DOUBLE-CRESTED CORMORANT DAMAGE TO A COMMERCIAL FISHERY IN THE APOSTLE ISLANDS, WISCONSIN

by Scott R. Craven and Esther Lev

ABSTRACT

The endangered classification of the double-crested cormorant (DCC) in Wisconsin resulted in complete protection and significant management efforts in the 1970's. These efforts, probably coupled with reduced pesticide loads, resulted in a resurgence of Wisconsin cormorant populations from a low of 66 pairs in 1972 to 1028 pairs in 1982. The DCC was reclassified as a threatened species in 1982. This apparent success story did not take into consideration the potential negative impact of an abundant piscivorous bird. In 1978 a colony of DCC's became established on a remote rocky island in the Apostle Islands National Lakeshore, in Lake Superior. From 17 pairs in 1978 the colony increased to 289 pairs in 1985. By 1982, commercial fishermen in the Apostle Islands began to complain about damage to the valuable catch of Lake Whitefish. They accused DCCs of feeding within pound nets and thus causing sub stantial damage by gilling and scaring captured whitefish. Annual loss was estimated at $5-10,000 distributed amongst 3 fishermen.

The interaction of DCC's and the whitefish fishery was studied from 1983-84. Food habits data did not suggest that commercial fish species were important to the diet of DCC's in the Apostle Islands. Observations suggested that the attraction of pound nets centered more on the use of net support poles for perch sites than on the availability of food within the net. Nine abatement techniques were tested. Damage was reduced for periods of up to 4 weeks by a combination of structural modifications that eliminated perching and an old-fashioned scare-crow. National Park Service policy precludes direct control of the increasing DCC population.

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INTRODUCTION

Double-crested cormorants (*Phalacrocorax auritus*) have conflicted with commercial fisheries along the coast of Maine, in Wisconsin, in the Great Lakes region in general (Matteson 1983), and perhaps in other areas. Such conflict was especially evident during the period 1920-45 and again in recent years. Reports of cormorant (DCC) depredations have been proportional to changes in cormorant numbers throughout much of their North American range.

Cormorants were abundant throughout the Great Lakes region throughout the 1800s (Lewis 1929). However, there were no reports of DCC colonies in the Great Lakes in the early 1900s. By the 1920s DCC numbers and colonies began to increase and as they did, so did complaints from commercial fishermen. Persecution by fishermen during the 1940s followed by the bioaccumulation of DDT, DDE, DDD, PCB, and other contaminants between 1950 and the early 1970s combined to devastate the DCC population of the Great Lakes. Subsequent protection and management reversed these trends during the 1970s. Vermeer and Rankin (1984) present an excellent review of historic DCC population trends.

Prior to the 1890s DCCs inhabitated the isolated and larger lakes of the northern and central parts of Wisconsin (Carr 1890). The number of colonies in Wisconsin increased substantially between the 1920s and mid-1950s (Matteson 1983). Between 1923 and 1966 cormorant colonies were observed in 16 Wisconsin counties (Anderson and Hamerstrom 1967, Scharf 1979). As noted, by the mid-1960s the Wisconsin cormorant population was reduced by pesticide contamination, human persecution and habitat loss. In 1972, with a total state population of 66 pairs (Matteson 1983), the DCC was listed as an endangered species. Positive management practices such as erection of artificial nesting structures were vigorously pursued by the Wisconsin Department of Natural Resources (Meier 1981). Only a decade later the number of nesting pairs had increased to a minimum of 1028 and the bird's status was downgraded to threatened. There are no documented explanations for the dramatic increase in population, however, reduced pesticide loads in the environment, immigration from other DCC populations, managemement, protection, and other factors are probably all involved.

In 1978, 17 pairs of DCCs were found nesting on Gull Island in the Apostle Islands National Lakeshore (AINL) in Lake Superior under National Park Service jurisdiction. By 1985 the Gull Island colony had increased to 289 nesting pairs and at least one satellite colony had been established. In 1980, only 3 years after the Gull Island colony was discovered, commercial pound net fishermen in the Apostle Islands began to complain about cormorant depredations. Fishermen claimed losses of 30-40% of the whitefish catch in 1982 due to direct consumption, scarring or gilling caused by DCCs (B. Swanson, pers. commun.). (Note: Gilling results when fish become entangled in the pound net mesh.) Five pound net fishermen were affected in 1982 and at least 40 pound nets which provided 60-70% of the commercial fisherman's income were involved in the depredation problem (Mary Halvorsen, pers. commun.). Thus the problem was viewed as serious by local resource managers. Fishermen attempted to abate depredations with rubber snakes, wind wheels, brightly-colored flags, eagle decoys, pieces of metal, and covered nets with no success.

In response to National Park Service (NPS) concern about the AINL depredations problem, we initiated a study of the DCCs in the Apostle Islands in 1983. Data were collected on the food habits and ecology of DCCs and the development of depredation abatement techniques.

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STUDY AREA

The principal area of research was the Apostle Islands National Lakeshore, Bayfield, Wisconsin (Fig. 1). The 22 Apostle Islands, 20 of which are part of the National Lakeshore, are located off the tip of the northern Wisconsin mainland in Lake Superior. The twenty islands comprise 15,778 hectares of land, ranging in size from Gull Island (1.2 ha) to Stockton Island (4,021 ha). The Apostle Islands lie in the transition zone between northern boreal coniferous forest and deciduous forest. Sugar maple (Acer saccharum), yellow birch (Betula lutea), hemlock (Tsuga canadensis), red pine, (Pinus resinosa), white birch (Betula papyrifera), white cedar (Thuja occidentalis), balsam fir (Abies balsamea) and black spruce (Picea mariana) are common trees (USNPS 1983). The understory of several islands is dense Canada yew (Taxus canadensis).

METHODS

Field research was initiated on July 11, 1983. Prior data were collected on the biology of the DCC in the Apostle Islands by USNPS biological aids in cooperation with WDNR staff. Collaboration between the Department of Wildlife Ecology, USNPS, and WDNR personnel and 3 commercial fishermen continued throughout the study. Observations of DCCs and data on their ecology, food habits and interaction with the commercial whitefish industry were collected from May-October, 1983 and May-September, 1984.

Four aerial surveys of the Apostle Island's cormorant population were conducted between July 17 and September 2, 1983. Each 2-hour survey was flown in the morning around all of the islands. Number of birds observed and location were recorded. Biweekly cormorant counts were conducted by boat in both years of the study. Boat counts concentrated on numbers of birds at pound nets and at key feeding areas. Pound nets in the north and south sectors of the AINL were censused on alternate days. Cormorant observations reported by USNPS and WDNR employees were collected and mapped.

One hundred and eighty four DCCs were banded on 3 trips to Gull Island (11 July, 8 August 1983 and 12 July 1984). Prefledging 3-7-week-old birds were banded with standard size 8 USFWS aluminum leg bands. Sixty-four of the birds were also banded with 3 different colored aluminum leg bands for individual identification. Flightless young were herded into a group, individually captured, and placed in nests covered with burlap to protect them from overheating. Nests with eggs were also protected. Birds were aged (Canadian Wildlife Service 1977) but not sexed.

Food habits of both immature and adult DCCs were studied by observation of feeding activity and collection of food remains. Adult and well developed immature birds regurgitate stomach contents when disturbed or frightened (Lewis 1929). Samples of regurgitations were collected at the Gull Island colony, placed in plastic bags, and frozen for later identification.

Cormorant pellets were collected from Gull and Eagle Islands (Fig. 1). Pellets are a mass of indigestible material enveloped in mucus and expelled by adult and subadult DCCs. Young birds do not begin producing pellets until they are able to fly (Ainley and Kelly 1981). Cormorants typically produce one pellet daily and these pellets are comparable to regurgitation samples as indicators of diet (Jordan 1959). In many cases food remains were digested to the point where fish species could not be identified by gross examination. Thus, we used otoliths as a diagnostic tool (Ainley and Kelly 1981). Fish otoliths (calcareous concretions in the inner ear) were easily separated from pellets. Since each species of fish has distinctive otoliths which are unaffected by digestion, we could identify fish species in all samples. The number of otoliths of each species was divided by 2 to estimate the number of fish eaten (Ainley and Kelly 1981). A reference collection of otoliths of common Lake Superior fish was developed. Samples of fish were caught, identified, and measured, then the otoliths were removed, mounted, and labeled.

To further document food habits, a 38 m (125 ft) experimental mesh gillnet was set in areas where cormorants were observed feeding. Mesh size of experimental net increases in roughly 1 cm increments from 2.5-8.9 cm along the length of the net, allowing sampling of diverse fish species and size classes. Gillnets were set for one or two nights in water depths of 4.5-6 m. Species and size of fish caught were recorded.

Nine deterrent (abatement) techniques were tested during the 2 field seasons (Table 1). Pound nets were selected to receive abatement techniques on the basis of cormorant activity, gilling rates, and the availability of a second net to serve as a control. Each technique was evaluated for a minimum of 2 weeks unless the technique was clearly ineffective. Bird activity at nets with deterrent devices was monitored for two weeks prior to placement of the device and continued after placement. Each experimental net was paired with an adjacent unprotected net. Location, time, number of birds, activity of the birds, and other avian species in the area were recorded. When possible, data on the number and species of fish caught and gilled were collected by observing the commercial fishermen as the nets were lifted. Additional data were provided by WDNR staff and the commercial fishermen.

RESULTS

Colony Size and Production

In 1984, Gull Island, the smallest of the Apostle Islands (Fig. 1) was the only known double-crested cormorant colony in the area. Gull Island lies only 30-70 cm above lake level and consists of a pebble and stone substrate with scattered growth of bluejoint grass (*Calamagrostis inexpansa*), red elderberry (*Sambucus pubens*) and mountain maple (*Acer spicatum*).

From the first discovery of DCCs on Gull Island in 1978, the colony increased dramatically to 254 nesting pairs in 1984. The slight increase of 11 pairs over the 243 pairs present in 1983 suggests that the size of the colony and its growth rate may be leveling off. The 1984 production rate of 1.67 young per nest (fledged) was 2.3 times greater than the 1983 rate of 0.73 young per nest. Based on weekly counts, the estimated 1984 population of adult DCCs (including nonbreeders) in the AINL was 700, up 100 from 1983.

The chronology of the nesting season varied between years. In 1984 DCCs arrived in Chequamegon Bay on 15 April, all young had fledged from Gull Island by 28 August, and DCCs began to move to staging areas in Chequamegon Bay by 28 August. In 1983, DCCs arrived on Gull Island in mid-April, flightless young were still present in the colony in mid-August, and birds were not observed on staging areas until 3 October. Overall, the nesting season was about 3 weeks earlier in 1984 than 1983.

Sexually immature DCCs concentrated at several other points in the AINL away from Gull Island. Eagle Island, 55 km from Gull Island, was the primary roosting area for nonbreeders. The interior of Eagle Island (9.7 ha) is dense white and yellow birch and Canada yew. Rocky ledges around the perimeter of the island provide excellent roosting sites. Up to 170 DCCs were observed at Eagle Island at any one time with smaller groups of 20-40 frequently observed at Little Manitou and Hermit Island Rock. In June of 1984, 3 nests, one with 2 eggs and 2 empty, were found on Eagle Island. These nests constituted the first known nesting attempt on Eagle Island. Neither of the 2 eggs hatched. In 1985, at least 10 nests with young were found in trees on Eagle Island, in addition to several ground nests.

Food Habits

Double-crested cormorants appear to be opportunistic feeders, feeding upon the most available and abundant fish source at a given time. One hundred and fifty regurgitation and pellet samples were collected and analyzed during the 1984 field season. Thirteen species of fish were identified in food remains but no single fish species dominated DCC diet in the Apostle Islands (Table 2). Small forage fish, ninespine sticklebacks (*Pungitius pungitius*), slimy sculpin (*Cottus cognatus*), spoonhead sculpin (*Cottus ricei*), and burbot (*Lota lota*) are the most frequently taken species. We found lake whitefish and lake trout (*Salvelinus namaycush*), the two important commercial species of the area, in only 2% of the samples. DCCs generally eat fish 12-15 cm long (Bartholomew 1942) and this was true for most samples we could distinguish.

Flock feeding behavior described by Bartholomew (1942) was not observed until October 1983 and August 30, 1984 when birds moved to a staging area in Chequamegon Bay. Lack of this behavior may be related to the fact that the commonly eaten fish species in the Apostle Islands do not school. Preferred feeding sites in the AINL tended to be shallow (5-18 m deep) sandy or shoal areas close to island shorelines (Fig. 4). DCCs have been observed diving to depths of 22 m (Lewis 1929), however, they tend to prefer feeding in shallow water.

Comparison of food samples between Gull and Eagle Island suggest that breeding adults and nonbreeders had a similar diet (Table 3). The four species most frequently eaten in both areas are small forage species rather than commercial species.

Abatement Techniques

Nine abatement techniques were tested. Each technique, the length of the test, and the generalized success/failure of the technique are summarized for ease of reference (Table 1). In general, DCCs adjusted to all abatement devices within 4 weeks or less of installation. DCC activity at nets dropped or was eliminated following installation of electric shockers, nails, cones, and scarecrows (dummies), with or without boats. Over time, bird activity approached pre-abatement levels. Combinations of techniques designed to make certain parts of the pound nets inaccessible for DCCs (cones, nails, electric shocker) and scare devices (scarecrow/dummy) were the most successful approach. The Av-Alarm device and models of predatory birds were ineffective. The Av-Alarm proved to be incompatible with the NPS wilderness objectives for the AINL.

Damage to Commercial Fishery

Throughout the summer commercial pound nets were monitored to determine the percentage of gilled whitefish. Fishing records before cormorant problems began suggest a natural gilling rate of 5% in the absence of cormorants (B. Swanson, pers. commun.). The average gilling rates for July and August, in excess of the baseline 5%, were essentially identical for 1983 (33.9%) and 1984 (31.8%). Gilling rates were also comparable to the 35% loss figures estimated for the 1981 and 1982 seasons (B. Swanson, pers. commun.).

Gilling caused an estimated economic loss of about $7000 for the period June-August 1983 and $4500 for the period July-August 1984 (Table 4). These estimates were based on a dockside value of $0.50 per pound for whitefish. Deduction of 5% of the total for normal gilling losses yielded an estimate of the economic impact of DCCs. However, some of the gilled fish are sold as second quality fish or smoked and sold. Thus the fishermen recover some of the loss. These data suggest that the total loss for both 1983 and 1984 would likely not exceed $15,000 distributed amongst 3 fishermen.

DISCUSSION

DCC Population and Interactions With Other Species

The Gull Island colony increased in 1984 for the 7th consecutive year. However, the rate of increase began to decline in 1983 and 1984 and the pattern of increase suggests that the colony followed a typical pattern of logistic growth (Fig. 2). The 1985 colony size of 289 pairs, determined after the previous analysis was completed, further supports a leveling off of the Gull Island colony. Extrapolation of the observed trend suggests that colony size will stabilize at about 325 nesting pairs (Fig. 2). The 1984 production rate of 1.67 young per nest was 2.3 times greater than the 1983 rate of 0.73. Since cormorants do not nest when 1 year old, the low production (we assume this rate is low in the absence of data from other years at Gull Island) cannot be responsible for the small increase in colony size between 1983 and 1984. We believe disturbance on Gull Island was the primary explanation for the depressed production in 1983.

Gull Island supported both a cormorant and a herring gull colony and the herring gull colony increased over the same period the DCC enlarged (S. Matteson, pers. commun.). When disturbed, the adult cormorants flushed, circled overhead and then landed on the water several hundred meters away, where they awaited cessation of the disturbance. They remained wary even after the departure of human intruders and were slow to return to the colony, leaving their young unattended for 20-60 minutes. Herring gulls are known to prey on unattended cormorant eggs and young (Ellison and Cleary 1975). Ellison and Cleary (1975) reported that gull predation in cormorant colonies often resulted in nest abandonment and failure. Other studies have linked human disturbance with increased gull and crow predation on DCC eggs and young (Mendall 1936, Drent et al. 1964, Vermeer 1970, Lock and Ross 1973, Kury and Gochfeld 1975). Ten visits to Gull Island by biologists between May and September and the presence of a red fox (Vulpes fulva) which was removed added to the disturbance on Gull Island in 1983.

Eagle Island (9.7 ha, Fig. 1) was the primary roosting area for nonbreeding DCCs and it also supported the only Great Blue Heron rookery in the Apostle Islands. Heron nests were located in white and yellow birch and a few spruce and fir over a dense understory of Canada yew; about half of the trees were dead. As noted previously, 3 DCC nests were found during surveys of Eagle Island in 1984. No DCC nests were found during heron surveys on Eagle Island in 1982 or 1983. The presence of 10 DCC nests in trees on Eagle Island in 1985 suggests that DCCs produced at Gull Island may begin pioneering new colonies when they reach breeding age.

Herons and cormorants are known to coexist in the same colony in other areas with herons nesting in the upper parts of the trees and cormorants nesting in lower limbs. However, there are also examples, notably from New York (S. Matteson, pers. commun.), where DCCs have taken over great blue heron rookeries and displaced the herons. Eagle Island will require annual surveillance for interspecific competition. Such new colonies suggest increased depredations problems for commercial fishermen.

Food Habits

Comparison of food samples between Gull and Eagle Island suggest that breeding adults and nonbreeders had a similar diet. One obvious difference, the prevalence of nine-spined sticklebacks at Gull Island is an artifact of our technique. Samples from Gull Island were both regurgitations and pellets; only pellets were collected at Eagle Island. Nine-spined sticklebacks could only be identified in regurgitations; their microscopic otoliths could not be detected in pellets. This species was abundant in the waters around both sites (USFWS, WDNR) and we suggest sticklebacks are, in fact, eaten in both areas. The top four species consumed in both areas are small forage species rather than commercial species. Cormorants do not appear to use fish of commercial species and size as a food source. We suggest that the attractiveness of the nets as perch sites results in gilling or damage to valuable fish simply due to birds presence. Natural perch sites are virtually non-existent in the waters around the islands. We observed cormorants diving in the pots of the nets but they rarely surfaced with fish in their mouths. Generally, the fish in the nets were too large for the cormorants to eat. A DCC may chase and subsequently gill fish as a simple stimulus response to movement below it while it is perched. In early September 1983 and 1984 DCCs were observed perched at nets where the pots had been pulled. Installation of alternative perch sites near active fishing nets with deterrents would provide more information on this theory and could serve as an additional abatement technique. However, due to cost and potential navigational hazard alternative perches were not installed.

The incidence of gilling increased as young DCCs fledged and more birds were observed around pound nets in late summer. Their inexperience may also contribute to the problem as they try to capture fish seen as they perch on pound nets. Most of the fish which appeared frequently in the DCC diet are small, shallow water, bottom species. Nine-spine sticklebacks, sculpins, menominee whitefish, burbot, and longnose suckers are all common in waters less than 10 m. Smelt and herring are also very abundant but may swim too fast for DCCs to utilize regularly. Whitefish frequent deeper water and are very sensitive to warm water. Thus they may be unavailable to DCCs except around pound nets.

MANAGEMENT RECOMMENDATIONS

Cormorant Population

As described, the double-crested cormorant population on Gull Island increased rapidly from 1978 through 1982. From 1982-1985 population growth slowed and began to level off. The curve produced by plotting the number of nesting pairs over time closely approximates a typical logistic growth curve. Unpredictable factors such as food supply, weather, disease, human intervention, and perhaps others, could result in substantial annual fluctuations in the nesting colony. However, in the absence of such factors these data suggest that the Gull Island Colony will stabilize at about 325 nesting pairs.

To the human eye, it appeared that space for nests is not limiting colony size on Gull Island. The colony of herring gulls on Gull Island also increased by about 50% during the period of growth in the cormorant colony (S. Matteson, pers. commun.). Since the gulls nest several weeks earlier than the cormorants, their nesting territories may exclude the cormorants from parts of Gull Island. Herring gulls may also exert more predatory impact on cormorant eggs and young birds as their numbers increase. Thus, herring gulls may be partially responsible for the ultimate size of the cormorant colony. However, it is impossible to predict exactly what factors are causing the cormorant population to stabilize. Human activity cannot be implicated in either the establishment or stabilization of the Gull Island colony, except to the extent that protection, management, and habitat improvement (e.g., reduced pesticide loads, etc.) have enhanced cormorant populations throughout the Great Lakes (Scharf and Shugart 1981). Thus we cannot conclude that the cormorant population in the Apostle Islands is "unnatural"; a classification which would allow greater management flexibility under National Park Service policy guidelines.

An attempt to set an optimum population size is not warranted if a "hands-off" management approach is to be taken. However, if management is undertaken in the future because of adverse impacts on other species, such as great blue herons on Eagle Island, then we suggest that a population of about 300-350 would be sufficient to ensure the safety of the DCCs in the AINL and minimize necessary control (management). The population data collected from 1978-1984, suggest that the colony is most productive at a level of about 200 and would thus require the maximum level of control (removal of birds). This would become an annual burden. If in fact the colony does begin to level off in the next 4-6 years, as the data suggest, then control in terms of bird removal would be kept at a minimum.

If the new colony identified on Gull Island is indicative of colonization of additional islands, then population management would have to be expanded.

Conflict with Fishery

The key resource management problem involving the cormorant population in the AINL is the conflict with the commercial fishery. Strong emotions, limited abatement techniques, legal restrictions, and other considerations make the fishery/cormorant issue very difficult to deal with. Recognizing these facts we offer the following recommendation/analysis for a variety of solutions:

1. Population reduction: The cormorant colony on Gull Island (or any newly identified nesting islands) is vulnerable to a variety of techniques to reduce

the number of cormorants including shooting, nest destruction, and excessive disturbance. Additionally, non-breeding cormorants or free-flying adults from the colony could be shot or trapped at or around roost sites or pound nets.
<u>Recommendation</u>: While this may be a popular solution with the fishermen, direct population reduction is incompatible with NPS policy and the legal status ("threatened") of the cormorant in Wisconsin. It would also be disasterous for public relations. It should not be considered.

2. Damage abatement: A variety of techniques to reduce fish losses to cormorants were tested and reviewed in the text. No single technique was 100% effective, but rarely is any abatement technique 100% effective in animal damage control work. Success must be measured in the reduction of loss rather than in terms of elimination. Several techniques did reduce loss in test nets.
<u>Recommendation</u>:
   a. Combine the techniques that showed promise; e.g., a dummy or dummy/boat combination in conjunction with metal cones on poles and an electrified wire or porcupine wire on the horizontal supports should reduce loss to tolerable levels.
   b. Concentrate use of abatement techniques during periods of peak gilling (July/August). Cormorants demonstrated substantial adaptability and tended to ignore scare devices after repeated exposure. Thus they should be used only when they can provide maximum benefit.
   c. Investigate the use of alternate perch sites as a means of "diluting" the problem. Observations suggest that the primary attraction of the poles and rigging of pound nets is as an ideal perch rather than as a feeding site. Installation of poles in suitable cormorant feeding areas away from active pound nets could occupy some birds that might otherwise be a problem at net sites. The navigational hazard posed by additional poles or floating perch sites would have to be resolved.
   d. A modified acoustic scare device is being developed at the University of Wisconsin for Canada goose damage control. The device senses the presence of birds by "hearing" their calls or detecting motion. Then and only then does it activate either a propane exploder or an amplified distress call. This would maintain the wilderness tranquility of the AINL but provide a scare device when it is needed.

3. Compensation: Wisconsin adopted new wildlife damage control legislation in 1983. The program provides abatement assistance and direct compensation if abatement fails for damage caused by deer, bear, and Canada geese. A segment (3%) of the Wisconsin Endangered Resources Fund (tax contribution program) is also earmarked for endangered wildlife damage compensation. The precedents, guidelines, and financial resources of these 2 programs suggest that some form of compensation for cormorant damage be examined as a possible solution.
<u>Recommendation</u>:
   a. Have all parties (WDNR, NPS, fishermen) agree on an acceptable baseline level of gilling and financial loss.
   b. Consider the possibility of direct compensation for loss (total or prorated depending on available funds) or in-kind compensation in

the form of longer seasons or a relaxation of other regulations compatible with fishery management objectives. Abatement devices could be purchased for the fishermen as a cost-effective use of limited funds in keeping with the "try abatement first" philosophy of animal damage control in Wisconsin.

c. Compensation or incentives could also be offered to encourage fishermen to use alternate fishing techniques less susceptible to cormorant damage or to avoid fishing in areas of cormorant activity.

In conclusion, an integrated approach of abatement, possible compensation programs or incentives, and long-term monitoring of the APIS cormorant population should allow the commercial whitefish fishery and the double-crested cormorant population to coexist.

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Table 1. Results of abatement techniques tested in the Apostle Islands, 1983-84.

Technique	Location	Trial Period	Results
Av-Alarm (audio scare device)	Madeleine Island	1 week	Not successful. Cormorants observed perching within 7 feet of speaker. Also poor public acceptance in populated areas.
Electric-shocker (electrified wires)	South Twin Island Rocky Island Sand Island Little Squaw Bay Raspberry Bay	2 months	Successful at keeping cormorants from perching.
Metal cones (on tops of poles)	Raspberry Bay	1 month	Successful at keeping birds off poles. Best used in combination with another technique to keep birds off the rest of the net.
Nails (same purpose as cones)	South Twin Island Rocky Island Sand Island	2 months	Successful at keeping birds off poles. Best used in combination with another technique to keep birds off the rest of the net.
Owl decoy (scare device)	Raspberry Bay Raspberry Island	2 days	Unsuccessful. Birds observed perching next to decoy within 2 days.
Mylar helium balloons (scare device)	Frog Bay Hermit Island	2 weeks	Unsuccessful alone. Best used in conjunction with scarecrow.
Hanging scarecrow	Roys Point Raspberry Bay South Twin Island		Successful for 1 month. After 4 weeks birds were observed perched on poles.
Boat (floating in pot of net)	Hermit Island	3 weeks	Successful for 2 1/2 weeks. Best used in conjunction with scarecrow.
Scarecrow/Boat	Cat Island Kapunky Bay Rocky Island	6 weeks	Successful. No birds observed at net for five weeks. Reduced gilling rate. Best used in combination with metal cones and mylar helium balloons.

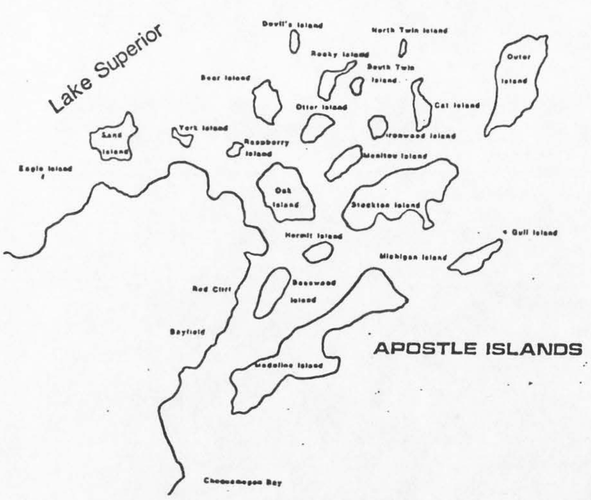

Fig. 1. Apostle Islands area, Lake Superior, Wisconsin

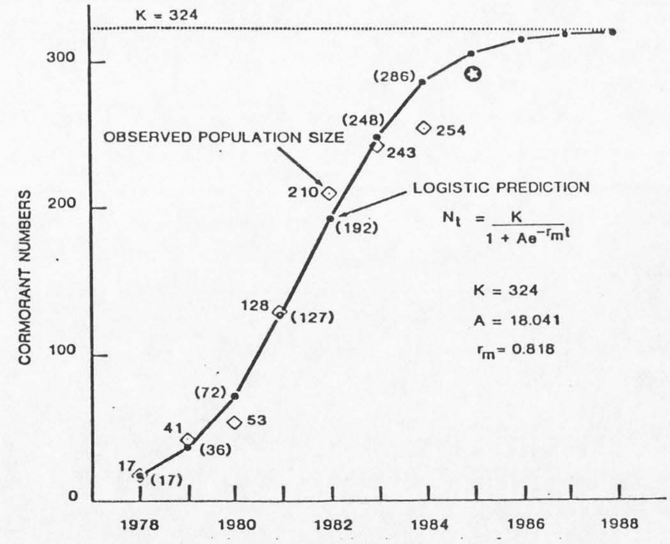

Fig. 2. Logistic growth curve fitted to observed cormorant numbers.

Table 2. Frequency of occurrence of fish found in regurgitation and pellet samples of double-crested cormorants, Apostle Islands, Wisconsin, 1984.

Species	Percent
Ninespine Stickleback	16.6
Slimy Sculpin	15.5
Spoonhead Sculpin	13.4
Burbot	13.3
Lake Northern Chub	10
Longnose Sucker	8.6
Trout Perch	8.3
Unidentified	5
Menominee Whitefish	2.4
Nothing	1.7
Smelt	1
Lake Trout	1
Common Whitefish	.8
Herring	.5
Worms	.5
4 Horn Sculpin	.1
	98.7

Table 3. Frequency of occurrence of fish found in 150 cormorant regurgitation and pellet samples collected from Gull Island and Eagle Island, 1984.

Gull Island		Eagle Island	
Species	%	Species	%
Ninespine Stickleback	20.2	Slimy Sculpin	34.0
Burbot	15.5	Spoonhead Sculpin	24.0
Slimy Sculpin	11.4	Menominee Whitefish	8.3
Lake Northern Chub	11.2	Lake Northern Chub	6.4
Spoonhead Sculpin	10.4	Longnose Sucker	6.4
Trout Perch	9.5	Unknown	5.5
Longnose Sucker	9.5	None	3.7
Unknown	5.3	Burbot	3.7
None	1.4	Common Whitefish	2.7
Smelt	1.0	Trout Perch	1.8
Lake Trout	1.0	Smelt	.9
Menominee Whitefish	1.0	Lake Trout	.9
Common Whitefish	.6	Unknown Invertebrates	.9
Herring	.6		
Unknown Invertebrates	.4		
4 Horn Sculpin	.2		
	99.2		99.2

Table 4. Estimated damage to the commercial whitefish catch caused by cormorants in the Apostle Islands, 1983-84.

Date	Total catch	% gilled	Lbs lost	$ lost
June 1983	16,376	31.4	5137	2569
July 1983	26,123	32.0	8364	4182
August 1983	2,720	38.6	1049	525
Totals	45,219		14,590	7276
June 1984	31,142	26.3	6845	3422
August 1984	7,800	37.6	2074	1037
Totals	38,942		8919	4460