AN OVERVIEW OF AVIAN PREDATION AND MANAGEMENT TECHNIQUES AT FISH-REARING FACILITIES

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ABSTRACT: As the aquaculture industry continues to expand in the United States, so too do the losses attributed to wildlife depredation. Because the industry is so diverse and the various types of culture are characterized by unique designs, operations, and arrays of cultured species, there is a need for corresponding uniqueness in predator management strategies and techniques. It is unlikely that, at any time in the near future, one universal method or approach will be developed to successfully resolve wildlife depredation problems in all facilities. However, numerous areas for improvement currently exist where potential reductions in the extent of loss can be achieved with minimal impact on the industry. Additionally, the industry must be willing to accept some loss simply as one of the natural costs of doing business.

Proc. 16th Vertebr. Pest Conf. (W.S. Halverson& A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1994.

INTRODUCTION

Problems with avian depredation in fish-rearing facilities are not new. In fact, hatchery managers have been coping with problems caused by piscivorous birds since the inception of fish culture (Cottam and Uhler 1937, Lagler 1939, Pough 1941). However, the nature and scope of depredation problems have changed over time such that these issues are now much more complicated and difficult to resolve. Early attempts at fish culture simply involved placing fish in a pond to mature and breed naturally (i.e., extensive culture) whereas today stocks are cultivated at extremely high densities, under artificial feeding, lighting, and breeding programs (i.e., intensive culture) (Lee and Newman 1992). The diversity of cultured species has increased from a relatively small number of important game or sport fishes to a wealth of food, bait, ornamental, and sport fishes. Further, although many small "mom and pop" facilities still exist, in general, the size (i.e., amount of area in production) of the typical, commercial aquacultural operation has grown substantially in recent years. Concomitant with these shifts in practice and operation has come both a numerical (i.e., greater diversity and number of predators) and functional (i.e., greater foraging success) response by predators (Draulans 1988). Other suspected problems attributed to predators in fish-rearing facilities, such as the transmission of disease from contaminated to uninfected stocks, recently have been documented and may be serious threats to the industry (McAllister 1993).

Other related changes have had significant impact on the depredation situation. Many "traditional" means of managing depredation losses in fish-rearing facilities are no longer legal or publicly acceptable. For example, although hatchery managers often viewed the use of pole traps or unregulated shooting as both efficient and cost effective means to reduce predation losses (Lagler 1939, Pough 1940, Parkhurst et al. 1987), provisions of the Migratory Bird Treaty Act prohibit their use in most situations today. Additionally, many segments of the general public find these techniques inhumane and without biological merit (Morrison 1975, Williams 1992). Logistical constraints and site-specific factors often limit the use or efficacy of many other currently available techniques to manage predation losses. Finally, although a deterrent may work well at one facility, there is no guarantee it will provide long-lasting protection against depredation losses at another. As a result, producers are reluctant to try new control methods, but they also have expressed an unwillingness to tolerate or accept some predation loss (Floyd et al. 1990). At the same time, public concern about perceived abuses and inhumane activities relating to control of predators in fish-rearing facilities is increasing and "environmentalists" are demanding more involvement in the decision-making process (Williams 1992, Floyd et al. 1990).

FACTORS AFFECTING AVIAN DEPREDATION

Diversity of Facilities and Operations

Depredation problems can arise in virtually any type of aquacultural endeavor except those where cultured stocks are contained indoors or in fully protected holding structures (Lee and Newman 1992). However, in certain aquacultural operations, facility design or the time or manner in which certain aquacultural procedures are conducted place those operations at higher risk to troublesome depredation problems. In general, there are four common approaches to culturing fish and each presents a unique repertoire of problems regarding susceptibility to depredation. These approaches include:

- Pond Culture. Ponds of varying depth, shape, and size are the most commonly used method to culture fish in the U.S. (Joint Subcommittee on Aquaculture 1983). Typically, ponds of natural or artificially-constructed origin are used and range in size from 0.25 ac. to 20 + ac. Gradual, often vegetated, embankments that slope into shallow waters are characteristic. Thus, these basins closely resemble the natural feeding sites of piscivorous birds and are quite conducive to foraging by wading predators. Commercial catfish and bait/ ornamental fish production in the U.S. relies almost entirely on use of pond culture, and a tremendous increase in the acreage of artificially-created water habitats, principally in the Mississippi Delta region, has occurred since the 1960s Stickley and Andrews 1989, Lee 1991). The large size (10 to 20 ac.) and multiple side-by-side arrangement of ponds generally preclude use of some effective predator management strategies, such as netting or overhead wires, due to logistic and cost problems. Additionally, large ponds provide ample area toward their center where birds find sanctuary from other harassment options simply because birds are out of effective range. Diving predators, such as the double-crested cormorant *(Phalacrocorax auritus),* frequently escape harassment by vanishing underwater at the first sign of potential danger rather than taking flight. Finally, typical methods of harvesting the cultured stock (i.e., drawing down ponds to concentrate fish and facilitate collection) attract predators and exacerbate depredation problems.

- Containment Culture (raceway, silo, tank). Fish are reared in permanent, rectangular or circular holding structures constructed of concrete, fiberglass, wood, or metal that often are grouped and arranged in series. Individual units can be subdivided to allow greater segmentation of stock, usually by size or age class. Containment culture in the U.S. originated with the production of traditional coldwater sportfish (e.g., trout, salmon) to supply the "put and take" fishery, but has since expanded to include a greater variety of purposes (Lee and Newman 1992). Unprotected containment units can provide good feeding platforms and easy access to fish stocks for predators; thus, such units are subject to severe depredation losses. However, the uniform and regular design of these units makes them relatively easy to fit with predator deterrent devices (either as single units or entire clusters). Closed or semi-closed systems (Lee and Newman 1992) are a particular style of containment culture where fishes are reared in completely enclosed, recirculating systems, usually indoors. As such, there is no opportunity for avian predators to gain access to the stocks.
- Cage and Net Pen Culture. Stocks of juvenile fish taken from a traditional containment hatchery are intensively reared to adults in floating net-pens or in rafted cages located in protected sublittoral fresh or salt waters (Lee and Newman 1992). Cage culture has been used for the production of salmonids for many years in Europe, but it is relatively new to the U.S. During the initial phase of production, fish reared under cage culture experience similar predation threats as those raised in containment culture, but, following placement in grow-out facilities, they are subject to unique depredation problems. Cages and pens can be fit with net covers to deter avian predators, but these devices often must be removed to perform routine operations. Additionally, special precautions are needed to prevent depredation by diving birds (e.g., cormorants) that attack from below the water's surface.
- Ranching. Fish ranching is similar to traditional containment culture during the initial phases of production, but then young fishes are released directly from the hatchery via natural watercourses to the sea where they will mature and return to the natal hatchery two to five years later as adults (Lee and Newman 1992). Ranching currently is restricted to the production of salmonids and is practiced principally along the Pacific Northwest coast. It involves more risk and uncertainty than other cultural practices because operators have no direct contact with or control over their stocks while at or in route to and from the sea. Usually < 3 % of the originally released stock is recaptured as adults (Joint Subcommittee on Aquaculture 1983).

Variability in Predator Populations

Among fish-rearing sites, considerable variability can exist within the predator population itself and will have significant impact on the extent and severity of depredation losses experienced. Predation losses are effected by the number of species and individuals of predators that are present, the length of time and time of year these predators are present, the foraging success of each predator species, and the range in behavioral plasticity or adaptability these predators exhibit in response to deterrents. I recently reviewed the extant literature on depredation in aquaculture and found that 67 avian species have been implicated as predators in fish-rearing sites whereas documented losses have been attributed to 58 species (Table 1). However, only about 12 species repeatedly have been reported as causing the most serious losses. The number of individuals of predators usually is a function of facility size or the amount of area in production that predators have access to. Larger facilities, particularly those that offer unrestricted opportunity for predators, generally will support a larger predator base. However, whether this represents a greater potential for loss proportional to total production is unclear (Draulans 1987). Other regulating factors, like territorial or resource defense, where evident, are likely to be less important at large sites where resources are plentiful and harder to defend efficiently. Seasonality of presence and length of time predators are present/year can have substantial bearing on extent of loss. Birds that arrive at a rearing facility early in the year and remain throughout much of the year obviously will have inflict more losses than those that stop temporarily during migration. The size of prey available at the time when birds arrive also may have substantial influence on whether or for how long birds stay (Parkhurst 1989). Finally, the level of persistence among various species of birds and their ability to circumvent deterrents may limit the selection and use of certain depredation management approaches.

ECONOMIC LOSS - HOW BAD IS IT?

The extent of loss (number of fish or dollar value) attributed to depredation is of great interest to aquaculturists, researchers, regulators, and others, but it is an area for which little reliable information presently exists (Parkhurst et al. 1987). Estimates of loss reported in the literature frequently suffer from use of inappropriate methodologies or ones based on faulty assumptions, use of data collected from dissimilar facility types (leading to invalid comparisons), and broad and questionable extrapolations from small pieces of factual data (Mills 1967). Perhaps of greater concern, hatchery managers often could not accurately identify the species

Table 1. Birds reported in the literature to be predators at fish-rearing facilities in the United States.

Species	Status[a]
Common Loon (*Gavia immer*)	D
Horned Grebe (*Podiceps auritus*)	D
Eared Grebe (*Podiceps nigricollis*)	D
Western Grebe (*Aechmophorus occidentalis*)	D
Pied-billed Grebe (*Podilymbus podiceps*)	D
American White Pelican (*Pelecanus erythrorhynchos*)	D
Brown Pelican (*Pelecanus occidentalis*)	D
Double-crested Cormorant (*Phalacrocorax auritus*)	S
Anhinga (*Anhinga anhinga*)	D
Great Egret (*Casmerodius albus*)	S
Snowy Egret (*Egretta thula*)	S
Cattle Egret (*Bubulcus ibis*) - (referred to as decoy species only)	R
Great Blue Heron (*Ardea herodias*)	S
Green-backed Heron (*Butorides striatus*)	S
Little Blue Heron (*Egretta caerulea*)	S
Tricolored Heron (*Egretta tricolor*)	D
Black-crowned Night Heron (*Nycticorax nycticorax*)	S
Yellow-crowned Night Heron (*Nycticorax violaceus*)	D
Least Bittern (*Ixobrychus exilus*)	D
American Bittern (*Botaurus lentiginosus*)	D
Wood Stork (*Mycteria americana*)	D
White Ibis (*Eudocimus albus*)	R
Mallard (*Anas platyrhyncos*)	S
Northern Pintail (*Anas acuta*)	D
Blue-winged Teal (*Anas discors*)	D
Wood Duck (*Aix sponsa*)	D
Redhead (*Aythya americana*)	D
Ring-necked Duck (*Aythya collaris*)	D
Canvasback (*Aythya valisneria*)	D
Lesser Scaup (*Aythya affinis*)	D
Bufflehead (*Bucephala albeola*)	D
Common Eider (*Somateria mollissima*)	R
Ruddy Duck (*Oxyura jamaicensis*)	D
Hooded Merganser (*Lophodytes cucullatus*)	D
Common Merganser (*Mergus merganser*)	D

Table 1. (continued)

Species	Status[a]
Red-breasted Merganser (*Mergus serrator*)	D
Osprey (*Pandion haliaetus*)	S
Bald Eagle (*Haliaeetus Leucocephalus*)	D
Northern Harrier (*Circus cyaneus*)	R
Northern Goshawk (*Accipiter gentilis*)	R
Red-tailed Hawk (*Buteo jamaicensis*)	R
American Coot (*Fulica americana*)	D
Yellowlegs (*Tringa* spp.)	R
Glaucous Gull (*Larus hyperboreus*)	D
Herring Gull (*Larus argentatus*)	D
California Gull (*Larus californicus*)	D
Ring--billed Gull (*Larus delawarensis*)	D
Franklin's Gull (*Larus pipixcan*)	D
Bonaparte's Gull (*Larus philadelphia*)	D
Forster's Tern (*Sterna forsteri*)	D
Common Tern (*Sterna hirundo*)	D
Arctic Tern (*Sterna paradisaea*)	D
Least Tern (*Sterna antillarum*)	R
Caspian Tern (*Sterna caspia*)	D
Black Tern (*Chidonias niger*)	D(?)
Great Horned Owl (*Bubo virginianus*)	D
Barred Owl (*Strix varia*)	D
Screech-Owl (*Otus* spp.)	D
Belted Kingfisher (*Ceryle alcyon*)	S
Black-billed Magpie (*Pica pica*)	D
Common Raven (*Corvus corax*)	D
American Crow (*Corvus brachyryhncos*)	D
Fish Crow (*Corvus ossifragus*)	R
American Dipper (*Cinclus mexicanus*)	S
European Starling (*Sturnus vulgaris*)	D
Common Grackle (*Quiscalus quiscala*)	S
Brown-headed Cowbird (*Molothrus ater*)	R

[a]Key to symbols: D=documented evidence of depredation losses caused by species; R=species reported as predator, but author(s) failed to provide direct evidence to support such claim; S=species reported in literature as being responsible for repeated and serious loss.

or estimate the numbers of predators responsible for depredations in their facilities nor could they document the extent of loses they experienced, whether to predators or other sources of mortality (Parkhurst et al. 1987). Lacking reliable data on the species responsible for depredations, the number of individuals of those species present, the foraging success of predators, the size of prey taken, and how long these predators fed there, determination of any reasonable approximation of economic impact is virtually impossible. Thus, unsubstantiated "guesstimates" tend to dominate the literature.

With a dearth of reliable data and an abundance of anecdotal accounts of substantial losses, one must be careful not to let perception replace reality. Not all producers or managers are experiencing problems with predators or the devastating losses so often seen in print. For example, Draulans (1988) found that a loss of only 8% of total fish production (minnows) could be directly attributed to bird predation. In view of all the other sources of potential fish loss, he concluded that bird predation was not a significant problem, or at least was one for which treatments were available. On the other hand, the general lack of reliable information must not be taken as indication that problems do not exist. In fact, Packham and Connolly (1992) found that depredation on aquaculture was deemed a serious problem in 27 states and of 32 potential wildlife damage issues in which USDA had involvement, depredation on aquaculture ranked fourth.

Recent estimates of the impact of predators will help place this problem in perspective. Broadway (1989) stated that the loss of fish to double-crested cormorants alone in southern catfish farms was approximately $3 million/year. Stickley and Andrews (1989), using a survey of 281 catfish farmers, calculated a loss of $3.3 million/year to cormorants in the Mississippi Delta area. Their figure did not include costs to harass birds or use other means to protect fish stocks (an additional $2.1 million/year). Thus, catfish farmers lost approximately $5.4 million annually to cormorants. Regarding depredation in baitfish operations, Hoy et al. (1989) calculated the loss of golden shiners over a three-month period to a mixed flock of approximately 100 herons and egrets at $1,800 to $11,160 (or $0.43 to $1.12/bird/feeding visit). Based on these rates and typical bird numbers in Arkansas, they estimated that baitfish farmers lost about $20,000 during a critical two-week period. In fact, the owner of one large minnow farm in Arkansas reportedly lost >$200,000/year to birds (Williams 1992). Hubley (1992) placed the yearly loss to birds at a south-central Pennsylvania state-operated trout hatchery at > 400,000 fishes, worth approximately $0.5 million. Parkhurst (1989) and Parkhurst et al. (1992) estimated that the number of fishes removed/year/site by all avian predators at ten different trout hatcheries in central Pennsylvania ranged from 1,550 to 773,530 whereas the annual economic losses (standardized) ranged from $49 to $4,120/raceway pool. Clearly, fish culturists are incurring some significant damage at the hand of avian predators.

DATA NEEDS AND DAMAGE MANAGEMENT APPROACHES

Where Are The Numbers?

To resolve existing problems with unreliable or insufficient data, we need to standardize our approach to and methods of data collection. At minimum, to adequately understand depredation in fish-rearing operations, we must be able to: 1) accurately identify and quantify the species of predators responsible for inflicting losses on fish stocks within individual facilities; 2) measure and document the foraging success and efficiency of these predators under specific site-by-site conditions; 3) quantify, by size and number, the fish being selected and consumed by each species of predator; and 4) determine when and how long these predators are present within the affected sites and actually devoting time to the pursuit of prey. Additionally, managers and researchers must refrain from using data obtained at one facility for analysis of a problem at another site, and assuming that the situation at the former site is indicative of conditions at another. Unless all aspects of the cultural operation, physical site conditions, and surrounding habitats are similar, the four basic parameters outlined above will differ and make such comparisons invalid.

With regard to managing depredation in fish-rearing facilities, Draulans (1987) has stated that one must study the interactions among cost, size of area involved, amount of protection desired or provided, and proximity of alternative food sources to fully evaluate the feasibility and potential success of any deterrent strategy. Draulans (1988) further concluded that: 1) it is very difficult to make general statements about a predator species' effect on fish stocks because of local differences in food availability and abundance; 2) realistic assessment of the extent and severity of depredation is only possible by study of individual sites and by collecting specific data on numbers and diet of predators and abundance and loss of fishes; and 3) the response of predators to increasing prey is both numerical (i.e., more predators will be present) and functional (i.e., increases in success and/or consumption by individual), yet there is little to indicate whether this directly translates to an increased economic loss. Thus far, few managers have undertaken or shown a willingness to do such analyses.

Draulans and van Vessem (1985) found that simply reducing the number of predatory birds did not necessarily equate with less damage experienced. In fact, small flocks of birds (10 to 20 individuals) usually accounted for most losses inflicted (Draulans 1987). They suggested that the standard for measuring the effectiveness of various deterrent strategies should not be on measuring the reduction of birds present, but on the reduction in economic losses inflicted.

Deterrent Options Revisited

Various authors (e.g., Lagler 1939, Mott 1978, Salmon and Conte 1981, USFWS n.d., Draulans 1987, Parkhurst et al. 1987, Littauer 1990, Kevan 1992, Pitt 1993) have reviewed literature on or evaluated the efficacy of existing methods to manage depredation in fish-rearing facilities. These works summarized our knowledge on the topic, identified research needs, and stimulated thinking on development of potential new techniques or deterrent strategies. However, it is readily apparent that a universal solution to all depredation problems in aquaculture has not yet been discovered nor is one likely to arise in the near future. Cultural operations today are so diverse that an expectation of having any one method effectively manage predators in all facilities is inappropriate. Therefore, predator management in fish-rearing facilities must incorporate an integrated approach (Hygnstrom 1990) that embraces facility siting and design, influence of operational aspects, and use of non-lethal and lethal controls.

Each component of an integrated approach must be weighed carefully to evaluate whether its advantages and likelihood of success outweigh the disadvantages and possible shortfalls. Some of these trade-offs are reviewed briefly below:

- Husbandry and Facility Siting/Design. Any decisions relating to siting and design of new fish-rearing facilities must include review of reliable information about potential local predation problems. Planners should devote as much attention to the selection of potential sites based on predation concerns (e.g., avoiding known migratory routes, well-established rookeries, or areas where fish-eating birds historically concentrate/roost) as they do for water quality/quantity or engineering issues. In some cases, there is little an aquaculturist can do to avoid potential conflict with predators, but where flexibility in siting exists, a thorough review of the potential impacts of predation should be made in advance. Sites with a high potential for conflict should be avoided or proper safeguards should be incorporated in facility designs early on. It is much cheaper to design and construct appropriate predator deterrents at the time of initial construction than to retrofit later. Additionally, every effort should be made to make a facility less attractive to predators by properly storing and cleaning up spilled feeds, regularly removing and properly disposing of dead or dying fishes, and controlling the growth of vegetation around holding structures (Salmon and Conte 1981). Finally, in older, established facilities, managers need to examine the potential usefulness of modifying holding structures to prevent birds from wading or feeding from the sides of raceways (Meyer 1981), removing "facilitating" structures that serve as perches or feeding/hunting platforms (e.g., light posts, overhead wires), and controlling vegetation within and adjacent to the facility that provides cover for roosting, hunting, or breeding (Schramm et al. 1987).
- Operational Influences. Options that examine "how we do business every day" often receive little consideration, but changes in routine operation and management of a fish-rearing facility, where appropriate and feasible, may provide substantial reduction in depredation losses. Factors to examine include the type/formulation of feed used and its mode of delivery (Salmon and Conte 1981), the timing of release or transplant of fry to outdoor holding structures (Parkhurst 1989), reducing production levels (Meyer 1981), locating vulnerable stocks closer to centers of human activity (Meyer 1981, Salmon and Conte 1981, Draulans and van Vessem 1985, Draulans 1987), selecting fish stocks less susceptible to predation (Matkowski 1989), training or conditioning fish to avoid predators (Thompson 1966, Fraser 1974, Stickney 1991), or providing alternative food sources for predators (Lagler 1939, Jurek 1974, Barlow and Bock 1984, Kevan 1992). Non-lethal Technologies. These measures generically include harassment (auditory and/or visual), physical barrier, and chemical deterrents. Although not commonly used with birds, live capture and release could be considered a non-lethal option. The intent of non-lethal measures is to frighten a predator away or prevent it from gaining access to the cultured stocks without killing or inflicting physical injury upon that predator. Examples of techniques typically used that fall in each of these categories include: harassment—propane cannons, predator distress calls, pyrotechnics, electronic noise makers, lights, effigies, decoys, dogs; barriers—perimeter fencing or netting, water spray devices, exclosures, overhead wires, electric wires, floats or roping; chemical-methyl anthranilate-based products (Dolbeer et al. 1992, Vogt 1994), alpha-chloralose (Woronecki et al. 1990). Harassment techniques are easy to use, are relatively inexpensive, enjoy wide public acceptance, but, because of habituation problems, typically offer only limited long-term protection to fish stocks. Physical barriers usually are viewed as being humane and thus enjoy broad public acceptance and they typically provide better and long-lasting protection. However, they are more permanent fixtures, are more elaborate or complicated and thus more expensive to install and maintain, and are subject to logistic constraints that limit their usefulness only to certain types of production facilities. Chemical deterrents are as yet unproven and, because most fish being reared are for human consumption, are subject to extensive registration testing requirements and regulatory reviews. Lethal Measures. Although most wildlife damage management professionals view lethal options (e.g., shooting, trapping, toxicants) as methods of last resort, there are situations where their use is appropriate and necessary. Littauer (1990) described a need to kill a few birds to enhance the efficacy of certain non-lethal deterrents or to reinforce or restore the inate fear in predators that remain after treatment. Managers claim to receive immediate self-gratification from the use of lethal methods and often view them simply as means to eliminate offending animals (Kevan 1992) whereas the general public often finds lethal techniques unacceptable (Morrison 1975, Randall 1975, Williams 1992). Little scientific data exists to show that lethal measures alone have any long-lasting effect on reducing predator abundance nor do they reduce fish losses if nothing else is done to make a foraging site less attractive to predators (Draulans 1987). In fact, predators removed by lethal methods will be replaced quickly by other individuals of the same or a different species. Additionally, lethal methods frequently remove only the inexperienced juveniles and, as a result may have serious local implications to the species with regard to recruitment (Meyer 1981).

WHAT'S AHEAD IN THE FUTURE

As noted earlier, the dearth of reliable scientific data on the extent of depredation losses is impeding substantive progress toward resolving existing conflicts with predators. Wildlife damage management professionals have recognized the need to address depredation in aquaculture as a high priority (Packham and Connolly 1992), however, funds to support the kind of research needed are limited. Further, prevailing attitudes and perceptions within both the industry and among stakeholders provide indication that "bumpy waters lay ahead." The recent survey (Floyd et al. 1990) of aquaculturists of the north-central states is troublesome, in that respondents believed they should be able to legally kill avian predators on their property without a federal/state permit. These respondents also indicated that they are not willing to invest money in techniques to prevent depredations. Concurrently, "environmentalists" wanted direct involvement in any decision-making process relating to depredation and the control of predators in fish-rearing facilities (Floyd et al. 1990). With increasing public scrutiny and demands for more responsible action by industry and regulators, positions are likely to become more retrenched and polar, possibly leading to litigation and legislative involvement. It appears this process may already have begun because the U.S. Fish and Wildlife Service, Division of Law Enforcement, has indicated that it may change the manner of how depredation kill permits are allocated (Frank Schoemaker, USFWS, Div. Law Enforce. Special Agent, personal commununication).

With the exception of complete enclosures (or resorting to closed-system production), no predator management technique or deterrent strategy will provide 100% protection for cultured stocks. Fish-rearing facilities are diverse, and each has its own suite of methods, practices, and types of organisms being cultured. Even among facilities producing similar cultured stocks, differences in facility or site qualities, surrounding habitats, range and distribution of predators, and population densities reduce the likelihood that any one technique will be effective in all situations (Parkhurst 1989). Thus, the objective of predator management programs should be to reduce damage to some economically tolerable level rather than attempting to effect complete control. Predator management programs should be cost effective and provide a level of protection that maintains sound economic standing. However, managers must recognize that, even under the best integrated pest management strategy, some loss still will occur.

For managers considering implementation of an integrated predator management approach, Littauer (1990) offered some useful suggestions: 1) use deterrents before a feeding pattern becomes established-it's much easier to stop a new problem than to break a well-established habit; 2) frighten birds away before they can land on the water's surface—it's much more difficult to get birds back into the air than to turn birds away and, with diving birds, they will avoid exposure to harassment by diving under water; 3) use a variety of techniques and change the location and/or combinations of passive deterrent devices to minimize the potential for habituation; and 4) use approved lethal methods for enhancement when non-lethal become ineffective. Draulans (1987) also suggested that aquaculturists reduce the encounter rate between predatory birds and cultured fish by: 1) increasing the depth of water in the holding structure or increasing the height of the walls or banks above the water; 2) locating economically valuable fish closer to human activity zones; 3) reducing exposure time of fishes to predators; and 4) considering the possibility of propagating buffer prey populations between valuable stocks and the predators' normal approachways.

Although much progress has been made in our understanding of depredation problems and in developing new technologies to cope with such problems, much new research needs to be initiated. However, a general lack of funding resources and/or opportunities is hampering research progress. Also, success in limiting depredation losses in one segment of the industry may not provide immediate relief to another due to the complexities and diversity of the industry. Because wildlife are public resources and the responsibility for their management lies with society, any successful resolution of depredation problems in fish-rearing facilities will not occur as a result of the actions of any one that no one entity, agency, or group—it will necessitate public involvement, discussion, understanding, and compromise.

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