does it alone reduce fish losses (34).

It is sometimes advised, however, that the authorized, legal killing of a few birds may be useful to scare off potential predators and to restore the effectiveness of other non-lethal deterrents (83). Proponents of lethal methods recommend that efforts be directed toward removing individuals that have learned to circumvent deterrents successfully rather than taking naive, ineffective feeders. This suggestion assumes that the person doing the killing can distinguish among individual predators. From the producer's perspective, lethal methods provide a visible means of eliminating offending animals and give immediate gratification (77).

Issue: Problems with Depredation Permit Process

All native birds in the United States either are protected by federal statute (Migratory Bird Treaty Act of 1918; Endangered Species Act of 1973) or are regulated as game by federal and state laws or regulations.[3] Provisions in the federal

[3] Seventeen species are regulated as game species; 23 introduced bird species receive no protection (such as house sparrows and European starlings).

acts, however, allow for the taking, under specified conditions and procedures, of protected species causing economic damage or presenting human health hazards (146).

The U.S. Fish and Wildlife Service, Division of Law Enforcement personnel reviews requests for and issues depredation permits. USFWS personnel also are required to monitor and enforce compliance with provisions of all permits--not just those to aquaculture--issued by the agency. Further, Division personnel are required to investigate any suspected cases of illegal taking of birds. Limited staffing and the need to cover considerable geographic areas within a region make monitoring for compliance and enforcement of permit provisions a monumental task.[4]

It is possible that violations of wildlife law go unchecked at aquacultural facilities. Some may result from lack of knowledge by operators about the law; others may be purposefully conducted violations with intent to eliminate unwanted wildlife. The regional supervisor for Region 1, USFWS Division of Law Enforcement described the situation facing him and his staff as follows:

There are an estimated 1,000 licensed aquaculture facilities in Region 1. It is believed that more than 90 percent of the facilities kill migratory birds. The estimate is based on off-the record comments from people in the industry and citizen complaints. Because of limited resources, we have been able to investigate only a fraction of the complaints received from the public and local officials (107).

Aquafarmers also have complaints regarding the depredation permit process, pointing to inconsistencies among state enforcement policies and to discrepancies between state and federal rulings.[5] Aquafarmers also complain about the lack of an incidental take clause within the depredation permit that would allow for the accidental killing of a limited number of birds not listed on a permit.

To address complaints about the permitting process and criticism of an inefficient permit record-keeping system, Congress could request regular progress reports from the U.S. Fish and Wildlife Service on the process for issuing depredation permits.[6] Congress also could request that USDA and USFWS conduct comprehensive surveys of aquaculture facilities to determine the extent of predation problems including species, estimates of losses, and methods of control.

The USFWS could be required to modernize its computer database program for bird depredation permits to attempt to answer critical questions--such as numbers of permits issued, and numbers of birds killed. Improved computer technology for the permit program might include applying geographic information system (GIS) methods toward resolving predation problems. Computer databases on the

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[4] Manual retrieval of records on permit data--which took approximately seven months to arrive at OTA, many in a different form for each USFWS region--exemplifies at least one shortcoming of the present system.

[5] Lack of agreement about a depredation permit between state and federal regulators led to a 1991 court case in *Pennsylvania: Aqua-Life* v. *Pennsylvania Game Commission Commonwealth*, No. 165 M.C. 1991.

[6] The USFWS, Division of Law Enforcement, has indicated the allocation process for depredation kill permits will be revised to include an objective and scientific basis for review (107). Current policy generally dictates that if the proper application is filed and base criteria are satisfied, a permit will be granted. In accordance with suggested revisions, permit requests would be reviewed by a panel, possibly consisting of representatives from permit authorities (USFWS, USDA), biologists, and independent industry representatives.

Decisions on the granting of requests for kill permits would be based on an evaluation of economic and physical impact to the operation, as well as the effects of take on the species involved. Where the predator population is determined to be unable to withstand significant reduction, or where justification for kill has not been made, a depredation permit would not be granted. The revised format would provide opportunity to monitor impacts of kill actions on ecological resources. The new format, however, may impede quick response to requests with justifiable need.

location of wildlife populations and their habitats, species status, hydrologic resources, and other environmental parameters could be used to improve aquaculture facility siting to reduce predation problems.

CONTROL METHODS

Much information is available on technologies to minimize predation by birds in aquaculture. None of the technologies, however, will guarantee 100 percent protection against predation losses. Control methods have to be effective, economically feasible, and environmentally safe. Although available technologies will provide some protection over varying periods of time, producers should not rely on one method to guard against losses. An integrated approach that combines a careful preliminary examination of facility location, design, construction, operation, and management for minimizing losses due to predators along with consistent application of different effective deterrent techniques will most likely provide the best protection from predation problems (box 4-3).

Methods of bird predator control at aquaculture facilities fall into four categories: facility siting, land husbandry, non-lethal, and lethal methods (table 4-1). None of the methods have proven 100 percent effective in deterring avian predators. Effectiveness of a particular control method will vary from facility to facility depending on such factors as facility type, size of cultured species, and management techniques (107).

Commercial production of catfish in large, contiguous ponds precludes use of

BOX 4-3. An Effective Bird Predation Control Program

Advice from several sources provides a realistic approach to bird predator control at most aquacultural facilities (83,112).

Before construction of an aquacultural facility:

- Evaluate chosen site to determine if it is the best possible site or if you are setting yourself up for predation problems that present technology cannot solve.
- Consider the size, shape, and layout of ponds.
- Get to know local ornithologists and enlist their help in determining bird populations, roosting sites, and behavior.

After construction of an aquacultural facility:

- Start your deterrent effort immediately. Discourage predators before they establish a feeding pattern.
- Frighten birds away before they land on the water's surface. It is much more difficult to get birds back into the air than to turn birds away while still flying. Once diving birds land, they can dive under water and avoid exposure to many harassment techniques.

Ongoing predator control methods:

- Use a variety of techniques and change the location and combinations of non-lethal controls to keep predators off-guard and to minimize the potential for habituation.
- Quantify losses from all sources: disease, water quality, and predation. Accurate data will help document losses due to predation and whether the losses are greater or less than annual predator control costs.
- With proper authorization, use lethal methods if necessary for enhancement of non-lethal methods.
- Report bird kills under permits accurately for numbers and species.
- Don't expect total elimination of a predator problem; strive for a reasonable reduction.

SOURCE: Office of Technology Assessment, 1995.

TABLE 4-1: Control Methods fro Avian Predators at Aquaculture Facilities

Control method	Technique	Predators affected[a]	Facility type	Comments on effectiveness[b]	Relative costs of control[c]
Facility siting and design	Avoid known predator roosts, rookeries, and migration routes	All	All	When flexibility exists for siting a facility, thorough review of potential sites in advance may preclude some predation problems.	Costs vary; less expensive when deterrents installed during construction rather than retrofitting
Good husbandry	Maintain clean facility	All	All	Simple, commonsense activities, such as cleaning up spilled feed, regularly removing dead stock, and controlling vegetation growth, can make a site less attractive to predators as well as prevent health and disease problems.	Minimal costs
Non-lethal methods					
Facility modification	Increase water depth in holding structure	Waders, ground feeders	Raceways	Increased water depth may prevent birds from wading, however, birds that typically use wading behavior can alter feeding methods and use diving and swimming techniques.	Variable costs
	Raise height of sidewalls of holding structure	Waders, ground feeders	Raceways	Raising height of sidewalls above the water's surface can place cultured stock out of reach of some predators; height required to keep predators away will vary with predator species.	High costs if facility is retrofit
	Increase slope of embankment	Waders, ground feeders	Ponds, raceways	Increased slopes around ponds or raceways can make it difficult for wading birds to reach the water's edge; gradual embankments duplicate natural feeding environ-ments and facilitate predator's access and feeding success.	High costs if facility is retrofit
	Remove perches and feeding platforms	Waders, aerial-divers, ground feeders	Ponds, raceways, net pens	Removing perches and platforms that might be used for feeding or hunting (such as light posts, electric wires, fence posts, and handrails) that are near or above culturing structures can eliminate or at least limit their usefulness to predators.	Variable costs
	Remove concealing cover and protective vegetation	Waders, aerial-divers, ground-feeders	Ponds, raceways	Removing cover and vegetation that conceals or protects predators can reduce their feeding success.	Low costs
	Roost/nest site dispersal	Waders, aerial-divers	Ponds, raceways	Forcing birds to relocate from a roosting site can reduce bird numbers on ponds; birds may not leave the general vicinity relocating to other undisturbed ponds or facilities within flight distance.	Moderate costs

TABLE 4-1: Control Methods for Avian Predators at Aquaculture Facilities (cont'd.)

Control method	Technique	Predators affected[a]	Facility type	Comments on effectiveness[b]	Relative costs of control[c]
Operational modification	Modify type of feed and feed delivery method	Aerial-divers, ground-feeders	Ponds, raceways, net pens	Floating feed attracts gulls and other surface feeding birds; non-floating pellets may reduce availability to predators; feed thrown carelessly may accumulate and attract predators.	Variable costs
	Alter on-site location of vulnerable stock	Waders, aerial-divers, swimming birds, ground feeders	Ponds, raceways	Predator activity is reduced in areas close to human activity; placing the most vulnerable or economically important stocks in structures close to activity centers may reduce losses to predators.	Low costs when space is available
	Careful selection of cultured stock	Waders, aerial-divers	Ponds, raceways	Certain biological characteristics among cultured stocks may influence their susceptibility to predators (e.g., depth occupied in water column).	Costs undetermined
	Provision of alternative food	Waders, aerial-divers, swimming birds, ground-feeders	All	"Buffer" food such as low-value fish may be placed in ponds at the peri-phery of the facility; abundance and ready access may make buffer food more vulnerable to predators causing them to leave higher valued species alone; results of method have been mixed; concerns exist regarding artificially increasing predator density with increased food supply.	Moderate costs
Auditory harassment	Predator distress calls (broadcast of a recording of a predator species' alarm call)	Waders, swimming birds, ground-feeders	Ponds, raceways, net pens	Effectiveness of method greatest when used at time predation problem first arises; response to playbacks varies with species, time of day, time of year, and distance predators are from speakers; may cause some birds to flock around sound; method subject to habituation.	Low costs
	Automatic exploders (small canons operated on bottled gas and controlled by electric timer)	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways	Effectiveness of method mixed; may be negative effects on cultured species; use not feasible in all locations, especially in areas with noise ordinances or when neighbors are nearby; method subject to habituation.	Moderate costs
	Pyrotechnics (explosive noise-making devices including cracker shells, bombs, whistlers, screamer rockets, and firecrackers)	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways, net pens	Effectiveness depends on firing range of device, weather conditions, experience and accuracy of operator; potential exists for non-target losses; method subject to habituation.	Moderate to high costs

TABLE 4-1: Control Methods for Avian Predators at Aquaculture Facilities (cont'd.)

Control method	Technique	Predators affected[a]	Facility type	Comments on effectiveness[b]	Relative costs of control[c]
	Sirens (similar to emergency vehicle sirens; can vary in pitch and attach to timers)	All	All	Method subject to habituation.	Low costs
	Electronic noise-makers	All	All	Results slightly more effective with mammals; effectiveness varies with intensity of noise and positioning; acoustic seal deterrents may pose negative effects on non-target species (e.g., drive whales and porpoises from feeding grounds; method subject to habituation.	Low to moderate costs
Visual harassment	Lights (streetlights, floodlights, flashers, strobe lights)	All	All	Effectiveness varies with predator species; may be more effective, at least initially, with nocturnal preda-tors; will temporarily blind and con-fuse predators and limit predation; method subject to habituation.	Variable costs
	Scarecrows and effigies	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways	Effectiveness varies with predator species; effects increase with incorporation of moving parts and when moved routinely to new locations; occasional human presence and use of pyrotechnics shot from near the effigy may reinforce the stimulus; method subject to habituation.	Low to high costs
	Predator decoys (models, silhouettes of hawks, owls, snakes)	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways, net pens	Effectiveness varies with predator species; method subject to habituation.	Low costs
	Reflectors (shiny-surfaced objects reflecting light)	All	All	Effectiveness varies with predator species; method subject to habituation.	Low costs
	Model airplanes	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways	Most effective when model planes fitted with pyrotechnic launches that haze birds as they attempt to land; birds already on water may dive to avoid the harassment; method limited by weather, flight obstruc-tions, need for frequent refueling; potential for crashing into pond and creating water quality problem.	Low costs
	Trained falcons	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways	Effectiveness limited by size of facility and finding interested and dependable falconer.	Costs undetermined

TABLE 4-1: Control Methods for Avian Predators at Aquaculture Facilities (cont'd.)

Control method	Technique	Predators affected[a]	Facility type	Comments on effectiveness[b]	Relative costs of control[c]
	Human presence	All	All	Effectiveness varies with use of supplements (pyrotechnics, recordings), size of ponds, and frequency of visits by humans; method subject to habituation.	Variable costs
Barriers	Perimeter fencing and protective netting	Waders, swimming birds, ground-feeders	Ponds, raceways, net pens, nearshore and offshore culture	Effectiveness varies with facility design and size and predator species.	Variable costs
	Water spray devices (stationary or rotating sprinkler units distributing jets or curtains of water over the water's surface)	Waders, aerial-divers, ground-feeders	Raceways, net pens	Provides both visual and auditory stimuli; reduces visibility of fish in water effectiveness varies with species and may be increased with greater water pressure and when operated cyclically rather than continuously.	Moderate costs
	Plastic sheet guards (Poly-ethylene sheeting suspended over gates of raceways)	Waders, ground-feeders	Raceways	Used to reduce predation by "stand and wait" predators such as common grackles; device can be cost-effective but may require increased personnel effort to perform routine maintenance chores.	Low to moderate costs
	Exclosure (any type of physical structure preventing an animal from gaining access to cultured stock; includes netting of entire facility or sepa-rate units and side netting or fencing)	Waders, aerial-divers, swimming birds, ground-feeders	Ponds, raceways	Effectiveness varies with size and design of structure; method subject to problems with structure failure, collapse during high winds or other inclement weather, entanglement of non-target and protected species in netting, hindering of routine maintenance operations, and secondary loss of stock when structure collapses into rearing pond	High costs
	Overhead wire grid (stainless steel wires or heavy gauge fishing lines suspended horizontally above water's surface)	Divers, swimming birds	Ponds, raceways, net pens	Size of grid must be adjusted depending on predator's size and feeding behavior; problems with overhead wire grids include excessive weight loading from ice or groups of birds perching on its supports, eventual weathering of material, maintaining sufficient support on long spans, and birds landing outside of the perimeter and walking into protected area	Moderate to high costs
	Top covers (tight fitting, framed covers mounted over culture units)	Waders, aerial-divers, swimming birds, ground-feeders	Raceways, net pens	Method may cause problems for routine facility maintenance or operation.	Moderate costs

TABLE 4-1: Control Methods for Avian Predators at Aquaculture Facilities (cont'd.)

Control method	Technique	Predators affected[a]	Facility type	Comments on effectiveness[b]	Relative costs of control[c]
	Electric wire and fencing	Waders, ground-feeders	Ponds, raceways, net pens	Effectiveness varies with feeding behavior of predators; method subject to habituation.	Moderate costs
Trap and release	Trap and release predators where allowed by law	All	All.	Where allowed by law, problems occur with disposing of captured animals; technique will not solve ultimate cause for conflict and may provide only temporary relief.	Moderate costs
Chemical deterrents	Repellents; include products such as ReJex-iT (product made from plant-derived chemical with grape-like odor) and A-C (alpha-chloralose) based compounds that sedate predators and allow for capture	All	Ponds	Use may be impractical because of human health and safety concerns, limits set by FDA for amounts of chemical contaminants allowed in consumable products, and predominance of chemicals designed for land-based applications.	New products
Lethal Methods					
Trap and kill	Trap and kill predators where allowed by law	All	All	Technique will not solve ultimate cause for conflict and may provide only temporary relief.	Moderate costs
Shooting	In most cases requires depredation kill permit	All	All	Technique will not solve ultimate cause for conflict and may provide only temporary relief.	Low to moderate costs
Toxicants	Use of toxicants subject to legal restrictions	Depends on chemical	Depends on chemical	Use of toxicants may be prohibited on wildlife in most states; "restricted use" products require pesticide certification.	Low costs

[a] Key to predators:

- Waders such as herons and egrets
- Aerial-divers such as gulls, kingfishers, osprey, pelicans
- Swimming birds such as cormorants, waterfowl
- Ground-feeders such as grackles, crows, magpies

[b] Habituation refers to the gradual diminishing of an animal's fright response to novel situations (107).

[c] Cost is relative to other methods; estimated by Parkhurst (107).

SOURCE: Office of Technology Assessment, 1995.

some effective control strategies such as netting or overhead wiring. Large ponds also provide ample central areas where birds find protection from many harassment technologies. Diving predators, the cormorant in particular, frequently escape harassment by vanishing underwater at the first sign of potential danger rather than taking flight. Organisms cultured in cages or net pens in open water may be subject to predation from marine fish, mammals, and birds.

Size of prey can bear on predation problems. For example, baitfish are small even as adults and the number of potential predators capable of efficiently handling such prey is large. Harvesting methods of cultured stock that draw down ponds to concentrate fish and facilitate collection also will exacerbate depredation problems.

Habituation is a key factor influencing the effectiveness of a predator control method. Habituation is a process where an animal's normal fright response to novel situations gradually is extinguished so long as the

stimulus poses no real threat to the animals (129). To remain effective, a stimulus must

be increased in intensity or altered in presentation. Many commonly relied upon techniques have limited effectiveness as predators "learn" that the devices do not pose a real threat. In other cases, the animal finds ways to circumvent the device and continue preying on cultured stocks. Examples of habituation include instances where predators learn how far to move to be out of range of noise-making devices and how to hunt from atop automatic exploders (e.g., moving away as the cannon discharges and returning shortly after to resume hunting).

The following paragraphs present brief descriptions of possible methods to control predators at aquaculture facilities. Unless otherwise noted, the information is summarized from an OTA contract paper on predation in aquaculture (107).

Facility Siting and Design

Decisions relating to the siting and design of a new aquacultural facility should be based, in part, on reliable information about potential predation problems. Developers should make a conscious effort to avoid constructing aquacultural facilities on known migratory routes, near well-established rookeries, or near areas where fish-eating birds concentrate (147). Facility design also should incorporate predation deterrents. Incorporating workable predator management technologies in the initial stages of construction may reduce lower economic losses once the facilities are operating.

Good Husbandry

The use of sound husbandry practices in any aquacultural facility plays an important role in minimizing problems with predators. Simple, common sense activities such as properly storing and cleaning up spilled feeds, regularly removing and properly disposing of dead or dying stock, and controlling the growth of vegetation around holding structures could provide substantial benefit by making a site less attractive to predators.

Non-Lethal Control Methods

Non-lethal control methods for predators of aquaculture facilities include modifications to facilities and to operational procedures, harassment techniques, barriers, live-traps, and chemical deterrents. Aquaculture facilities may be made less attractive to predators if water depth or slope of pond embankments is increased. Use of non-floating feed, and locating vulnerable stocks close to the center of human activity where predator activity may be lowest, also can be helpful.

Harassment involves using auditory or visual techniques to trigger a fright response. Auditory harassment techniques include automatic exploders and predator distress calling (a broadcast of a recording of a call emitted by an animal in response to alarm). Visual harassment techniques include lights, scarecrows, and human or animal presence to harass birds and prevent them from landing.

Several types of barriers may prevent or deter predators. Fencing or netting may be installed around the perimeter of a facility, or water spray devices may distribute jets of water over the water's surface to provide both visual and auditory stimuli. The cost of the barrier and the size of aquaculture facility will dictate the feasibility of a particular barrier.

Trapping a predator may require a state and/or federal authorization. Where legal and appropriate authorization has been obtained, several types of cages and box traps enable capture of live and uninjured animals. The trapped predators can then be transported away from the aquaculture facility.

Some chemicals may be used to deter selected avian predators from ponds. One such product has a plant derivative base with a grape-like odor (methyl anthranilate,

MA). Various formulations of MA form a coating on the water surface that avian predators find unpleasant. These been tested under controlled pen conditions with captive birds and under field conditions in culture ponds. Experimentation continues on developing formulations and applications suitable for use in commercial aquacultural operations. Concerns with use of chemical deterrents in aquacultural operations include human health and safety issues (e.g., potential for chemical contaminants in consumable foods) and the possibility that foul-tasting substances may make the cultured organism unpalatable to humans as well as other predators.

Lethal Control Methods

Use of lethal technologies in wildlife management follows a decision to kill animals causing damage to property (142). Lethal methods may include trapping and killing, using toxicants, or shooting. Traps to capture and kill birds in aquacultural facilities have been used historically (up to the early 1970s); however, no recent studies document use of traps on fish-eating birds. Many states have regulations prohibiting the use of toxicants or poisons on nuisance animals. The potential for non-target losses and secondary hazards usually preclude their use except under carefully controlled applications. Some facilities employ personnel to "ride shotgun" around ponds specifically to harass and shoot birds.

BIRD DEPREDATION PERMITS

To shoot most predatory birds, an aquaculture facility owner must obtain a bird depredation permit (box 4-4). Information on number of depredation permits issued and total take of protected species under such permits is collected by the Regional Offices of the USFWS, Division of Law Enforcement. Depredation permits are applicable to a wide spectrum of wildlife conflict areas and, thus, are not restricted to problems experienced in aquacultural facilities.

Data on take of birds often are not separated by specific commodity area, making summary information for aquaculture not readily available. The retrieval system established by the regional offices was designed primarily to facilitate their internal tracking of the names and locations of permittees, when permits were issued, and the species for which the permit covered. Data on the results of actions taken by a permittee under the provisions of their permit are contained only in annual reports filed by the permittee with the regional offices; in most instances, this information is not computerized and retrieval is made only by reviewing each report manually.

Summary data provided to OTA from the USFWS, Division of Law Enforcement, Regional Offices on permits issued, thus, came in differing and sometimes incompatible data sets, precluding exact summarization. For example, some regions reported data over varying periods of years, Region 4 did not report any permits before 1985, and Region 7 did not provide any data, replying "no activity" (figure 4-1). In light of incomplete data sets and a poor retrieval system for reviewing permit records, the following remarks must not be viewed as conclusive.

A total of 51,553 birds representing 38 species or groups of species were taken by permittees at aquacultural operations nationwide between 1989 and 1993 (table 4-2). Double-crested cormorants (25,930 birds or 50.3 percent of total take), great blue herons (9,443 birds or 18.3 percent of total take), and great egrets (4,242 birds or 8.2 percent of total take) were taken most frequently according to reports filed by

Figure 4-1. U.S. Fish and Wildlife Service Regions

Region 1: California, Hawaii, Idaho, Nevada, Oregon, Washington, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, and the Pacific Trust Territories; **Region 2**: Arizona, New Mexico, Oklahoma, and Texas; **Region 3**: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin; **Region 4**: Alabama, Arkansas, Louisiana, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Florida, Tennessee, Puerto Rico, and the U.S. Virgin Islands; **Region 5**: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia; **Region 6**: Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming; **Region 7**: Alaska

BOX 4-4: Bird Depredation Permit Process

The U.S. Code of Federal Regulations, title 50, includes six sections: two depredation permit processes (sections 21.41 and 21.42), and four special "standing depredation orders" where a permit is not required to take birds (sections 21.43-21.46). Section 21.41 allows the USFWS, Division of Law Enforcement, to issue kill permits for the take of protected species. Section 21.42, which allows the take of migratory game birds deemed responsible for serious economic damage to agriculture--including aquaculture--stipulates that a depredation permit must be issued by the Director of the USFWS before take occurs.

The four standing depredation orders, where an individual permit is not required, are quite specific: Section 21.43 relates to the take of selected species of grackles, blackbirds, magpies, and crows causing physical damage to agricultural/livestock operations, wildlife, or ornamental and shade trees or where numbers of these birds present a nuisance or health hazard; section 21.44 is limited to the treatment of passerine (non-perching birds such as woodpeckers) damage in California; section 21.45 allows for the take of purple gallinules in Louisiana rice fields; and section 21.46 provides protection against depredation by jays to commercial nut crops in California and Washington.

The U. S. Fish and Wildlife Service, Division of Law Enforcement (in consultation with field personnel of USDA's Animal and Plant Health Inspection Service, Animal Damage Control), administers, maintains records on, and enforces compliance with section 21.41 depredation permits. Persons wishing to obtain a depredation permit must file an application with the Division of Law Enforcement's regional office serving the applicant's geographic area (there are seven regional offices). The application must describe the following: 1) the species for which a kill permit is desired; 2) the site where damage has occurred; 3) the type of damage inflicted; 4) an estimate of the amount of damage incurred; and 5) a demonstration that all reasonable efforts have been made to stop the damage through use of non-lethal technology.

Permits issued to individuals may cover an entire year (typically those permits issued to a federal or state facility) or have a fixed time period within which authorized take may occur. Permits should stipulate the number of individuals and the species that can be taken. When a permit expires, the issuant is required to file with the Regional Office a report that describes the species and number of individuals actually taken under the provisions of the permit. Failure to prepare and submit an annual report usually prevents the applicant from receiving another permit in the future. The carcasses of any birds taken do not necessarily have to be surrendered to federal authorities, but leg bands and other data pertinent to marked individuals must be reported to the USFWS Migratory Bird Laboratory. In some cases, depredation kill permits have been issued as a means of achieving a temporary reduction in predation pressure while other non-lethal techniques can be put in place.

In most states, regulations also exist that afford protection to non-game species (i.e., those for which a regulated season does not exist) and special permits from the state wildlife agency are required to take such birds. As is true under stipulations of the federal statute, applicants must show good cause to justify the need for removing such animals using lethal means. Reporting requirements similar to those of the USFWS exist at the state level.

SOURCE: Office of Technology Assessment, 1995.

permittees with the USFWS. Other birds taken in relatively high numbers included snowy egrets (1,208 birds, 2.3 percent of total take), little blue herons (1,379 birds or 2.7 percent), black-crowned night herons (1,734 birds or 3.3 percent), ring-billed gulls (1,050 birds or 2.0 percent), and belted kingfishers (1,197 birds or 2.3 percent).

Authorized take of birds by permit from 1989 to 1993 was greatest in Region 4 (34,698 birds or 67.3 percent of total take), followed by Region 6 (7,985 birds or 15.5 percent), Region 1 (3,915 birds or 3.0 percent), and Region 2 (1,050 birds or 2.0 percent). As reflected by data on reported kill, cormorants, wading birds, gulls and terns, and selected species of waterfowl appeared to be troublesome for aquaculturists nationwide whereas other species or groups were problematic only

within a particular region (e.g., pelicans in Region 4; grackles in Region 6). Of all

TABLE 4-2: Reported authorized kill of bird predators at aquacultural facilities in the U.S., 1989-1993 (U.S. Fish and Wildlife Service, Division of Law Enforcement)

Species/Group	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total
Swimming birds							
Grebes				708			708
Western Grebe	36					9	45
Pied-Billed Grebe						22	22
Pelican				225			225
American Pelican						19	19
Double-Crested Cormorant	1,494	824	1,356	19,620	1,514	1,122	25,930
Anhinga				42			42
Mallard						76	76
Common Eider					14		14
White-Winged Scoter	48						48
Old Squaw					7		7
Goldeneye						10	10
Merganser		52					52
Common Merganser	15					270	285
American Coot	75			363		37	475
Waders							
Egret			5				5
Great Egret				4,242			4,242
Snowy Egret	738			363		107	1,208
Heron	50	158		154			362
Great Blue Heron	350		122	7,295	136	1,540	9,443
Green-Backed Heron	6					13	19
Little Blue Heron				1,379			1,379
Black-Crowned Night Heron	662					1,072	1,734
Aerial-divers							
Gull	249			265			514
Herring Gull	2		28		631	186	847
California Gull						364	364
Ring-Billed Gull	8		13			1,029	1,050
Franklin's Gull						17	17
Bonaparte's Gull						17	17
Forster's Tern						285	285
Common Tern						38	38
Caspian Tern	175					3	178
Great Horned Owl						18	18
Belted Kingfisher	7	16	18	42	61	1,053	1,197

TABLE 4-2: Reported authorized kill of bird predators at aquacultural facilities (cont'd.)

Species/Group	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Total
Common Raven						93	93
American Crow						14	14
Common Grackle						391	391
Total	**3,915**	**1,050**	**1,542**	**34,698**	**2,363**	**7,985**	**51,553**

NOTE: Some species were identified without full common name in USFWS data
SOURCE: Office of Technology Assessment, 1995.

species, double-crested cormorants were taken most frequently in all regions except Region 6, where great blue herons topped the list.

The number of depredation permits issued to aquacultural operations nationwide has increased since 1980 (figure 4-2). The largest increases have occurred in Regions 3 and 4.[7] Although the national trend in reported kill of avian species at aquacultural facilities in the United States is increasing, a significant increase (+516.1 percent) in take of birds in Region 4, particularly in Arkansas and Mississippi, is driving this trend.[8] Of the 35 states in which depredation permits had been issued and for which reports of take were filed with the USFWS for the period 1989 to 1993, Arkansas led all states in total take (27,072 birds; 52.5 percent of national total); Mississippi ranked second in total take (5,295 birds; 10.3 percent of national total) (107).[9]

[7] Total number of permits issued remained stable or declined in Regions 1, 5, and 6; permits have increased only slightly in Region 2. States receiving noticeable increases in number of issued permits include Texas (up from zero in 1980 to 16 in 1994), Minnesota (up from two in 1979 to 44 in 1984), Arkansas (up from zero in 1985 to 55 in 1984), and Mississippi (up from zero in 1985 to 39 in 1994). Number of permits issued has declined in Washington (down from eight in 1980 to one in 1994), Maine (down from 14 in the 1980s to seven), New Hampshire (down from seven in the 1980s to zero in 1994), and Kansas (down from 10 in the 1980s to three).

[8] Nationally, 42,892 birds were reported taken under depredation permits issued to aquacultural sites during the period 1979 to 1989. In the following five-year period (1989-1993), 51,553 birds were reported taken (a 20.2-percent increase). Outside Region 4, however, the take of birds under permit appears to have declined, remained stable, or increased only slightly. For example, a comparison of five-year averages (1985-1989 vs. 1989-1993) in Regions 1 and 2 revealed a slight increase (+12.1 percent) and a major decline (-41.2 percent) respectively. There was a moderate increase in reported kill in Region 6. Unfortunately, because no other regions provided data on yearly take that would allow tracking of five-year averages, accurate prediction of trends is not possible.

[9] California (3,542 birds; 6.9 percent of national total) ranked third. Arkansas also led the nation in terms of take for selected species of birds: double-crested cormorant: 112,092 (58.2 percent of national reported take), great egret: 3,320 (78.2 percent of national reported take), great blue heron: 5,531 (58.6 percent of national reported take), little blue heron: 1,366 (99.0 percent of national reported take), and American coot: 342 (72 percent of national reported take). California led the nation in take of snowy egrets (738; 61.1 percent of national reported take), Nebraska led for belted kingfishers (569; 47.5 percent), and Utah was highest for black-crowned night herons (970; 55.9 percent).

States or territories not reporting any take of birds (or where depredation permits were not issued) between 1989 to 1993 included: Region 1: Hawaii, Oregon; Region 2: New Mexico; Region 3: Illinois, Indiana; Region 4: Kentucky, Puerto Rico, Virgin Islands; Region 5: Delaware, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, Vermont, West Virginia; Region 7: Alaska.

Figure 4-2. Bird depredation permits issued to aquacultural facilities by U.S. Fish and Wildlife Service, Division of Enforcement, 1979-1994.[1]

[1]Data for all years for all regions were not available. Numbers were reported separately for some years and in groupings of years making direct comparisons impossible.

Data for some years were summarized as follows:

Region 1 1990-1994: 15 permits
Region 2 1991-1994: 25 permits
Region 3 1991-1994: 93 permits
Region 5 1980-1988: 41 permits; 1989-1993: 19 permits
Region 6 1980-1988: 38 permits; 1989-1993: 33 permits

Number of permits appearing in yearly total may include new permits as well as renewals of permits issued in previous years.

An entry into a year's total number of permits for a region may represent a permit issued to an individual to help address a predation problem at a single facility. Another entry into a region's yearly total of permits may represent a blanket permit issued to a state agency to address predation problems at all of the cultural facilities within that state. Although in each case only a single permit appears in the total, actual take may be occurring at as many as 10 or more sites. Thus, the total number of permits issued for a particular year may be a misleading indicator of the extent of activity actually occurring in the field.

TRENDS IN BIRD POPULATIONS

Only a small number of avian predators associated with aquacultural operations have demonstrated any documented and widespread changes in breeding, migration, or wintering patterns. This does not mean that such changes have not occurred for other species, or, that observed changes are due to aquaculture. In fact, it is highly likely that small scale, local shifts in avian activity patterns have occurred in response to specific catastrophic events or alterations in habitat. Documentation to support such a hypothesis, however, is scattered and not easily summarized for the number of species of avian predators concerned (107).

The Breeding Bird Survey (BBS), sponsored by the U.S. Fish and Wildlife Service and Canadian Wildlife Service, provides some indication of changing trends of bird populations (data from Patuxent Research Lab, Maryland). In brief, trained volunteers survey observation routes during the breeding season, counting species seen and heard. While providing valuable information on population status and trends, this data set may lack reliability. Potential sources of error include inclement weather, misidentifi-cation of species, and non-detectability of species. Thus, the following interpreta-tions, based on BBS data must be viewed with caution.

Using a 25-year summary (1965-1989) and a 10-year summary (1982-1991) of BBS data, OTA examined the population trends for eight species of birds commonly observed as predators of aquaculture farms: double-crested cormorant, great egret, snowy egret, great blue heron, little blue heron, black-crowned night heron, ring-billed gull, and belted kingfisher. In general, of these eight species, three experienced increases in populations in both the 25- and 10-year BBS summary periods: great egrets, snowy egrets, and ring-billed gulls. Two species experienced an increase in the 25-year summary period and had stable to decreasing trends in the 10-year summary period: double-crested cormorants and great blue herons. Three species experienced declines in both the 25- and the 10-year BBS summary periods: little blue herons, black-crowned night herons and kingfishers (107).

A cursory comparison of population levels with number of birds killed with depredation permits shows that most birds were killed in regions where populations are stable or increasing (cormorants, great egrets; great blue herons in Region 4; snowy egrets in California and Region 4; black-crowned night herons and ring-billed gulls in Region 6). Some areas with population declines issued no permits for the declining species (e.g., great egrets in Region 5) There are, however, several examples of birds killed in areas where trends in at least one of the two-summary periods show declines (e.g., cormorants in Maine; great blue herons in Region 6). Because of the uncertain completeness of the data on number of depredation permits issued, species and numbers killed and levels of populations in local and regional areas, none of these relationships can be considered conclusive. Thus, while speculation can be made on the effects of aquaculture on the population trends of some bird species (e.g., populations of some species increase as new food sources from aquaculture facilities become available), conclusive evidence is not available.

CONCLUDING REMARKS

Extent of loss to aquaculture facilities from bird predators is of great interest and concern to aquaculturists, researchers, and regulators. Lack of reliable information on predators responsible for losses and numbers and size of prey taken makes

reasonable approximations of economic impact difficult to determine.

There will, in all likelihood, never be one universal method that will resolve all conflicts between with wildlife and aquaculture. Aquacultural enterprises today are diverse in terms of facility design, practices, and types of organisms cultured. Even among facilities producing similar cultured stocks, differences in facility or site qualities, surrounding habitats, range and distribution of predators, and predator population densities reduce the likelihood that any one control technique will be effective in all situations.

A reasonable approach to a predator deterrent program may be to minimize damage to an economically tolerable level rather than to attempt complete control. Operators must be aware of the potential for adaptation and habituation in predators and develop plans to deal with these problems. Given currently available tech-nology, an integrated strategy that employs several deterrents used in rotation will provide the most long-lasting and effective means of limiting predation. Even under such an approach, operators must recognize that some losses will occur.