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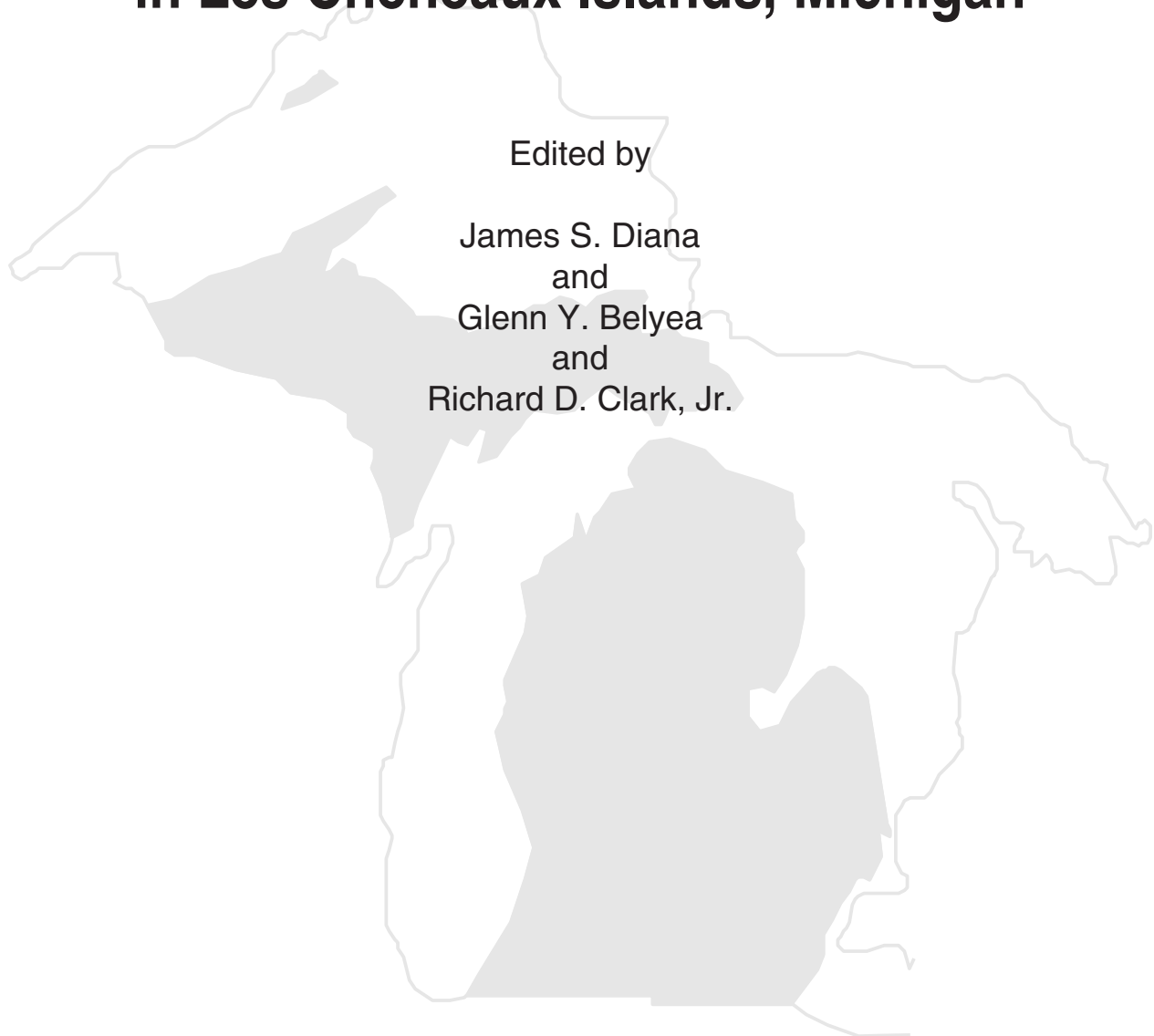
STATE OF MICHIGAN
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History, Status, and Trends In Populations of Yellow Perch and Double-Crested Cormorants in Les Cheneaux Islands, Michigan

Edited by

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and
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HISTORY, STATUS, AND TRENDS IN POPULATIONS OF YELLOW PERCH AND DOUBLE-CRESTED CORMORANTS IN LES CHENEAUX ISLANDS, MICHIGAN

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CHAPTER 1

GENERAL INTRODUCTION

James S. Diana and Susan L. Maruca

Since the late 1970s, the previously threatened double-crested cormorant (henceforth called cormorants; common and scientific names of organisms in this report are listed in Appendix 1) has made an impressive comeback in the Great Lakes (Scharf and Shugart 1981, Ludwig 1984, Weseloh et al. 1995) and now numbers as many as 50,000 in Michigan waters alone (Chapter 3). From approximately 1940 through 1960, cormorants were almost exirpated from the Great Lakes due to dichloro-diphenyl-trichloro-ethane (DDT)-related eggshell thinning and hatching deformities (e.g. Weseloh et al. 1983). The recent explosion of cormorants has been attributed to a reduction in the concentration of DDT and its metabolites in the water, as well as protection from human disturbance, increased nesting and foraging habitat on artificial reservoirs (Campo et al. 1993, Simmonds et al. 1995), and a ready food supply in the form of introduced alewife in the Great Lakes (Price and Weseloh 1986, Ludwig et al. 1989). Since 1980, diet studies in the Great Lakes show that alewife is the most prominent prey item for cormorants in nearly every location where alewife and cormorants are found together (Belonger 1983, Craven and Lev 1987, Karwowski et al. 1992, Ludwig et al. 1989, Ross and Johnson 1994, Weseloh and Ewins 1994). Cormorants appear to be generalist feeders that consume prey species on the basis of energetic profitability, which often results in the consumption of commercially or recreationally important species such as stocked trout or salmon fingerlings, yellow perch, and walleye.

Yellow perch populations have been declining in many areas of the Great Lakes for several decades, most likely as a result of repeated recruitment failures (Lucchesi 1988, Haas and Schaeffer 1992), and fisheries managers are now concerned that predation pressures from the newly abundant and growing populations of cormorants will either contribute to the further decline of yellow perch fisheries or hold them at unacceptably low levels.

In Les Cheneaux Islands of northern Lake Huron, the perch fishery, which had for decades been economically important to the area (Diana et al. 1987), has experienced a marked decline since the late 1970s (Lucchesi 1988). Concern from anglers and local citizens helped generate a Michigan Department of Natural Resources (MDNR) study in the mid-1980s, which revealed that growth overfishing (over-harvest to the point where size at harvest declines dramatically) may have been at least partially responsible (Lucchesi 1988). A 175-mm minimum size limit was instituted in 1987 in an effort to reduce mortality for smaller fish, but it did not help the fishery as predicted (see Figure 4-1). During this time abundance of cormorants have increased in the area. Cormorants naturally reestablished at St. Martins Shoal, just west of Les Cheneaux Islands, in 1980 after many years of absence, and in 1995 the local population occupied three nesting colonies and numbered approximately 4,000 breeding pairs plus an estimated 2,000 to 3,000 juvenile birds (Chapter 3).

The purpose of this project was to evaluate cormorant-perch interactions in Les Cheneaux Islands area. In particular, we evaluated population trends in cormorants and yellow perch, then determined the effect of cormorant foraging on the yellow perch fishery. This report documents a series of independent but related studies on various aspects of the project. Major funding for the project came from Michigan Department of Natural Resources, with supplemental funding from the U.S. Fish and Wildlife Service and the University of Michigan.

This report is subdivided into eight chapters and five appendices, each with separate authors who researched each component. The main

project results are outlined in Chapters 3 to 6. Each section is complete in itself (text followed by figures and tables), except the References section, which was compiled for all chapters combined.

Due to the multiple chapters and authors for this document, we suggest that citations to specific components of this work be made like an edited volume. For example, citation of information from Chapter 6 would be:

Maruca, S. L. 1997. The impact of cormorant predation on yellow perch in Les Cheneaux Islands, Lake Huron. Pages 50 to 73 in J. S. Diana, G. Y. Belyea, and R. D. Clark, Jr., editors. History, status, and trends in populations of yellow perch and double-crested cormorants in Les Cheneaux Islands, Michigan. Michigan Department of Natural Resources Fisheries Division, Special Report No. 17, Ann Arbor.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

Susan L. Maruca

Les Cheneaux Islands are located on the north shore of Lake Huron east of the Straits of Mackinac near Cedarville, Michigan (Figure 2-1). The area consists of at least 23 islands surrounded by glaciated channels and bays that interconnect to form a physiographically diverse, largely oligotrophic aquatic ecosystem. Aquatic habitats in the area fall into three general categories: shallow, productive inner bays (0 to 3 m); deeper channels and bays, often with some submergent vegetation (3 to 10 m); and deep outer bays and shoals more directly connected to Lake Huron (10+ m). Substrates in the area range from fine-grained silt and clay to coarse-grained pebbles and larger rocks. Most of the shoreline and original forest vegetation in the area has been disturbed as a result of development (Lucchesi 1988).

The study area boundary selected (Figure 2-1) was established in an effort to "contain" the entire yellow perch population within the study area. Little information exists regarding yellow perch movements in Les Cheneaux Islands area; however, Lucchesi (1988) found that none of the 11,649 yellow perch he tagged during spawning in Mackinac, Sheppard, or Flower bays were recovered outside the islands. The bounded study area contains approximately 11,860 ha (29,317 acres) of water (F. Cheneir, U.S. Geological Survey), most of which is suitable yellow perch habitat. Cormorant colonies are located on Goose and Crow Islands, both contained within the study area, and on St. Martins Shoal, just west of the study area (Figure 2-1).
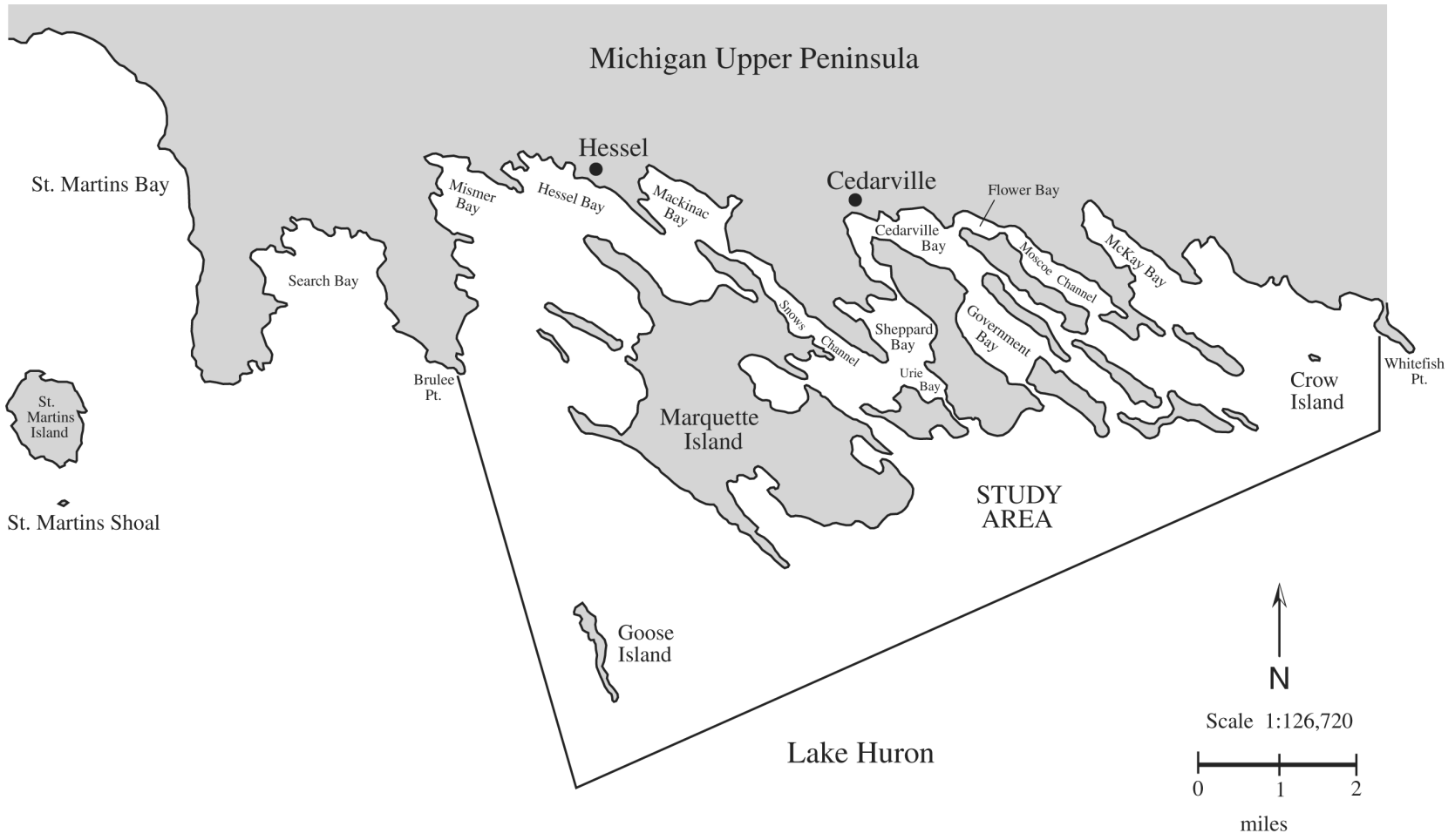
Figure 2-1.–Les Cheneaux Islands study area in northern Lake Huron. Cormorant colonies are located on St. Martins Shoal, Goose Island, and Crow Island.

Michigan Upper Peninsula

St. Martins Bay

St. Martins Island

St. Martins Shoal

Hessel

Mismer Bay

Hessel Bay

Mackinac Bay

Search Bay

Brulee Pt.

Marquette Island

Snows Channel

Sheppard Bay

Urie Bay

Cedarville

Cedarville Bay

Flower Bay

Government Bay

Moscoe Channel

McKay Bay

Crow Island

Whitefish Pt.

STUDY AREA

Goose Island

Lake Huron

N

Scale 1:126,720

0   1   2

miles

4

CHAPTER 3

POPULATION STATUS AND DIET OF CORMORANTS IN
LES CHENEAUX ISLANDS AREA

James P. Ludwig and Cheryl L. Summer

Introduction

The purposes of the studies outlined in this chapter were to: 1) evaluate the status, history, and trends of growth in the cormorant population; 2) analyze banding data on the birds banded in, or recovered in, Les Cheneaux Islands; 3) band large numbers of chicks produced within the study area and within a 75 mile radius of Cedarville; and 4) collect fish consumption data following the methods and protocols described in Ludwig et al. (1989).

Background

The populations of cormorants in the upper Great Lakes and all across North America are in the midst of the 20th century's second massive population explosion of waterbird species. Previously, the ring- billed gull demonstrated a similar continent-wide population explosion, increasing rapidly on the Great Lakes after 1926 from small prairie populations on widely scattered inland lakes east of the Rocky Mountains (Ludwig 1968, 1974). At the turn of the century, ring-billed gull colonies were essentially restricted to breeding sites on inland (often saline to hypersaline) lakes from Colorado and Utah northward through the lake districts of the Canadian prairie provinces. The species had once bred in Ontario waters of Lake Huron around the turn of the century but was reported to be absent from the upper Great Lakes from 1906 to 1925. The first 'modern' colony was found at St. Martins Shoal near Les Cheneaux district in 1926 by William I. Lyon, an early bird bander (Ludwig 1943).

By World War II, ring-billed gulls had spread over many Michigan coastal islands that are waterbird breeding areas. By 1960 the population in the upper Great Lakes was estimated at 27,000 nesting pairs which then grew explosively to 141,000 pairs by 1967. In the late 1970s the entire population in the upper and lower lakes was nearly a million individuals, with annual nesting counts in the range of 400,000 to 500,000 nests (Blokpoel and Tessier 1986, Scharf and Shugart 1991). This rapid population growth was attributed to new food availability in the form of non-native alewife and rainbow smelt in the Great Lakes, exploitation of agricultural food sources, an insectivorous habit, very early maturation for a gull species (2-year-old ring-billed gulls nesting compared to 3- to 5-year-olds for almost all other gull species), and general low sensitivity or less exposure to the highly toxic organochlorine contaminants released into the Great Lakes (Ludwig 1968, 1974). Other species, including herring gulls and the four resident Great Lakes tern species, have also demonstrated widespread population changes in the last five decades, owing mostly to exposures to toxic contaminants (Kubiak et al. 1989, Ludwig et al. 1993a, b). In summary, the Great Lakes have been a highly dynamic colonial waterbird habitat for the entire 20th century. When the current cormorant population explosion is placed into this historic context, it is merely the most recent large scale fluctuation for colonial waterbirds in North America east of the Rocky Mountains, with pronounced emphasis in the Great Lakes.

The breeding history of cormorants on the Great Lakes is remarkably similar to the ring-billed gull. Cormorants were not reported to breed in Michigan by Barrows (1912), although he clearly suspected that they nested occasionally in the state around the turn of the century. Wood (1951) noted breeding records in the 1930s from Isle Royale and the Huron Islands in Lake Superior. Summer distributions left no doubt that a few birds were breeding in

northern lakes Michigan and Huron. Both authors noted that the species was an abundant breeder in the Canadian waters of lakes Huron and Erie. Successful annual breeding occurred in colonies near Blind River, Ontario in the 1930s. William I. Lyon, a bird bander, made 11 annual trips to this district between 1932 and 1944, banding cormorants on every visit. It is only by his efforts that the historic banding database (analyzed later in this chapter) exists.

The breeding population of cormorants in the Upper Great Lakes during the 1930s was probably centered on the eastern half of the North Channel and the northern half of Georgian Bay, with a few birds to the west in Lake Superior and in the northern third of Lake Michigan. F. E. Ludwig (unpublished data) accumulated records of occasional breeding by cormorants at Black River, Scarecrow and Thunder Bay islands, and Pismire and Hat islands in the Beaver Islands, plus Bellow's Island in Grand Traverse Bay of northern Lake Michigan. Wood (1951) reported cormorant breeding regularly at the Huron Islands in Lake Superior in the 1930s. Although there are no nest census data to confirm this, we suggest that the 1940s population in Michigan was 200 to 500 nesting pairs, and about 1,500 to 2,500 in the Canadian waters of Lake Huron. Persecution by commercial fishermen and predation during nesting probably regulated the populations at these low levels.

Numerous Civilian Conservation Corps projects of the 1930s on inland tax-reverted lands in northern Wisconsin and Michigan included construction of many low head dams. These projects produced flooded inland impoundments, a habitat type identical to that of the Canadian prairie provinces where the continental cormorant populations were highest. These artificial floodings became cormorant and heron breeding refugia by the outbreak of WW II. Many were colonized extensively, but few data on breeding populations were recorded. For example, Bond Falls Flowage and Michigamme Reservoir in the Upper Peninsula were invaded by nesting cormorants sometime in the late 1940s, and successful breeding of at least a few pairs was noted at both sites in 1952 (Ludwig 1984). Numerous inland impoundments in northern Wisconsin, managed as state wildlife refuges, became the primary sites where the species survived the DDT era from 1947 to 1976 (Ludwig 1984).

By 1960, it was clear that Great Lakes' cormorant populations were in rapid decline, owing to dieldrin (DDE)-mediated eggshell thinning (Weseloh et al. 1983). The last successful breeding in Michigan waters of the Great Lakes was apparently at the Huron Islands in 1957 or 1958, and the last confirmed Great Lakes nest site in the lower peninsula consisted of three nests at Black River Island in 1954. By the 1960s, the species had vanished from all Michigan Great Lakes sites, and even from inland impoundments. The cormorant population was also declining rapidly in the Canadian waters of Lake Huron (F. E. Ludwig, unpublished observations). From 1960 to 1967 not one observation of cormorants in Michigan waters was made during the annual surveys of gull and tern populations conducted by the Ludwigs (Ludwig 1962, 1968, 1974). In 1966 and 1967, only four sites were left in the North Channel district with any pairs attempting to nest. Weseloh et al. (1983) reported the lowest Great Lakes population in 1972 and 1973, when just 125 breeding pairs were left, attempting to nest at six small sites in northeastern North Channel and Georgian Bay, and two sites in Lake Erie. Annual nest productivity was reduced to 0.1 to 0.2 chicks per nest, far below the level of about 0.8 needed to maintain the population (Ludwig et al. 1995).

DDE concentrations in eggs were measured at 22 ppm (mg/kg wet weight) in North Channel birds in 1972 (Weseloh et al. 1983), from cormorants which were undoubtedly feeding on some of the least contaminated fish then available from the upper Great Lakes. The estimated low adverse effect level is 3 ppm DDE for significant thinning of eggshells. Eggshell thinning was cited as the immediate cause of reproductive failure. Recent work suggests that this population could not reproduce at a replacement rate until the DDE in their eggs fell to <10 ppm, and could not sustain population growth until levels dropped to 6 ppm (Ludwig et al. 1995). The species seemed headed for extinction in the early 1970s: it was

placed on Michigan's first threatened and endangered species list in 1976 as "probably extirpated". Domestic DDT use was banned in 1972.

Throughout this period of reduced reproductive success of cormorants due to DDT-group chemicals on cormorants, other less sensitive species were able to take advantage of the vast new food resource of alewife in the Great Lakes. Ring-billed gull numbers had exploded (Ludwig 1974), the Caspian tern population more than doubled between 1962 and 1978 (Ludwig 1965, 1979), and herring gulls seemed to have recovered from the acute but localized impacts of DDT-group chemicals on their population (Ludwig and Tomoff 1966, Ludwig and Ludwig 1969).

As DDT/DDE levels declined rapidly and cormorants reappeared in the late 1970s in the Great Lakes, there was a high food abundance for a foot-propelled diver. The first successful nesting recorded was in 1978 by 24 pairs at Gravelly Island, northern Green Bay, which fledged 29 chicks. This apparently desirable return of a threatened species from near extirpation was soon overshadowed by the explosive increase in cormorant numbers causing damage to vegetation on nesting islands (Ludwig 1984), as well as possible damage to valuable sport and commercial fish populations (Craven and Lev 1987). By 1981, 318 nests were found in seven colonies across the state (Ludwig 1984). By 1986 there were at least 1,094 nests in Michigan (Table 3-1). The 1995 nesting population in Michigan waters of the Great Lakes was estimated to be approximately 18,000 nests (Table 3-2): at least 25 major colonies were occupied. The nesting population in Michigan could have been as high as 20,000 pairs in 1995. The group of nesting cormorants in Les Cheneaux Islands area was estimated at 4,414 pairs, 24% of the surveyed nesting population (18,572 pairs) in Michigan.

For the first eight years of this recovery, the increase in nesting numbers averaged 72% per year. During the nine nesting seasons from 1987 through 1995, this rate of growth decreased to perhaps 25% in 1994 and 1995. However, because the population base on which the rates of increase are calculated is large, the total number of birds added to the population increased, while growth rates decreased. For example, a 72% increase from 318 pairs in 1984 would have been an additional 229 pairs in 1985. However, a 25% increase in 1995 would mean an additional 4,293 pairs added to the population in 1996.

In 1995 there were at least 25 major colonies of cormorants in Michigan, and very likely others, particularly in Grand Traverse Bay and parts of central and western Lake Superior. Table 3-2 lists the colonies known to the authors and estimates their population sizes based on visits made in 1995 where either counts of active nests were made, or banding visits were made to tag chicks. If no visit was made to a known colony in 1995, we predicted the population size in 1995 based on trends in cormorant populations, knowledge of the site, and probable disturbance to occupied sites since our most recent visit. We assume that these colonies comprise between 85 and 95% of the actual breeding population for the state in 1995. We also projected the breeding population in 1996 (21,465 pairs nesting) and 1997 (25,758 pairs nesting) under unsupported assumptions that growth rates will remain at 25% in 1996 and then drop to 20% in 1997. These projections assume that no major diseases will affect the population, and that no control efforts will be started in that time. In addition to breeding birds, there will be one- and two-year olds that migrate to the Great Lakes and frequent the area of the colonies. We project the summertime 1997 population of Michigan cormorants to be near 70,000 individuals, up from an estimated 48,000 birds in summer 1995.

In nearby Canadian waters there are many more cormorant colonies. Those nearby colonies of the North Channel and northern Georgian Bay known to the authors are listed in Table 3-3. For this incomplete survey, we estimated 22 active major colonies and 14,982 nesting pairs. However, we are certain that this is a considerable underestimate of the actual population, perhaps by 25 to 33%.

Methods

Banding

There are four sets of banding data available for Les Cheneaux Islands area: 1) historic data from the pre-DDT era (1932 to 1944) which consist of 22 recoveries of birds banded outside of the area as chicks, but recovered within the study area; 2) recent data from 1979 through 1994 consisting of 55 recoveries of birds within the study area from all banding sources in North America, 16 of which were of birds raised in the study area; 3) recoveries (202) received through 26 June 1995 of birds banded as chicks within Les Cheneaux area colonies between 1983 and 1994; and 4) bands on birds shot for the diet samples (Appendix 2).

Data on bird banding recoveries are stored at the U. S. Fish and Wildlife Service Bird Banding Laboratory (BBL), Patuxent Wildlife Research Center, Laurel, Maryland using 10-minute blocks of latitude and longitude as locations. These blocks extend the boundaries of the study area because data are reported only as a recovery within a 10-minute block, and information is usually not available with greater resolution. In order to capture all recoveries of birds that were within an hour's flying distance of Les Cheneaux Islands area (Chapter 2), all BBL recoveries (154) that had been made within the area from 45°40' to 46°10' by 83°10' to 84°50' were requested.

Active cormorant breeding colonies were present throughout a larger area and could have contributed many breeding adults to growing colonies in Les Cheneaux Islands. While there are only two colonies technically within the study area (Goose and Crow), three colonies (St. Martins Shoal, West Saddlebag Reef, and Wheeler Reef) are tangent to the study area and recoveries of their chicks are included in this analysis. Five Ontario colonies are peripheral to the study area (Table 3-4), and one Lake Superior colony (Tahquamenon Island in Whitefish Bay) is immediately north of the study area. Recoveries of birds banded in these latter six colonies are not included in this analysis, although these peripheral colonies contribute numerous birds to migratory flocks of cormorants passing through the study area, especially during post-nesting dispersal (Table 3-4). A review of these data suggests that Les Cheneaux Islands are strongly influenced by birds traveling to and from these peripheral colonies, while these and even more distant colonies have contributed nesting birds to Les Cheneaux Islands area (Table 3-5).

Results and Discussion

Banding

A total of 22 recoveries were made between 1932 and 1944 from birds banded within the study area (Table 3-6). Fifteen of these recoveries were made within Les Cheneaux Islands, and 3 of these were made by commercial fishers from birds trapped in gill nets (Table 3-7). The lack of recoveries after 1944 reflects cessation of banding in Canadian colonies after 1944, and the subsequent near extinction of the species in the Great Lakes.

Interestingly, all birds caught in gill netting operations came from the North Channel district of Lake Huron, specifically the areas around Blind River, Ontario and the islands of Doucet, Black and Chrysler Rocks (46°06' x 82°51'), Cousins Island (46°04' x 82°49') or West Island (46°05' x 83°00'). All of these sites were described as cormorant rookeries in the 1920s and 1930s, and were early foci of banding efforts by William I. Lyon. By 1962, cormorants had been extinguished at all of these sites near Blind River except Doucet Rock, where 8 nests persisted in 1973 (Weseloh et al. 1983, Ludwig, unpublished data.). All birds recovered in the study area were banded as chicks in the immediate vicinity of these islands. Cormorants have regained large nesting numbers on these same sites in the last decade; more than 3,500 nests were present on these islands in 1994.

Recently, 55 birds have been recovered for the period 1979 to 1994 from within the larger recapture area (Table 3-6). Of these, 35 were taken in the study area, 17 from the Lake Huron shoreline on both sides of the study area, and three from the North Channel or False Detour Channel areas. Only 16 of these (29%) were

birds raised in the study area, while 18 (33%) were recruited into the area from Lake Michigan, 14 (25%) from the North Channel and Georgian Bay, and 6 (11%) from Lake Superior (Table 3-5). Although not shown in this table, Les Cheneaux colonies contributed only 7 banded birds to other upper Great Lakes colonies during this period. This is particularly interesting given the history of intense cormorant banding in Les Cheneaux Islands from 1982 to 1994. Compared to other areas of the upper Great Lakes, only Green Bay colonies have been as thoroughly banded since the population recovered (1978 to 1994).

Recovery sources (Table 3-7) were significantly different in the recent vs. historic period (Chi Square, P<0.01), assuming that the ways of reporting recoveries have not changed between the two time periods. The early data set had predominant recaptures from commercial fishers (68%), while the later data show only 19% captured similarly. Of 202 birds tagged from 1983 to 1994 in the study colonies, 18% of those reported through 26 June 1995 were entangled in fishing gear.

Tables 3-6 through 3-10 provide summaries of the banding data accumulated by the Ludwig banding team (F. E. Ludwig 03491, J. P. Ludwig 08195 and F. E. Ludwig II 09097) for all juvenile birds banded at the two study area and three tangent colonies. Since 1983, these banders have tagged over 9,800 chicks at the five colonies. As of 26 June 1995, 202 recoveries have been reported from these bandings. None of the shot birds (Appendix 2) are included in this data set. The vast majority of recoveries (86%) came from birds tagged at St. Martins Shoal, reflecting the large proportion of chicks banded there from this sample. Birds ranging up to 8 years of age have been recovered (Table 3-6), although these banders tagged birds at St. Martins Shoal beginning in 1984.

Cormorants have dispersed from Les Cheneaux area to 21 different jurisdictions (Table 3-9), with 87% traveling along the Mississippi flyway. Furthermore, Dolbeer (1992) reported that the vast majority of all cormorants banded in Lake Huron appeared in winter in the Mississippi flyway. These data suggest that the migration pathway to and from the lower Mississippi River and Gulf of Mexico is through Les Cheneaux area for many cormorants from the upper Great Lakes. Numbers of Canadian birds should be expected during the April to May and August to October migration periods.

Birds have been recovered in 15 ways (Table 3-10) with most (51%) simply found dead (cause of death unknown). Entanglement in fishing gear is the second most often reported cause of death (17%), with 8% killed in control operations at southern US fish ponds, and 5% killed for scientific specimens of various types. Only 8 (4%) of the birds recovered were reported to have survived the encounter with the observer reporting the band number. Three of those taken as scientific specimens were from a Texas study of cormorant food habits (Campo et al. 1993). If birds killed by persons engaged in fishing and research due to complaints arising from fishing are combined, then 30% of the birds in this sample were killed in activities directly related to human sport or commercial fishing, including control operations. This compares to 68% in the samples before World War II.

A listing of band numbers and ages for banded birds shot by MDNR for the study of food habits is provided (Appendix 2). A total of 373 birds were collected between April and October 1995, and 53 were banded (14.2% of the sample). Of the 53 banded birds, 26 (49%) were banded as chicks outside Les Cheneaux Islands and tangent study areas. These data are very similar to the banding data supplied in Tables 3-5 through 3-10. However, this sample (Appendix 2) is of a markedly older group of breeding age birds, as many of the birds were between 8 and 11 years old.

Changes in reported mortality patterns for banded cormorants are undoubtedly due to several factors. First, the impact of fishing gear has changed owing to the greatly decreased use of gill nets in the last two decades. Conversely, more birds appear to be fouled in sportfishing gear in the last decade. Second, the fishing habits of these birds are probably quite different today compared to 60 years ago when there were no alewife available in shallow to mid-

waters during the summer period (Ludwig et al. 1989), which is when the majority of people see or encounter cormorants fishing today. Historically, cormorants were probably feeding on what fish were available in mid-water and deeper habitats. These birds would have very likely exploited sculpins, ninespine stickleback, chubs, rock bass and perch. Smelt, perch and centrarchids were likely sought when they congregated to spawn. Third, the size of the angling population was far smaller 60 years ago than today, which greatly limited the number of angler-cormorant interactions then.

Food Habits

Data on food habits were collected from 19 cormorant colonies visited for banding operations in 1995 (Table 3-11). Records were kept of all recognizable prey items, largely fish, regurgitated by chicks as they were disturbed by banders; some 6,293 items were identified comprising 21 species. Non-fish prey items were a mudpuppy and several crayfish (not identified to species). Sticklebacks were not differentiated to genus. Suckers, shiners and sculpins were only identified to genus. Numbers of prey items were converted to estimates of biomass using the weights for fish disgorged by cormorants (reported in Ludwig et al. 1989). Unpublished food data from samples gathered in 1990 from the same colonies and districts are presented in Tables 3-12 and 3-13 to provide information on possible trends in cormorant diets.

There were large differences in diet among data collected from nestlings throughout the region (Table 3-11). These differences may reflect diet changes due to locality, time of collection, or both factors. The least diverse diet was observed in Lake Michigan colonies where cormorants essentially fed their chicks alewife with only an occasional different species. The diet in Les Cheneaux Islands area was somewhat more diverse, with more sticklebacks, sculpins, and smelt present, although alewife comprised almost 3/4 of the biomass and 3/5 of the food items recovered from colonies. The diet in Canadian colonies was much more diverse, and division among prey species more pronounced. Alewife was essentially half the diet with six other species contributing 5% or more of the diet. Only in Canadian waters of the North Channel of Lake Huron were perch encountered in regurgitated samples in 1995; perch were encountered in all sampling regions in the 1986 to 1989 and 1990 samples. Yellow perch were observed in diets from five of ten colonies visited in the North Channel, although 2/3 of all perch occurred at one colony (Flat Point Reef in the extreme eastern end of the North Channel).

The changes in biomass consumed by cormorants (Table 3-12) by the major fish species were collected over three sampling periods, 1968 to 1989 (reported in Ludwig et al. 1989), 1990 (J. P. Ludwig, unpublished data), and 1995 (this study). Two changes stand out as trends over time. Alewife has increased as the bulk of the diet fed to cormorant chicks. Perch in the diet has declined consistently in every area of lakes Huron and Michigan. These data hint that perch declines are region-wide. Another likely alternative is an increase in abundance of alternate prey. These trends are further supported when the samples are grouped for all regions by the three sample periods (Table 3-13). These data show a steady increase in alewife and a steady decrease in perch in the diet. Smallmouth bass also show a decline, but this may be an artifact of small numbers recovered in the samples. There was also an increase in the number of species represented, from 18 in 1986 to 1989 to 21 in 1995. There were novel species such as a mudpuppy and lamprey in 1995 samples, and other prey species made up an increasing, although minor, part of the diet in Canadian colonies.

Yellow perch composed just 1.2% of the prey items in the 1995 samples (69 of 6,293 items), while alewife (2,467) and sticklebacks (3,149) were the largest part of the cormorant diet numerically. Perch did not appear in samples from either northern Lake Michigan or the northern Lake Huron colonies. Perch were in regurgitations at 13 of 21 colonies (56%) in the 1986 to 1989 period, in 10 of 21 (46%) colonies in 1990, but only in 5 of 19 (26%) colonies in 1995.

Population Modeling

The history of the cormorant population is largely consistent with the model of population growth presented by Ludwig (1984) which projected a population growing – without immigration from inland sites and other states or provinces – at 40% per year. The growth rate in Michigan from 1978 to 1988 averaged over 70% per year (Table 3-1), and afterwards slowed to about 25% in the last three years. The banding data for Les Cheneaux Island area (Table 3-5) are conclusive evidence for immigration of breeding aged birds from both Lake Michigan as far west as Wisconsin and Ontario as far east as the northeastern corner of Georgian Bay, with one bird coming north from Lake Ontario. This decline in population growth rate is consistent with a lower rate of immigration as nesting habitat begins to saturate. However, even though the rate of growth is dropping consistently, the absolute numbers of cormorants continue to increase very rapidly (Table 3-1).

Ultimately, this population will stabilize (or decrease) only when mortality of all birds exceeds reproductive success. Without human intervention, this is likely to be a decade in the future. In stable colonial waterbird populations, an age structure develops over time that is dominated by older birds. Cormorants are long-lived, with reproductive strategies adjusted to bursts of success and periods of complete failure (Ashmole 1963, Lack 1966, Ludwig 1974). Currently, the Michigan cormorant population is dominated by young birds; the mean age of breeding adults is about 3.9 years and 99% are less than age 10. In a stable population with an estimated 10% adult death rate, 34% of the breeding adults would be 10 years or older. Reproductive output in a number of long-lived bird species declines after 10 to 12 years of age (Lack 1966). The necessary age distribution for this effect will not develop in the cormorant population of the Great Lakes for almost another decade.

Parasites may affect future population sizes. Debilitation of adult cormorants by parasites may accomplish much population control if the debilitation lowers rates of reproduction. However, because many intermediate hosts are involved in transfers of endoparasites, time is required to increase the rate of infection to a point where parasites become effective population controls. A burgeoning population is often largely parasite-free until the infected intermediate host populations are established as parasite reservoirs. It is not likely that population control from this cause will happen in the near future.

Epizootic diseases of bacterial and viral origins, such as avian cholera or Newcastles disease virus (NDV), are far more likely to cause mortalities which may limit cormorant population growth. Avian cholera killed 14,500 cape cormorants in eight islands off South Africa in 1991, or about 8% of that breeding population. A reduced food supply was cited as the stress factor that initiated the outbreak (Crawford et al. 1992). The causal bacterium is common worldwide and has caused numerous mortalities in North American waterfowl (Botzler 1991). Once established in dense populations, avian cholera tends to reappear in epizootic outbreaks when other factors stress populations, especially food shortages (Combs and Botzler 1991).

Already in North America there have been two significant outbreaks of NDV in cormorants. The first in 1990 was of a moderately pathogenic form of the NDV that attacked primarily the visceral organs of affected birds. Ring-billed gulls, white pelicans and cormorants were the primary victims of this outbreak. An estimated 6,000 birds of all species died on the prairie provinces in Canada, as far east as Minnesota (Botzler 1991). The second outbreak in 1992 infected cormorants from the Rocky Mountains eastward to Quebec and Maine. The NDV in this outbreak was classified as neurotropic (affecting the central nervous system primarily), and of high virulence. Adult cormorants were largely unaffected, although many fewer than normal numbers of eggs hatched in 1992 at many colonies. Large chicks succumbed to the disease at rates ranging from 5 to 40%. Many infected chicks that survived were crippled and died when they were unable to fish properly or migrate with the onset of winter (J. P. Ludwig, unpublished data). Probably a third of the chick productivity in the

Great Lakes colonies in 1992 was lost during this outbreak. It is likely that a major reason for the decline in population growth rates since 1992 was the NDV outbreak.

NDV is known to reduce clutch size and hatchability in infected chicken flocks that tolerate the disease. All current breeding cormorants in this population were exposed to the virus in 1992, and possibly since. The St. Martins Shoal colony in 1994 had a lowered hatch rate, but no birds with NDV symptoms. It is likely that at least some cormorants in the Great Lakes are carriers of the virus. Worldwide, cormorants have experienced such outbreaks of NDV at least since 1948 (Botzler 1991). It is virtually certain to reappear as population densities increase and food availability become a problem (Crawford et al. 1992). Future outbreaks are likely to become more frequent and severe.

The availability and access to food, both in the Great Lakes and the southern wintering grounds, may ultimately limit population growth of cormorants. Winter food supplies are important to provide the basis for the pre-breeding condition of adults. Other than studies conducted in Texas on wintering cormorant diets (Campo et al. 1993) and many complaints by catfish farmers on the Mississippi delta, little is known about the winter bioenergetics of cormorants or whether winter food shortages occur. Summer shortages of food locally near colonies in the Great Lakes, if they occur, are more likely to affect nutrition, brood size, or frequency of disease outbreaks. Many authors have cited delayed breeding (Ashmole 1963), or abandoned breeding (Crawford and Dyer 1995) among marine seabirds as other responses to failing food supplies.

Cormorant clutch size early in the population expansion averaged 3.83 eggs (Ludwig 1984). However, it decreased to 3.09 during the 1994 pilot study in Les Cheneaux Islands area, and was even lower in 1995 (2.97), a 22% reduction from the clutch size recorded early in population expansion. These reductions could ultimately lead to fewer chicks being raised, and lower population growth rate. Clutch size reductions are interesting because they are opposed to the general trend of clutch size increases with bird age. Generally the first clutch or two laid by a female is smaller than what she will produce for about a decade once full maturity and breeding experience is acquired. Therefore, if other factors do not limit breeding, one would expect clutch size actually to increase as an older age structure is achieved in this population. Since the reverse is being recorded, some density-dependent factors may be involved.

We encountered noticeably emaciated chicks at the Wheeler Reef, Egg Island, Elm Island and Flat Point Reef colonies in 1995. Food resources may be limiting, at least in local areas of the upper Great Lakes. Persistent low-grade NDV infections could be causing reduced clutch size as well. Crawford et al. (1992) established that lower food availability and higher density of breeding birds were contributing factors to the intensity of the 1991 South African outbreak of avian cholera in cape cormorants.

Previously, Caspian terns nesting on the Great Lakes reduced their clutch size from a mean of 2.83 eggs per nest in 1963 and 1964 to 2.06 eggs per nest in 1986 to 1991 (Ludwig 1979, Ludwig et al. 1993a). When the alewife population was very large in the 1960s, there was a superabundance of food during the tern nesting season, which probably enabled terns to maintain a higher mean clutch size and reproductive output (Ludwig 1965). As alewife availability declined, productivity in Caspian tern colonies declined where alewife populations were scarcest (Ludwig 1979). Several colonies in Georgian Bay relocated from islands surrounded by deep waters near the center of the bay to coastal areas, where other prey species could be exploited in shallower waters. Clutch size dropped to 1.91 eggs per nest in northern Georgian Bay as alewife largely disappeared from tern diet in this region, and two colonies relocated over 16 km into shallow water fishing grounds (J. P. Ludwig, unpublished data). The responses of Great Lakes Caspian terns are very similar to those reported by Cairns (1987) for marine seabirds facing severe food stress. In theory, the increasing dependence of cormorants on alewife eventually may make cormorants vulnerable to

fluctuating or decreased alewife populations, much as Cape cormorants in South Africa are to anchovy fluctuations (Crawford et al. 1992). A collapse of alewife stocks, which were 72% of the fish biomass fed to their chicks in 1995 (Table 3-13), could reduce cormorant chick survival.

Nesting space may also become a limiting factor, acting in concert with local food supplies. In a given area, the distance that an adult must travel to find food for its chicks is controlled by access to food and competition with other cormorants. When food declines, the effort to find food becomes more energetically costly. If the islands used as breeding sites are too close to one another, then competition for food will increase. Under these circumstances, or in cases where individual colonies are saturated, density-dependent competition for food can become a limiting factor to population size.

Cormorants have specialized feeding behaviors that undoubtedly lessen the food stresses that other Great Lakes waterbirds must face. Two feeding behaviors are very important. First, similar to other highly social Pelicaniformes, cormorants may use flock feeding strategies whereby concentrations of fish are exploited cooperatively (Anderson 1991). Also, when food is a serious limiting factor to plunge-diving gulls and terns, it may not be a problem of the same magnitude to foot-propelled diving cormorants that can reach prey unavailable to surface feeders. There are records of cormorants being caught in nets set at more than 35 m depth. The most effective plunge diving competitor for cormorants on the Great Lakes is the Caspian tern, which can penetrate about a meter of water on a dive. The ability to exploit deeper water is an immense advantage for cormorants in competition with other colonial waterbirds for food.

The cormorant population expansion has great momentum since there are non-breeding 1- (and probably most 2-) year-old birds already fledged that are waiting to mature and begin nesting. Even if all reproduction fell to replacement rate in 1996, the population would continue to grow at least until 1998 as these age classes begin nesting.

We predict that left alone the cormorant population of the upper Great Lakes will continue to grow for another 7 to 9 years, before leveling off at an estimated 88,000 nesting pairs (Tables 3-14 and 3-15). The current pattern of 2 year olds breeding (confirmed by 6 band recoveries of nesting individuals this age class in colonies in 1987 to 1990) will probably change to first nesting at ages 3 or 4. We predict that clutch size will also be reduced from 3.4 eggs/nest to about 2.6 to 2.9 eggs/nest. Parasites and diseases will likely take an increasing toll on adults. We predict that fledging rates will fall from about 2 chicks per nest to an average of about 0.8 to 1 chicks per nest. Mortality of the chicks in the first six months after fledging will probably rise to near 40%, prebreeding mortality will probably rise from 35 to 70% of fledglings, while adult mortality rates are predicted to rise from to 12 to 15% annually. These predicted rates are close to those existing in the ring-billed gull population (Ludwig 1967, 1974) which has achieved a balance in the upper Great Lakes after its explosive growth between 1955 and 1972.

Table 3-1.–Changes in breeding cormorant numbers in Michigan 1978 to 1995, with projections for the breeding population in 1996 and 1997.

Year	Estimated pairs	Average annual rate of increase	Data source
1978	24	n/a	Ludwig 1984
1984	318	56%	Ludwig 1984
1986	1,094	82%	Ludwig, unpublished data
1988	3,494	72%	Ludwig, unpublished data
1990	5,855	31%	Ludwig, unpublished data
1992	8,705	22%	Ludwig, unpublished data
1995	17,172	25%	This study
1996	21,465	25%	This study
1997	25,758	20%	This study

Note: The average annual rate of increase is back calculated from the census figures over the indicated interval. For example, in order for the population to grown from 5,855 pairs to 8,705 pairs between 1990 and 1992, that requires an average addition of 22% of the breeding pairs to the population in this interval.

Table 3-2.–Active colonies and estimated breeding numbers of cormorants in 1995.

Colony name	Location	Year established	Estimated number nests/ basis year for estimate	
Traverse Island	Lake Superior	1989	300	estimate/1992
Huron Islands	Lake Superior	1990	300	estimate/1992
Tahquamenon Is.	Lake Superior	1980	800	visit, est./1995
Fisherman's Is.	Green Bay, LM	1988	800	estimate/1994
L. Gull Is.	Green Bay, LM	1981	900	estimate/1994
Gull Island	Green Bay, LM	1992	400	estimated/1994
Rocky Island	Green Bay, LM	1993	200	estimate/1994
Snake Island	Big Bay de Noc, LM	1981	2,200	visit, est./1995
Naubinway Is.	Lake Michigan	1986	725	visit est./1995
Epoufette Is.	Lake Michigan	1992	50	estimate/1992
Gull Island	Beaver Islands, LM	1981	550	visit est./1995
Trout Island	Beaver Islands, LM	1993	150	visit est./1995
Grape Island	Beaver Islands, LM	1988	2,300	visit est./1995
Hat Island	Beaver Islands, LM	1982	2,150	2 visits est./1995
Green Island	Straits of Mackinac	1995	70	visit est./1995
St. Martins Shoal	Les Cheneaux area	1980	1,954	3 visits count/1995
Goose Island	Les Cheneaux area	1987	1,766	2 visits count/1995
Crow Island	Les Cheneaux area	1990	311	3 visits count/1995
W. Saddlebag Reef	Les Cheneaux area	1988	383	4 visits count/1995
Propellor Island	Potagannising Bay	1995	18	visit est./1995
Advance Island	Lake George	1989	100	estimate/1990
Gull Island	Thunder Bay LH	1985	750	estimate/1992[a]
Scarecrow Island	Thunder Bay LH	1981	760	estimate/1994
Bird Island	Thunder Bay LH	1989	600	estimate/1994
Little Charity Is.	Saginaw Bay	1991	35	estimate/1994[b]
Total colonies = 25			18,572	pairs breeding

[a] Colony visited by L. Feyk.
[b] Colony visited by K Grasman, D. Best. The year of estimates are the last year the authors visited this colony and made a count.

Table 3-3.–Canadian colonies of cormorants near Les Cheneaux Islands area in 1995.

Name	Location	Year formed	Estimated 1995 size (nesting pairs)
Wheeler Reef	S.W. Cockburn Island	1989	567[a]
Kalulah Rocks	W. North Channel	1988	120
Africa Rocks	W. North Channel	1982	520
Birch Island	North Channel	1995	80
Bird Island	North Channel	1995	125
Middle Grant Island	North Channel	1990	800
Herbert Island	North Channel	1986	860
Talon Rocks	North Channel	1992	200
West Island	North Channel	1989	1,900
Doucet Rock	North Channel	1973	465
Cousin's Islands	North Channel	1986	1,050
Batture Island	North Channel	1989	300
Egg Island	North Channel	1990	625[a]
SW Gull Rock	North Channel	1987	450[a]
Elm Island	North Channel	1988	960
Flat Point Reef	North Channel	1993	480
W. Mary Is. Reef	E. North Channel	1990	200[a]
Heywood Rocks	E. North Channel	1991	150[a]
West Rock	N. Georgian Bay	1985	2,350[b]
Elie Shingle	N. Georgian Bay	1989	550
Gull Island	N. Georgian Bay	1987	1,450
SW Gull Rocks	N. Georgian Bay	1988	780
Totals	22 Colonies		14,982

[a] Probable sites of human egg predation in 1995.
[b] 20 adult cormorants found shot to death at this site on 22 June 1995.

Table 3-4.–Size and status in 1996 for nesting colonies of cormorants in Les Cheneaux Islands area.

Colony location	Latitude x Longitude	Study category	Size (nesting pairs)	Status
Goose Island	$45^o 55'$ x $84^o 26'$	Study area	1,766	Increasing
Crow Island	$45^o 58'$ x $84^o 14'$	Study area	311	Increasing
St. Martins Shoal	$45^o 58'$ x $84^o 32'$	Tangent to area	1,954	Increasing
West Saddlebag Reef	$45^o 57'$ x $84^o 03'$	Tangent to area	383	Increasing
Wheeler Reef, Ont.	$45^o 54'$ x $83^o 30'$	Tangent to area	567	Stable
Herbert Island, Ont.	$46^o 08'$ x $83^o 16'$	Peripheral	860	Increasing
Middle Grant Island, Ont.[a]	$46^o 08'$ x $83^o 20'$	Peripheral	800	Increasing
Bird Island	$46^o 08'$ x $83^o 23'$	Peripheral	120	New 1995
Kalulah Rocks, Ont.[a]	$46^o 15'$ x $83^o 36'$	Peripheral	120	Decreasing
Africa Rocks[a]	$46^o 15'$ x $83^o 38'$	Peripheral	520	Stable
Tahquamenon Island, Lake Superior[b]	$46^o 35'$ x $84^o 58'$	Peripheral	~800	Stable

[a] Colony size was estimated from nest counts done in 1994 and 1995.
[b] Approximately 80% of the nests were destroyed in this colony sometime after May 13.

Table 3-5.–Source colonies for the 55 banded cormorants recovered in the study area.

Source colony	Number of recoveries
Local	
St. Martins Shoal	15
Goose Island	1
Lake Huron, Michigan	
Gull Island, Thunder Bay	1
Lake Superior	
Tahquamenon Island	4
Others in Ontario	2
Lake Huron, Ontario	
Africa Rocks	1
Herbert Island	4
West Island	4
Cousins Island	2
West Island, Georgian Bay	2
Gull Rock, French River	1
Lake Michigan	
Hat Island	6
Pismire/Grape, Beaver Islands	2
Big Gull Island, Beaver Islands	1
Little Gull/Gravelly, Green Bay	2
Gravel, Green Bay	1
Sister Island, Green Bay	6

Table 3-6.–Ages at recovery of banded cormorants in Les Cheneaux Islands area. Column 2 for all birds banded in the study area and recovered anywhere from 1983 to 1994; Column 3 for all banded birds recovered in the study area from 1932 to 1944; and Column 4 for all birds banded in the study area and recovered from 1979 to 1994.

Age (years)	Number recovered 1983 to 1994	Number recovered 1932 to 1944	Number recovered 1979 to 1994
0 to 6 Months	75	15	20
1	61	5	8
2	19	0	8
3	14	1	6
4	11	0	4
5	4	1	4
6	5		1
7	0		2
8	2		2
Total	202	22	55

Table 3-7.–Historic data on source of recovery for cormorants banded in the study area and recovered. Column 2 for birds recovered anywhere from 1932 to 1944; Column 3 for birds recovered in the study area in 1932 to 1944; Column 4 for birds recovered anywhere in 1979 to 1994; Column 5 for bird recovered in the study area in 1979 to 1994; and Column 6 and 7 for overall data.

Description	1932 to 1944		1979 to 1994		Overall data	
	Number	Number in Les Cheneaux only	Number	Number in Les Cheneaux only	Number	Number in Les Cheneaux only
Found dead	3	1	34	23	37	24
Found sick	2	0	1	1	3	1
Entangled in fishing gear	15	13	11	5	26	18
Drowned	1	1	0	1	1	1
Skeleton found	1	0	1	0	2	0
Caught by hand			1	0	1	1
Found injured on highway			1	1	1	1
Sight record by telescope			1	1	1	1
Only band number obtained			4	3	4	3
Total	22	15	55	35	77	50

Table 3-8.–Sources of banded cormorant fledglings from Les Cheneaux Islands area which have been recovered since 1983.

Colony	Number recovered	Year first banded
St. Martins Shoal	167	1984
Goose Island	13	1988
Crow Island	0	1992
West Saddlebag Reef	11	1988
Wheeler Reef, Ontario	11	1990
Total	202	

Table 3-9.–Localities of recoveries for 202 cormorants banded in Les Cheneaux Islands area.

Political jurisdiction	Number recovered	Flyway used
Michigan	43	Mississippi
Louisiana	29	Mississippi
Wisconsin	26	Mississippi
Mississippi	23	Mississippi
Florida	22	Mississippi
Arkansas	17	Mississippi
Ontario	13	Atlantic
Tennessee	4	Mississippi
Texas	3	Mississippi
Illinois	3	Mississippi
Georgia	3	Atlantic
Alabama	4	Mississippi
Quebec	3	Atlantic
New York	2	Atlantic
Cuba	2	Mississippi
Ohio	1	Atlantic
Missouri	1	Mississippi
North Carolina	1	Atlantic
Delaware	1	Atlantic
Connecticut	1	Atlantic
Oklahoma	1	Mississippi

Table 3-10.–Method of recovery for cormorants banded in Les Cheneaux Islands area.

BBL Code	Description	Number reported	Alive
00	Found dead	103	
26	Entangled in fishing gear	34	2
01	Found sick	16	
44	Killed in control operations	17	
17	Drowned (at power plant)	7	
16	Collected scientific specimen	10	
45	Killed on highway	4	
03	Found injured	3	1
52	Sight record with telescope	2	2
58	Caught by hand	2	2
28	Skeleton only found	1	
50	Trapped and released	1	1
89	Band number only recovered	1	
98	Caught due to poisoning	1	
28	Caught due to starvation	1	
	Total	202	8

Table 3-11.–Percent composition (by number and weight) of prey in the diet of nestling cormorants by region of lakes Huron and Michigan, 1995.

Fish species	Northern Lake Michigan (N = 1,006)		Northern Lake Huron (N = 843)		North Channel, Georgian Bay (N = 4,444)	
	Number	Weight	Number	Weight	Number	Weight
Alewife	85	93	60	72	26	52
Rainbow smelt	<1	<1	6	6	3	5
Sticklebacks	4	<1	16	1	61	6
Suckers	<1	2	1	10	<1	8
Yellow perch	0	0	0	0	2	7
Sculpins	0	0	15	2	2	<1
Rock bass	0	0	<1	<1	2	9
Smallmouth bass	0	0	<1	1	<1	3
Shiners	<1	<1	0	0	1	<1
Salmon/trout	0	0	0	0	<1	<1
All others	4	4	2	6	3	6

Table 3-12.–Percent composition by weight of fish species in nestling cormorant diets for data collected from 1986 to 1995. Number collected in parentheses.

Fish Species	Northern Lake Michigan			Northern Lake Huron			Canadian Lake Huron		
	1986-89 (280)	1990 (288)	1995 (1,006)	1986-89 (1,974)	1990 (680)	1995 (843)	1986-89 (2,867)	1990 (2,372)	1995 (4,444)
Alewife	72	71	93	64	78	72	97	48	52
Stickleback	<1	<1	<1	6	3	1	5	5	5
Rainbow smelt	3	3	<1	3	<1	6	9	11	6
Yellow perch	1	1	0	3	2	0	26	16	11
Sculpins	<1	<1	0	5	1	2	<1	1	1
Suckers	14	14	2	12	5	13	4	5	8
Rock bass	0	<1	0	<1	<1	<1	8	7	9
All other species	5	3	1	2	3	6	5	3	5

Table 3-13.–Average percent by weight of fish species in cormorant diets (all locations and dates combined) for different time periods from 1986 to 1995.

Fish species	1986 to 89	1990	1995
Alewife	58	66	72
Sticklebacks	4	3	2
Rainbow smelt	5	5	4
Yellow perch	10	6	4
Sculpins	2	1	1
Suckers	10	10	7
Rock bass	3	3	3
Smallmouth bass	3	2	1
Carp	3	4	1
Whitefish	<1	0	0
All other prey species	2	1	5

Table 3-14.–Ten-year projection of cormorant population numbers for the upper Great Lakes.

Year	Growth rate (%)	Breeding population	Possible limiting factors
1995	25	41,000	Nesting habitat
1996	20	49,200	Food in local areas
1997	17	57,564	Disease increasing
1998	14	65,623	NDV, parasites increasing
1999	12	73,498	Adult age-structure changing
2000	9	80,113	Nesting space and food critical
2001	5	84,118	All control factors increased
2002	3	86,642	Birth and death rate equilibrium
2003	1	87,508	Population reaching maximum size
2004	0	87,508	

Table 3-15.–Hypothesized changes in population parameters at different phases of growth for cormorants in the upper Great Lakes during different growth phases.

Characteristic	Value
Unlimited growth phase 1978 to 1985 (24 to 1,000 pairs)	
Age at first breeding	1 to 2 years
Clutch size	3.8 to 4.0 eggs/nest
Age of adults	Virtually all young adults
% of pairs successful	85 to 95%
Chick death rates in:	
colonies	<20% of hatchlings
first six months	15 to 20% of fledglings
pre-breeding	25%
Annual adult death rate	6 to 8%
Rapid growth phase 1986 to 1995 (1,000 to 41,000 pairs)	
Age at first breeding	2 years
Clutch Size	3.2 to 3.6 eggs/nest
Age of adults:	Dominated by young adults
% of pairs successful	70 to 90%
Chick death rates in:	
colonies	< 30% of hatchlings
first six months	25 to 35% of fledglings
pre-breeding	35 to 40% of fledglings
Annual adult death rates	8 to 12%
Growth slowing phase 1996 to 2003 (88,000 pairs)	
Age at first breeding	3 to 4 years
Clutch Size	2.6 to 2.9 eggs/nest
Age of Adults	Well distributed, all ages
% of pairs successful	55 to 70%
Chick death rates in:	
colonies	40 to 50% of hatchlings
first six months	40 to 50% of fledglings
prebreeding	55 to 70% of fledglings
Annual adult death rates	12 to 15%

CHAPTER 4

POPULATION DYNAMICS AND FISHERY STATISTICS FOR YELLOW PERCH IN LES CHENEAUX ISLANDS AREA

Philip J. Schneeberger and Steven J. Scott

Introduction

In order to fully understand the impact of cormorant predation on yellow perch in Les Cheneaux Islands area, it was necessary to collect current population and fishery statistics for the yellow perch population. These fishery statistics were put into context through comparison with data from other years and from other perch populations throughout the Great Lakes. This chapter is subdivided into four sections whose goals were to: 1) estimate the size of the yellow perch population; 2) estimate total mortality for the population; 3) evaluate the sport harvest; and 4) evaluate the size and age structure of the perch population.

Yellow Perch Population Estimate

Methods

During mid-April 1995, monel jaw tags were attached to 8,463 yellow perch in Les Cheneaux study area. Fish were collected using 12 fyke nets measuring 2 x 1.3 m with 19-mm bar mesh. Nets were set in about 1 m of water. Most fish (81%) were tagged in Cedarville Bay, and the rest were tagged in Mackinac Bay (13%), Flower Bay (3%), and Sheppard Bay (3%). Tags were stamped with unique numbers and "MICH DNR, NEWBERRY." Total length and sex were determined and recorded for each tagged fish.

Tag return information was solicited from anglers by posting notices at launch sites and resorts. MDNR representatives met with local angling groups to encourage their cooperation with the tagging program.

An estimate of the yellow perch population in Les Cheneaux area was made using tag-return information and applying the Petersen formulae modified by Chapman (Ricker 1975) using number tagged (M), number of recaptured tags (R), and number in sample (C). The Petersen population estimate was made using recapture data collected from July through October 1995. May and June data were excluded from consideration because: a) catch and effort were relatively low in May and June; and b) conditions justifying the validity of the Petersen application were better met using July to October data. The number of tag returns was multiplied by a correction factor of 1.7 to account for non-reporting. Petersen's modified formula for population size (N), variance of the estimate (V), and 95% confidence intervals for the estimate are:

$$N=(M+1)\cdot(C+1)/(R+1)$$

$$V(N)=((M+1)^2\cdot(C+1)\cdot(C-R))/((R+1)^2\cdot(R+2))$$

$$95\%CI=V^{\frac{1}{2}}\cdot1.96$$

However, there was variance already associated with sample number (C), derived from the July-October catch estimated in the creel survey. Following Freese (1962) and Cochran (1977), the calculation of variance for the population estimate thus became:

$$V(N)=B^2\cdot V(C),$$

where B was a constant $[(M + 1)/(R + 1)]$.

Parameter values used for calculations were:

M= 8,402	Total number tagged minus number of tags returned Apr-Jun, corrected for non-reporting: 8,463 - (36·1.7) = 8,402.
R = 199	Returns from July through October multiplied by the non-reporting correction factor: 117 · 1.7 = 199.
C= 65,746	Monthly creel estimates for July through October: 30,219 + 19,905 + 7,655 + 7,967 = 65,746
V(C) = 82,416,638	Variance for monthly creel estimates for July through October: 41,441,407 + 16,699,482 + 5,292,300 + 18,983,449 = 82,416,638

Results and Discussion

Length range of tagged fish was 152 to 384 mm. The population estimate for yellow perch 150 mm and greater within Les Cheneaux study area was 2,762,360, with a variance of 145,486,812,500, and a 95% confidence interval of 747,597.

Lucchesi (1988) used several different methods to estimate numbers of yellow perch in Les Cheneaux Islands area in 1986. Estimates for perch 175 mm and larger ranged from 80,000 to 1,800,000, but Lucchesi considered his best estimate to be between 400,000 and 900,000. This best estimate was based on the ratio of tagged to untagged perch observed by creel clerks during June 1986. Use of this approach was rejected for estimating the 1995 population because of evidence that the number of tagged fish seen by clerks was biased upward. Clerks observed and recorded 28% of reported tag returns, but saw only 2% of the estimated 1995 sport catch of yellow perch.

Six assumptions implicit for the Petersen population estimate were given by Ricker (1975). All assumptions were reasonably met in Les Cheneaux study as described below.

1) *Marked and unmarked fish suffer the same natural mortality*: Violation of this assumption would occur if tagged fish experienced significantly greater mortality due to handling and tagging, or if the tag itself affected swimming or made tagged fish more noticeable to predators. Tagging for the population study occurred in April 1995, when weather conditions were harsh (cold, wind, and waves), and it was noted that some tagged fish showed pronounced signs of stress upon release. However, no quantified evaluation of handling mortality was made at the time. In April 1996, 400 yellow perch were trapped, tagged, and held in live cages. An additional 400 untagged perch were held in separate live cages. All fish in both groups were still alive after 48 h. Although weather conditions were not as severe in 1996 as in 1995, it seems reasonable to assume that mortality in 1995 directly attributable to handling was negligible. This still does not address the increased mortality that could have befallen tagged fish in 1995 during the time it took them to recover fully. Fish in live cages were protected, but recovering fish in open waters could have been subjected to increased predation if their swimming ability was temporarily inhibited or if they were highly visible to avian predators while struggling near the surface in an effort to regain equilibrium. After recovery, we do not expect that fish would have experienced greater predation mortality due to their being tagged.

2) *Marked fish are as vulnerable to angling as unmarked ones*: Although it is conceivable that tagging affected vulnerability of fish to angling by inhibiting hook penetration at the location of the metal band, it is unlikely that the effect would be measurable, and there is no precedent for giving this proposition much consideration. Therefore, we believe that this assumption was not violated.

3) *Marked fish do not lose their mark*: An evaluation of this assumption was carried out by tagging yellow perch, releasing them into experimental ponds, then draining individual ponds after 1-, 6-, and 12-month intervals, and examining all perch for tag retention (Appendix 4). In every case, tag retention was 100%. Other authors have also found excellent retention of ring jaw tags and monel butt end tags similar to

those used on Les Cheneaux perch (Stauffer and Hansen 1969, McAllister et al. 1992).

4) *Marked and unmarked fish become randomly mixed; or the distribution of fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water*: Lucchesi (1988) tagged and released perch in Mackinac, Sheppard, and Flower bays, and found that most tagged perch were caught within a limited distance from where they were tagged. In 1995, yellow perch were mostly caught and released in Cedarville Bay. Perch were tagged in mid-April, but tag-return data from April, May, and June were ignored when estimating population size, in part to allow post-spawning fish time to disperse and mix throughout the study area. Tag-return data compiled from July through October showed that tagged fish had a fairly wide distribution (Table 4-1). Sport-fishing catch and effort were not estimated for separate locations within the study area, but the distribution of tag-return locations probably also reflected relative distribution of fishing effort.

5) *All marks are recognized and reported on recovery*: Anglers catching tagged fish should have been aware of the tagging program through posters and by word of mouth. Resort owners and most sport anglers (resident and visiting) have an intense interest in Les Cheneaux perch fishery, and it is reasonable to expect that most people were inclined to cooperate with the program. Jaw tags are inherently noticeable, because anglers, of necessity, focus their attention on the fish's mouth area when removing hooks. Some non-reporting must be assumed, however. Based on differential return rates for reward and non-reward tags, Haas et al. (1988) calculated a correction factor of 1.6 for Lake St. Clair walleye. Subsequently, Thomas and Haas (1994) reported a reward/non-reward tag-recovery ratio of 2.84 for walleye in western Lake Erie. The Lake St. Clair and Lake Erie tagging studies were carried out over several years, whereas Les Cheneaux tagging and recovery were limited to a single open-water season. Also, creel clerks helped collect tags in Les Cheneaux, and the tagged species was

yellow perch rather than walleye. Stroud and Bitzer (1955) found a non-reporting rate of 25% for yellow perch in Massachusetts lakes. Lucchesi (1988) got very high but differing tag return rates using two different reward systems for yellow perch in Les Cheneaux. Taking all of the above into account, the value of 1.7, used as a 1995 correction factor for non-reporting in Les Cheneaux, was an informed guess.

6) *There is only a negligible amount of recruitment to the catchable population during the time the recoveries are being made*: Yellow perch were tagged prior to their season of growth. Les Cheneaux perch grow approximately 12 to 25 mm per year (Diana et al. 1987, Lucchesi 1988), and most growth occurs during the period of water warming when food is abundant. Most tagged perch between 165 and 175 mm, and some between 150 and 165 mm would have grown to catchable size (175-mm minimum size limit) between April and July. Growth continues through September, but slows after July as more energy is used for gonad development. The bulk of the 1995 sport fishing catch and effort, as measured by the creel survey, took place after June. Basing the population estimate on tag-return and creel-survey data collected during and after July, the problem of undersized fish growing to recruit into the fishery was accounted for to the extent to which fish tagged in the 150- to 174-mm length interval recruited to the late-summer fishery, and were representative of untagged fish of similar sizes. Exploitation rates (R/M) from July to October were 2.3% for perch that were 150- to 175-mm when tagged, 2.4% for perch 175 mm and larger, and 2.4% for all tagged perch. Agreement among these rates showed that undersized perch probably did recruit to the July to October fishery as expected. A comparable exploitation rate of 3.6% was estimated for yellow perch based on tag returns in bays de Noc, Lake Michigan (Marquette Fisheries Station, unpublished data). Lucchesi (1988) found much higher exploitation rates (25 to 42%) for yellow perch in Les Cheneaux during the mid 1980s, in part because fishing effort was more than four times greater in 1986 than in 1995 (see Sport Harvest Estimate

section). In any case, accounting for recruitment to the catchable population seemed adequate.

Yellow Perch Mortality

Methods

Total annual mortality was calculated for yellow perch caught in gill nets during fall 1995 and aged from scale samples. Mortality was derived from coded age frequencies and formulae described by Robson and Chapman (1961). For comparison, and to determine if a discernible trend in mortality was occurring during the 1990s, like methodology was applied to gill net catches from other years for which suitable data were available. In addition, a mortality rate was calculated from a pooled data set (1993 to 1995) to obtain an estimate having reduced potential bias associated with year-to-year recruitment variations. Survival was calculated from tag-return data using Model 1 of the computer program ESTIMATE (Brownie et al. 1985), resulting in an independent derivation of total annual mortality.

Results and Discussion

Estimates of total annual mortality for individual years ranged from 0.35 in 1991 to 0.70 in 1994 (Table 4-2). Estimates from 1995 data (0.45) and pooled 1993 to 1995 data (0.49) were intermediate between the extremes. The mortality derived from tag-returns (0.47) was within 2 SE of the estimate from 1995 gill net data.

A comparison of estimates among years indicates that total annual mortality rate increased from 1991 to 1994, then decreased for 1995. However, the two years for which mortality estimates were highest had the most truncated age structures in gill net catches, probably due to variable year-class strength. The Brownie estimate of mortality was based on only one year of tag returns, but its close agreement with the 1995 Robson-Chapman estimate lends credibility to both estimates. Lucchesi (1988) estimated total annual mortality

at 0.55 ± 0.09 for Les Cheneaux yellow perch populations in 1986. The 1986 and 1995 estimates were not statistically different, even though higher mortality would have been expected in the mid 1980s when the exploitation rate and fishing effort were so much greater. Lucchesi (1988) estimated that hooking mortality of yellow perch was around 25%, and this source of mortality could weigh more heavily on populations subjected to high fishing pressure.

Total annual mortality rates for yellow perch in other areas of the Great Lakes ranged from 0.38 to 0.64 (Table 4-3). McComish and Shroyer (1996) considered the 0.62 total annual mortality rate in Indiana waters of Lake Michigan high, and stated that it would lead to rapid population decline if recruitment was consistently low. These same authors calculated mortality rates of 0.57 to 0.97 for yellow perch 190 mm and larger. In southern Green Bay, commercial and sport fisheries for yellow perch were sustained under a total annual mortality rate of 0.85 for fish 190 mm and larger (Johnson et al. 1992). Total annual mortality ranged from 0.50 to 0.91 for yellow perch populations in some of Michigan's inland lakes (Schneider 1971, Schneeberger 1988, Schneider 1993).

Sport Harvest Estimate

Methods

An estimate of sport harvest was made through a contact creel survey conducted in Les Cheneaux Islands area. The survey was conducted from 1 May through 31 October 1995. The creel survey was based on a stratified design using simple random sampling within strata (see Rakoczy and Svoboda 1995 for details on creel survey methods). Survey clerks also collected tag-return information.

Concurrent with the creel survey, flights over the study area were made on a random schedule (random take off times during day light hours). Flights were made five days each week (three randomly picked weekdays plus both weekend days), although some flights were canceled due to weather conditions. During each

of 245 total flights, all boats were counted within the study area, except sailboats and commercial vessels. The ratio of non-fishing boats (pleasure boats) to fishing boats was calculated using angler party interview sheets. Count data were used to calculate fishing effort using mean number of boats by weekday, by weekend day, and by month. Catch rates, determined from weekend and weekday interviews, were used to estimate total catch. Details concerning use of aerial boat counts for calculating fishing effort were described by Ryckman (1981).

Results and Discussion

Total catch of yellow perch from May through October 1995 was 66,469. July was the month of greatest catch and effort, and the fishery from July through October accounted for 99% of the yellow perch catch and 77% of total effort. Numerically, yellow perch was by far the most important species in the fishery.

Between 1979 and 1995, five creel surveys were conducted in Les Cheneaux (Table 4-4). Except for an extremely high value in 1986, yellow perch catch estimates for all years were within 2 SE of each other. Fishing effort was much more variable than catch among years, and only 1979 and 1995 effort values were not significantly different from each other. Catch-per-hour was significantly higher in 1980 compared to other years, and the lowest catch-per-hour was estimated for 1991.

Boat counts from aerial surveys were used to estimate effort in 1986, 1991, and 1995 surveys, but not in 1979 and 1980. Lucchesi (1988) found that effort estimated from aerial counts was about 2.5 times higher than the estimate from ground counts, and catch was approximately proportionate. Applying this factor to 1979 and 1980 estimates would affect comparisons among years, though the 1986 estimates would still be significantly higher than any other year. Both adjusted catch and effort for 1979 would be significantly higher than in 1995. Adjusted catch in 1980 would be significantly higher than in 1995, but effort

would not be statistically different. Catch per hour figures would stay about the same.

The waters of Les Cheneaux comprise a dynamic area of physical and biological complexity. Part of the biological complexity results from proximity to open waters of Lake Huron and the St. Mary's River, and is reflected by species composition and numbers in creel surveys (Table 4-5). Les Cheneaux sport fisheries were consistently dominated by yellow perch, but catches of perch varied nearly six fold in the period between 1979 and 1995. Yellow perch populations vary throughout their range due in part to differences in year class strength, but it is worth considering that sport catches of other species in Les Cheneaux varied even more dramatically than perch, and fluctuations of some could have contributed to the fluctuations of yellow perch. For example, with some lag as would be expected from a predator, the trend for numbers of northern pike was roughly parallel with that for perch. Dramatic periodic influxes of relatively large numbers of smallmouth bass, chinook salmon, pink salmon, and lake trout also could have had considerable influence on the fish community of Les Cheneaux, even if they didn't affect yellow perch directly. Also, white perch were documented for the first time in the 1995 creel survey, and if future numbers increase, white perch may affect yellow perch populations through competition as they have in other waters (Parish and Margraf 1990, Prout et al. 1990).

Year-to-year variation in fish numbers was also seen in fall gill net samples, though trends were not comparable to sport-fishery estimates (Newberry District Office, unpublished data). Gill net catch-per-unit effort (CPE) for yellow perch ranged from 14.0 to 41.8 between 1985 and 1995, while northern pike CPE ranged from 10.7 to 23.8, and white sucker CPE ranged from 0 to 29.0. Yellow perch CPEs for 1994 and 1995 were fairly high relative to the previous years, perhaps indicating that the population is increasing (Figure 4-1).

Size and age structure

Methods

To obtain information about population size structure of yellow perch, lengths were measured and recorded from five sources: a) a net-run sample of 325 yellow perch caught in 13-mm mesh fyke nets in April 1995; b) tagged perch; c) sport-caught perch measured by creel clerks; d) perch caught in graded mesh gill nets; and e) perch caught in assessment trawls. The fyke net sample was biased toward mature fish because sampling was performed during spring when spawning aggregations of perch concentrated in shallow water. Likewise, length-frequencies of tagged fish represented spawning-run fish that also were graded by handlers (no fish < 150 mm was tagged). Lengths measured by creel clerks were, of course, influenced by the 175 mm minimum size limit for yellow perch. Gill-net catches were biased because yellow perch smaller than 125 mm were not fully recruited to the gear. Trawling produced few fish of any size. All sampling methods collected few small fish.

As a consequence of the scarcity of small yellow perch in samples described above, there was a corresponding lack of size-at-age and age-structure data for younger fish. It was necessary to gain some idea about the magnitude of these under-sampled perch to put cormorant predation into a proper perspective. Therefore, numbers of perch at small sizes and young ages were constructed by combining information from the estimated yellow perch mortality rate, population size, and the age structure of perch caught in gill nets. A tool needed for this exercise was a length-at-age key created from yellow perch data collected from bays de Noc, Lake Michigan, 1988 to 1995 (Table 4-6). Growth of yellow perch in Les Cheneaux Islands area and bays de Noc appeared to be similar based on a comparison of size-at-age of larger fish, while small, young perch were well represented in trawl samples in bays de Noc.

Results and Discussion

Given that the total annual mortality rate for yellow perch in 1995 was 0.45 (see Mortality section), the complementary survival rate was 55%. Starting with 1,000 2-yr-old perch and applying this survival rate through age 11 yielded a smoothed, idealized age structure for a population that had no variation in year-class strength (Table 4-7, column B). The population estimate from tag returns was made for yellow perch 150 mm and greater, and according to the length-at-age key, only a portion of the 2-, 3-, 4-, and 5-year old perch were 150 mm or greater (Table 4-7, column C). Multiplying values in columns B and C produced numbers of perch 150 mm and longer in the hypothetical population (Table 4-7, column D). The relative contribution of different age groups to the sub-population (≥150 mm) was derived by dividing the number at each age by the total (Table 4-7, column E). Partitioning the population estimate (2,762,360 - see Population Estimate section) according to these percentages gave the theoretical age distribution of the estimated population (Table 4-7, column F). These numbers were then expanded to include fish smaller than 150 mm by dividing the numbers in column F by the percentages in column C, and dividing the resultant number of 2-yr olds by the survival rate to get the number of yearling perch (Table 4-8, column B). Finally, the length-at-age key was applied to numbers at age (Table 4-8, column B) to approximate numbers per 25 mm group (Table 4-8, column D).

To put the population size in perspective, size of the study area was estimated, using Michigan Resources Information System (MIRIS), and both numbers and kg of perch per hectare were calculated. Les Cheneaux study area was calculated to contain 11,860 ha (29,317 surface acres) of water (Frank Chenier, Geological Survey, Escanaba, Michigan, personal communication). Virtually all the water within the study area was of suitable depth for yellow perch. Using the area estimate, the estimated total number of yellow perch in each 25-mm size class and mean weight at size data (Table 4-8), we calculated the number of perch per ha at 826, and the biomass at 35 kg per ha.

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The number of yellow perch 175 mm and greater was 137 per ha. Haas and Schaeffer (1992) reported up to 6,506 yellow perch per ha in Saginaw Bay, Lake Huron. Schneider (1973) measured or estimated yellow perch standing crops in 19 inland Michigan lakes at 1 to 70 kg per ha.
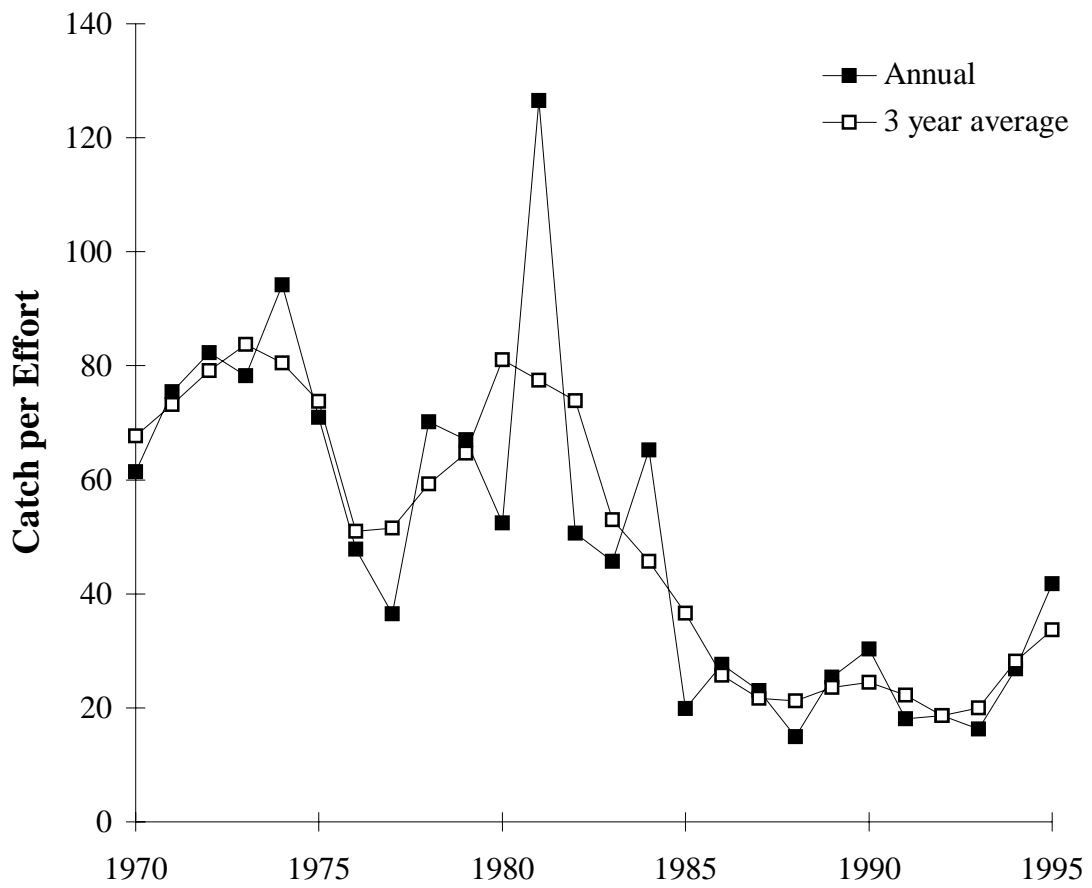
Figure 4-1.–Catch per effort for gillnet collections of yellow perch from Les Cheneaux Islands area, by annual and three year running averages.

Table 4-1.–Location of yellow perch tag returns in Les Cheneaux study area from July through October 1995.

Location	Tag returns	
	Number	Percent
Cedarville Bay	62	53.0
Cheneaux Channel	4	3.4
Government Bay	5	4.3
Hessel Bay	11	9.4
Moscoe Channel	2	1.7
Muscallonge Bay	17	14.5
Urie Bay	2	1.7
Unknown	14	12.0
Total	117	100.0

Table 4-2–Total annual mortality rates (A) and instantaneous mortality rates (Z), estimated from fall gill net catches in Les Cheneaux Islands area for selected time periods from 1991 to 1995.

Parameter	1991	1993	1994	1995	1993 to 1995
Ages[a]	3 to 12	4 to 7	3 to 6	2 to 8	3 to 14
RCS[b]	0.65	0.41	0.30	0.55	0.51
HS[c]	0.66	0.45	0.34	0.53	0.54
χ^2 [d]	0.16	0.47	2.34	0.77	1.19
2 SE[e]	0.06	0.12	0.07	0.04	0.04
A	0.35	0.59	0.70	0.45	0.49
Z	0.43	0.88	1.19	0.60	0.67

[a] Ages included in estimates
[b] Robson-Chapman's "best" estimate of survival
[c] Heincke's estimate of survival
[d] Chi-square statistic comparing the two survival estimates (not significantly different for $\chi^2 < 3.84$)
[e] 2 SE of RCS = 2 SE of A

Table 4-3.–Total annual mortality rates (A) for Great Lakes yellow perch populations.

Location	Time period	A	Source
Michigan waters of Lake Erie	1989 to 1993	0.38	Thomas and Haas (1994)
Les Cheneaux, Lake Huron	1995	0.45	This study
Western Basin of Lake Erie	1989 to 1993	0.46	Thomas and Haas (1994)
Southern Lake Michigan	1976 to 1979	0.48 (Females) 0.52 (Males)	Wells and Jorgenson (1983)
Les Cheneaux, Lake Huron	1969 to 1986	0.55	Lucchesi (1988)
Saugatuck, Lake Michigan	1978	0.56	Rybicki (1985)
Bays de Noc, Lake Michigan	1989 to 1995	0.57	Marquette Fisheries Station (unpublished data)
Chequamegon Bay, Lake Superior	1973 to 1988	0.58	Bronte et al. (1993)
Benton Harbor, Lake Michigan	1979	0.60	Rybicki (1985)
Indiana waters of Lake Michigan	1980 to 1993	0.62	McComish and Shroyer (1996)
Saginaw Bay, Lake Huron	1983 to 1984	0.64	Keller et al. (1987)

Table 4-4.–Yellow perch catch, effort (hours), and CPE (catch-per-hour) for May to October creel survey estimates in Les Cheneaux Islands area, 1979, 1980, 1986, 1991, and 1995. (Two standard errors in parentheses.)

Year	Catch	Effort	CPE
1979[a]	78,916 (35,300)	79,928 (14,400)	0.99 (0.60)
1980[a]	74,278 (9,955)	34,470 (3,135)	2.15 (0.48)
1986[b]	389,444 (68,401)	372,781 (46,128)	1.04 (0.22)
1991[c]	103,409 (22,345)	174,252 (22,199)	0.59 (0.15)
1995	66,469 (18,168)	72,439 (11,071)	0.92 (0.29)

[a] Derived from Ryckman and Lockwood (1985).

[b] From Lucchesi (1988).

[c] From Rakoczy (1992).

Table 4-5.–Angler harvest by species for fish taken in Les Cheneaux Islands area, estimated from creel surveys, May to October 1979, 1980, 1986, 1991, and 1995.

Species	1979	1980	1986	1991	1995	Total
Yellow perch	78,916	74,278	389,444	103,409	66,469	712,516
Lake herring	15,945	11,666	13,745	–	5,004	46,360
Rock bass	3,236	5,266	18,327	12,461	3,541	42,831
Northern pike	415	4,031	9,163	10,391	1,404	25,404
Pumpkinseed	–	–	9,163	1,596	310	11,069
Bullhead (sp.)	–	–	–	9,763	634	10,397
Smallmouth bass	–	73	4,582	1,920	485	7,060
Round whitefish	–	–	4,582	1,174	–	5,756
Pink salmon	–	–	–	5,699	11	5,710
Chinook salmon	–	–	4,582	963	–	5,545
Lake trout	5,133	–	–	–	–	5,133
Brown trout	461	14	–	175	7	657
White perch	–	–	–	–	421	421
Splake	–	–	–	–	340	340
Channel catfish	–	–	–	301	–	301
Walleye	–	–	–	115	–	115
White crappie	–	–	–	77	–	77
Black crappie	–	–	–	71	–	71
Brook trout	64	–	–	–	–	64
Rainbow trout	–	–	–	41	–	41
Muskellunge	–	–	–	38	–	38
Other	–	–	4,582	8,027	16	12,625
Total	104,170	95,328	458,170	156,221	78,642	892,531

Table 4-6.—Length-at-age key for yellow perch during the month of April, derived from bays de Noc samples (Les Cheneaux samples for ages 10-11).

Age	N	Percent in length interval (mm)												
		25-50	51-75	76-100	101-125	126-150	151-175	176-200	201-225	226-250	251-275	276-300	301-325	326-350
1	116	0.18	50.36	47.67	1.34	0.45								
2	311		0.32	5.14	29.26	48.55	13.83	2.89						
3	313			0.32	5.43	34.19	38.98	18.53	2.56					
4	174				0.57	5.75	31.61	29.31	22.99	9.20	0.57			
5	130					4.62	5.38	22.31	38.46	16.92	7.69	3.08		1.54
6	56						8.93	3.57	30.36	21.43	17.86	10.71	3.57	3.57
7	30						3.33	3.33	23.33	10.00	10.00	23.33	20.00	6.67
8	14							7.14	7.14	7.14	28.57	28.57	21.43	
9	7									28.57	14.29	42.86	14.29	
10	2											50.00	50.00	
11	5											20.00	60.00	20.00

Table 4-7.–Values used and derived to estimate age distribution for yellow perch in Les Cheneaux Islands area.

A Age group	B Hypothetical number at age[a]	C Proportion at age $\geq$ 150 mm[b]	D Number at age $\geq$ 150 mm	E Proportion at age of fish $\geq$ 150 mm	F Expected age distribution of fish $\geq$ 150 mm (E · 2,762,360)
1					
2	1,000	0.1672	167	0.1470	406,082
3	550	0.6007	330	0.2905	802,411
4	302	0.9368	283	0.2492	688,255
5	166	0.9538	159	0.1395	385,409
6	92	1.000	92	0.0804	222,243
7	50	1.000	50	0.0442	122,234
8	28	1.000	28	0.0243	67,228
9	15	1.000	15	0.0134	36,976
10	8	1.000	8	0.0074	20,337
11	5	1.000	5	0.0040	11,185
Total	2,216		1,137	1.0000	2,762,360

[a] using annual survival of 0.55
[b] based on length-at-age key

Table 4-8.–Values used and derived to estimate numbers-at-age and numbers-per-size group for yellow perch in Les Cheneaux Islands area.

A Age group	B Estimated age structure of all fish[a]	C Size group(mm)	D Mean weight per size group (mm)	D Estimated number of all fish per size group[b]
1	4,415,850	25 to 49	0.5	7,949
2	2,428,718	50 to 74	2.5	2,231,594
3	1,335,795	75 to 99	6.9	2,234,146
4	734,687	100 to 124	15.0	846,537
5	404,078	125 to 149	30.6	1,716,635
6	222,243	150 to 174	51.4	1,134,475
7	122,234	175 to 199	80.2	640,004
8	67,228	200 to 224	118.4	459,300
9	36,976	225 to 249	167.3	211,175
10	20,337	250 to 274	228.5	111,668
11	11,185	275 to 299	303.4	112,225
12		300 to 324	393.4	68,951
13		325 to 349	500.1	24,547
Total	9,799,331			9,799,206

[a] corrected estimates including fish $150 \leq$ mm (Column F/Column C in Table 4-7)
[b] based on Column B and length-at-age key

CHAPTER 5

CORMORANTS COUNTS

Glenn Y. Belyea

Introduction

Two methods were employed in 1995 for counting cormorants in Les Cheneaux Islands area. The main method was through island-wide aerial surveys, but during early spring, ground counts were also made for cormorants on Cedarville Bay.

Methods

The aerial surveys were conducted three times per week between 17 April and 1 October 1995. The approximately 163 km survey route covered all nesting colonies, bays, channels and open lake areas within the study area. The surveys were flown by the same pilot in a Cessna 172 Superhawk at an average ground speed of 152 km/h and an average altitude of 61 m (range 30 to 91 m). All flights began at 0700 and took approximately 1.2 hours. A total of 72 surveys was conducted. The sampling scheme was developed using data previously collected by Soulliere and Maples (1994). The flight frequency was chosen based on variability of previous flights and the need to stratify by weekend/weekday. This stratification allowed us to test the hypothesis that weekend counts would be lower because of increased human disturbance. Flights were randomly allocated to 2 weekdays and 1 weekend day per week, and were spaced to allow for one make-up day for bad weather per survey. Few of these make-up days were needed and all were conducted on that alternate day. The pilot was experienced at making aerial cormorant counts, having flown numerous cormorant surveys in 1993 and 1994 (Soulliere and Maples 1994).

From 1993 through 1996, Carl TerHaar (the local conservation officer) made daily counts of cormorant numbers in early spring on Cedarville Bay, which is the main yellow perch spawning area in Les Cheneaux Islands, and attracts many cormorants from mid April to mid May. Most counts were made between 0600 and 0700 when daily cormorant numbers seemed to peak in that area.

Results and Discussion

Cormorant numbers from flight records rapidly increased through April and May, then generally stabilized during June and July. Numbers climbed rapidly again in late July as the young birds fledged from the nesting colonies. Numbers then declined rather sharply until nearly all birds had migrated from the area by early October (Figure 5-1, Table 5-1).

While cormorant numbers in Cedarville Bay generally increased each year, the pattern of their occurrence based on ground counts is more interesting than the actual numbers (Figure 5-2). Cormorants arrived in the bay about 11 or 12 April and increased until about mid May when they suddenly decreased to near absence. This mid May departure date coincided almost exactly with the switch from yellow perch composing 47% of their diet (by weight) to only 1% (Chapter 6). Perch at this time probably dispersed out of the bay and cormorants turned to other food sources that were more readily available, such as alewife and stickleback. The pattern of the 1995 and 1996 observations (Figure 5-3) is even more interesting. The winter of 1994-1995 was very mild, resulting in a very early ice out on Cedarville Bay and early perch spawning. It was just the opposite in 1995-1996 with a very delayed ice out and perch spawning. Despite these very different springs, the pattern of cormorant activity was somewhat similar. Birds did arrive about 8 days later in 1996 and left about 6 days later than in 1995. This seems to indicate that weather conditions may have some impact on cormorant arrival and perch dispersal.
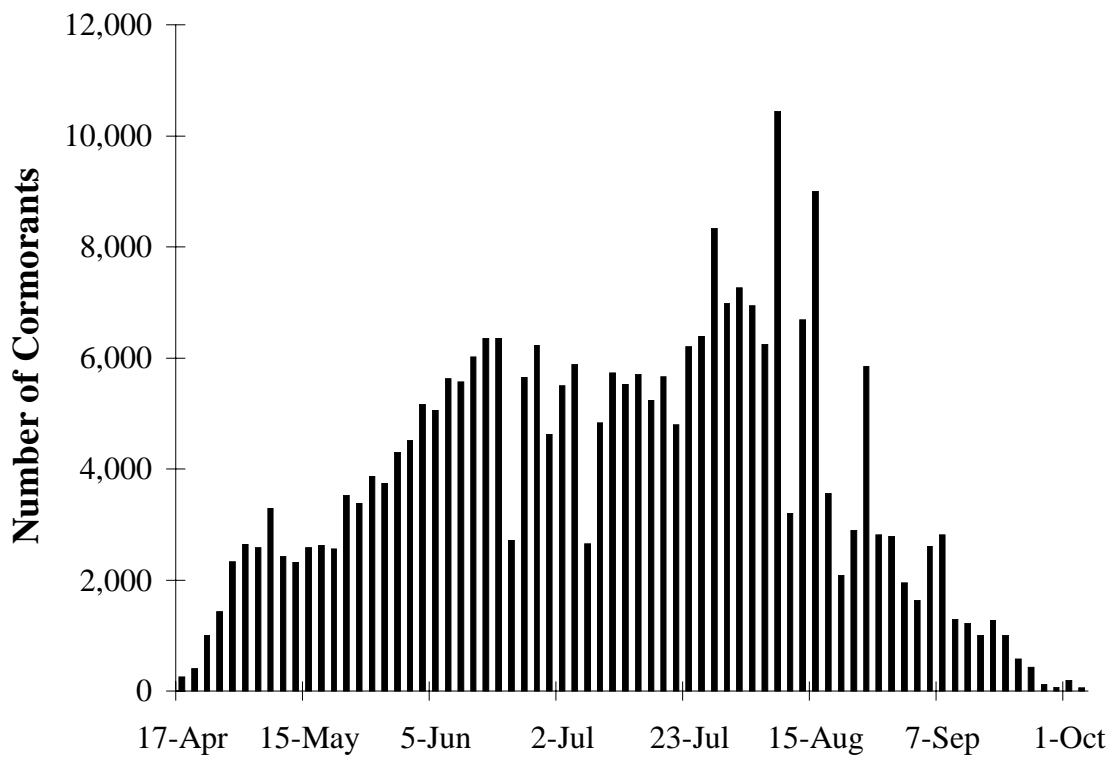
Figure 5-1.–Aerial survey counts of cormorants in Les Cheneaux Islands area during 1995.
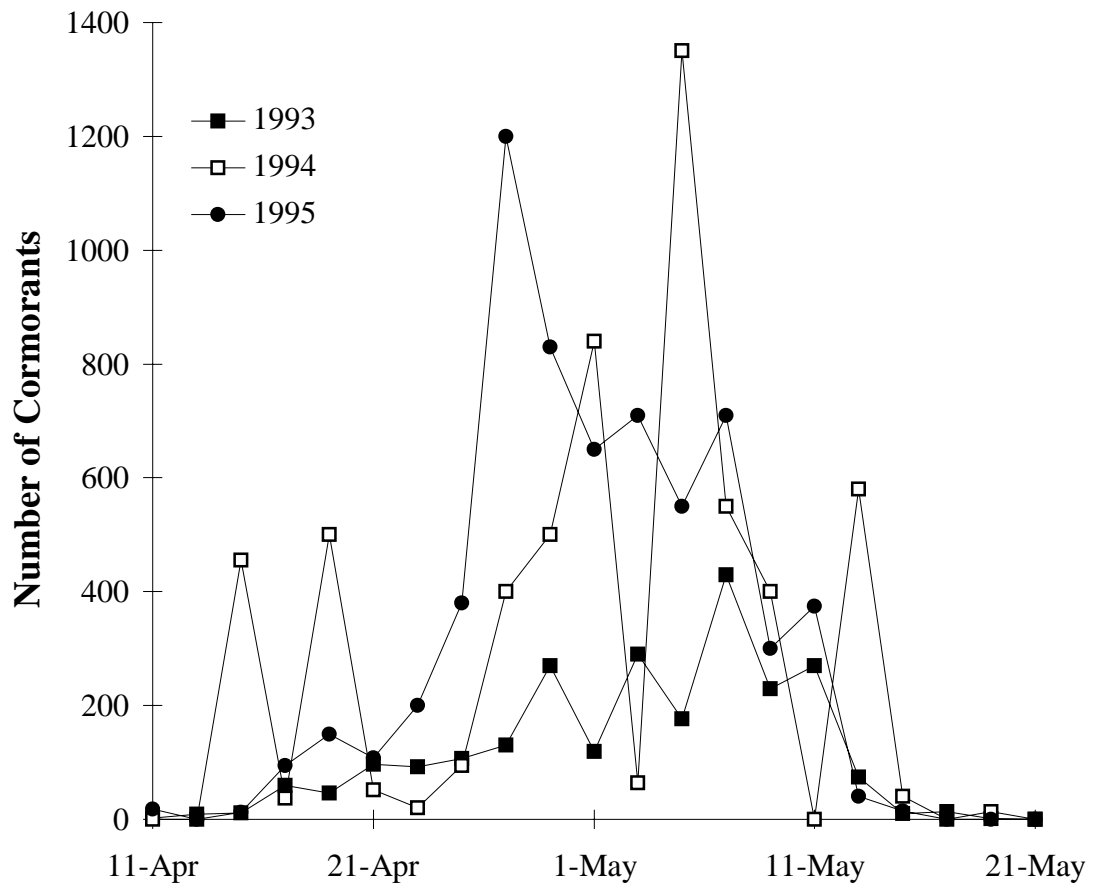
Figure 5-2.–Number of cormorants counted from ground on Cedarville Bay, Les Cheneaux Islands area, in 1993 to 1995.
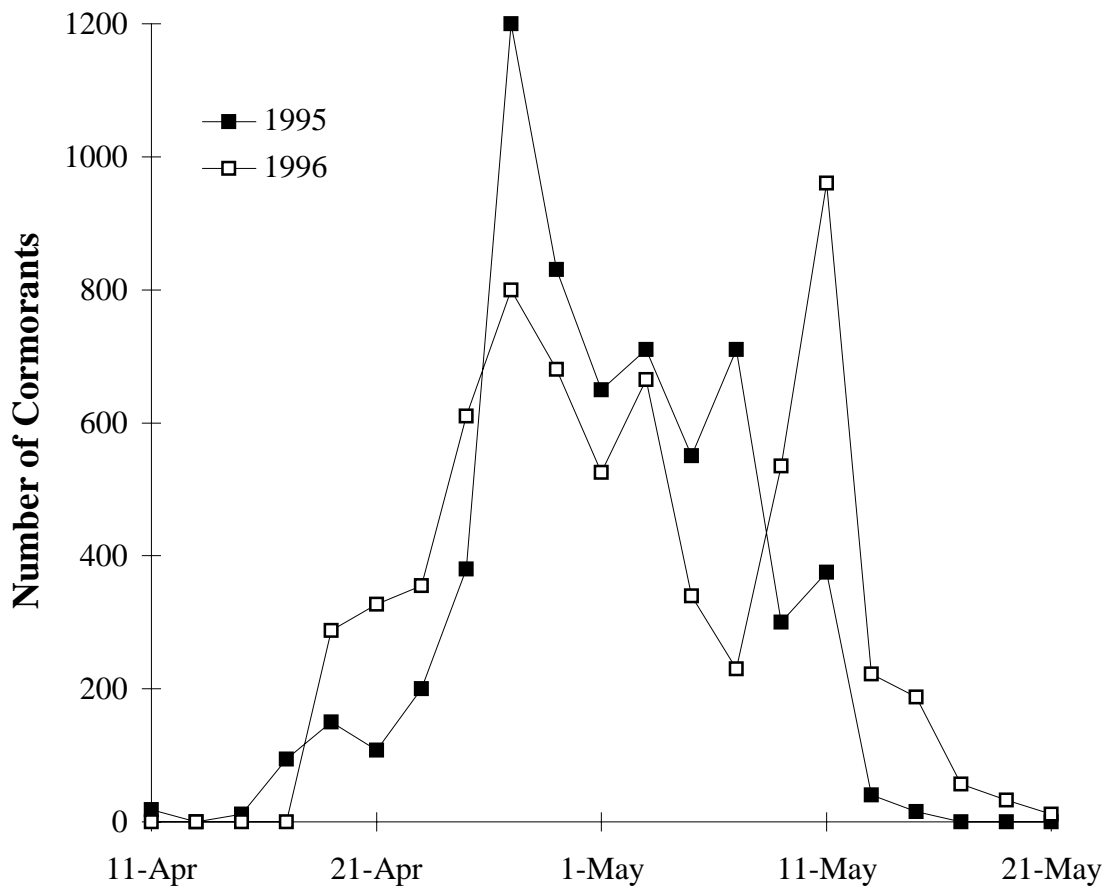
Figure 5-3.–Number of cormorants counted from ground on Cedarville Bay, Les Cheneaux Islands area, in 1995 and 1996.

Table 5-1.–Aerial survey dates and numbers of cormorants counted in Les Cheneaux Islands area in 1995.

Date	Number	Date	Number
4/17/95	249	7/14/95	5701
4/22/95	407	7/16/95	5231
4/24/95	1000	7/19/95	5656
4/26/95	1427	7/22/95	4800
4/30/95	2328	7/23/95	6201
5/2/95	2637	7/25/95	6389
5/4/95	2586	7/27/95	8336
5/7/95	3293	7/29/95	6985
5/11/95	2425	7/31/95	7262
5/12/95	2321	8/3/95	6939
5/15/95	2585	8/6/95	6252
5/16/95	2634	8/7/95	10446
5/18/95	2564	8/11/95	3204
5/21/95	3530	8/13/95	6683
5/23/95	3379	8/15/95	9004
5/25/95	3871	8/19/95	3563
5/30/95	3750	8/20/95	2084
5/31/95	4304	8/22/95	2892
6/1/95	4517	8/24/95	5841
6/3/95	5163	8/26/95	2807
6/5/95	5063	8/28/95	2794
6/9/95	5623	8/30/95	1945
6/11/95	5573	9/2/95	1633
6/13/95	6019	9/5/95	2607
6/15/95	6351	9/7/95	2814
6/17/95	6351	9/10/95	1290
6/19/95	2719	9/12/95	1217
6/22/95	5650	9/14/95	999
6/25/95	6226	9/17/95	1285
7/1/95	4624	9/19/95	999
7/2/95	5498	9/21/95	572
7/3/95	5881	9/23/95	428
7/4/95	2657	9/27/95	118
7/6/95	4827	9/29/95	70
7/9/95	5733	10/1/95	197
7/11/95	5527	10/4/95	59

CHAPTER 6

THE IMPACT OF CORMORANT PREDATION ON YELLOW PERCH
IN LES CHENEAUX ISLANDS, LAKE HURON

Susan L. Maruca

Introduction

Since the cormorant population expansion began 15 years ago, no studies on the Great Lakes have endeavored to examine simultaneously the cormorant diet composition, cormorant population dynamics, fish population size and mortality, and sport catch. Without all of these pieces, the question of cormorant impacts on fisheries cannot be fully addressed. The objective of this chapter was to determine the relative impacts of cormorant predation and human angling on the yellow perch population in Les Cheneaux Islands area by examining all of the above within the same year. This objective was accomplished by estimating size- and age-specific perch mortality rates in 1995 and partitioning mortality into three sources: cormorant predation, sport harvest, and other causes. Fisheries and angling data for yellow perch were collected by MDNR and analyzed in Chapter 4. This chapter contains details regarding cormorant consumption of perch and perch mortality from cormorant predation, as well as a comparison of the three sources of perch mortality.

Methods

Cormorant Diet Composition

Cormorant diet composition has been examined for several locations within the Great Lakes using nestling regurgitations and/or adult pellets (Belonger 1983, Craven and Lev 1987, Christie et al. 1987, Ludwig et al. 1989, Karwowski et al. 1992, Ross and Johnson 1994). In general, cormorant diets show a high degree of spatial variability and tend to reflect the fish species composition for each site, making it necessary to examine cormorant diets on a site-by-site basis. Although sampling diets using regurgitations and pellets is easier, faster, less expensive, and less destructive than sampling live birds, the information that can be drawn from these methods is limited in several ways. First, chick regurgitations are available only for the two months that chicks are in the nest and immobile, and because cormorant diets are temporally variable, diet composition during other times remains unknown. Second, with both regurgitations and pellets, information regarding spatial sources of prey items is only very general. Finally, estimates of diet composition from pellet data contain an obvious bias, in that some important prey items may be drastically underrepresented because the bones are either too small (as with sticklebacks) or too soft (as with alewife) to always be retained in the stomach and expelled as a pellet (Johnstone et al. 1990). Because I wished to obtain an unbiased estimate for diet composition over the entire period of cormorant residence and for a very specific area (Les Cheneaux Islands), stomach analysis was chosen as the most appropriate method to estimate cormorant diet composition for this study.

The stomach analysis was conducted using 373 cormorants sampled in 1995. From 17 April through 6 October, an average of 15 birds per week were randomly shot within the study area. Stomachs from these birds were removed and preserved in 10% formalin, and the contents later identified in the laboratory. No more than four days elapsed between sampling dates. If possible, sex of cormorants was identified in the field by examining gonads, although sex of some birds was identified later by museum ornithologists and some (especially immature birds) could not be identified to sex. All birds were weighed. In order to minimize the number of empty stomachs obtained, birds were sampled either after they had been observed to forage for

20 minutes or as they were flying to the nesting colonies from the study area, presumably after feeding. Only 52 of the 373 stomachs were empty (14%), a rate lower than that observed for similar studies (e.g. Campo et al. 1993).

Prey items were identified to species when possible, with the exception of sculpins, shiners, and crayfishes. Meristic characters were used to identify intact fish; bones and bone fragments were used for digested prey items. Standards for bone identification were obtained from the fish skeleton collection at the University of Michigan Museum of Zoology. Lengths of all intact fish were measured, except for sticklebacks and sculpins, for which subsets of approximately 100 fish per taxon were used. The weight of each intact fish was estimated using published length-weight regressions (Schneider et al. 1991) for all taxa except yellow perch. The weight of each digested fish was taken to be the average weight of all intact fish of that taxon. To provide more detailed length frequency information for yellow perch, lengths were estimated for many digested fish using cleithrum or preopercle lengths and regressions for total length to bone length obtained from museum specimens. Of 184 yellow perch found in cormorant stomachs, 106 lengths were measured directly, 46 were estimated from cleithrum or preopercle lengths, and 32 were not obtained. Weights were estimated as with other taxa, using length-weight regressions developed from yellow perch collected in Les Cheneaux Islands area. Cormorant diet composition was then determined by calculating the proportion by weight of each fish taxon in the diet.

In order to characterize temporal variability of cormorant diet, 1995 was divided into six time periods, each of which represented a dietary period for cormorants that was qualitatively different and separated from neighboring periods by observed habitat shifts. For example, from mid-April to mid-May cormorants were observed to feed intensively in shallow (depth < 3 m) bays within Les Cheneaux Islands, but from mid-May through the first of July the birds fed almost exclusively in bays of intermediate depth (3 to 10 m). The dates for each time period were determined as follows. First, cutoff date ranges were determined from qualitative observations of foraging birds and preliminary results of diet analysis. A BASIC program (Appendix 5) was developed to select dates from these ranges such that differences in the diet between periods were maximized; specifically, the program minimized the probability that the distributions of prey items consumed were equal across periods. This was achieved by selecting dates that maximized a Chi-square statistic for a 2-way layout with variables period and prey taxon. For simplicity, only the seven most important prey categories (plus "other") were used. In order to examine temporal variability in cormorant consumption of perch on a finer scale, the six periods were further divided into subperiods of 9 to 12 days, and the proportion (mass) of perch in the diet was calculated for each subperiod.

Several gender-based analyses were performed for birds collected through the first four dietary periods only (mid-April through mid-August 1995), after which aging and identifying sex of cormorants became difficult due to diminished gonads, loss of breeding plumage, and molt. Sex ratio of all adult birds sampled was compared with an even sex ratio using a one-way Chi-square (χ^2) goodness-of-fit test. Sex-related differences in adult body weight, exposed culmen length, and lengths of yellow perch consumed were determined using the t-test. Interdependences among sex of cormorant, time period, and yellow perch consumption were examined with a three-way loglinear analysis of categorical data, using the likelihood ratio statistic (G). Each of 194 reliably sexed adults with food in the stomach was classified according to sex (male or female), time period sampled (yellow perch spawning or other), and yellow perch consumption (presence or absence in stomach). All possible statistical models were tested and the best model selected using a combination of partitioning and stepwise procedures. The strengths of relevant associations were measured using Pearson's coefficient of mean square contingency (C). All statistics were considered significant at an alpha of 0.05.

Abundance of Foraging Cormorants

Aerial counts of foraging and roosting cormorants in Les Cheneaux Islands study area were conducted from 17 April through 6 October 1995, at the rate of approximately three per week (see Chapter 5 for details). All counts were conducted beginning at 7:00 a.m. Separate counts were made for birds on the three nesting colonies as well as birds foraging in the channels and bays of the study area. Undoubtedly there was a high margin of error for counts of birds on St. Martins Shoal and Goose Island, each of which hosted several hundred to several thousand birds on any given day. However, the counts for these colonies appeared to be reasonable when compared with nest counts made during ground surveys over the same general time period (Chapter 3). The birds counted on the colonies undoubtedly fed in other locations besides the study area, so I also estimated the proportion of birds from each colony that foraged in the study area, hereafter called the study area usage. Ground observations of bird movements to and from each colony were conducted during May and June 1995. Each colony was observed on at least four different days and during as many different times of the day as possible, within limitations set by weather patterns and travel time. Movements (arrivals or departures) were classified as "study area" or "other", and the calculated study area usage was then simply the mean proportion of study area movements weighted by the length of the observation period. Because no ground observations were made after 1 July, I simply assumed that study area usages remained constant throughout the following months, although it is possible, given the general observation that there were fewer birds feeding in the study area during late summer and fall, that usages declined during this time.

For each day k that an aerial count was made, a quantity called cormorant equivalents (CE_k), or the equivalent number of cormorants feeding in Les Cheneaux Islands area, was defined as

$$CE_k = B_k + \sum_i (U_i)(C_i)_k \qquad (1)$$

where B_k is the number of birds counted in the bays on day k, U_i is the study area usage for colony i, and $(C_i)_k$ is the number of birds counted on colony i for day k. Finally, weekly means of cormorant equivalents were calculated for the entire period of occupation in 1995.

Cormorant Daily Consumption

Field estimates of daily consumption for birds can be extremely difficult, expensive, and time-consuming. The most accurate method is to inject subjects with doubly labeled water (Williams 1985, Webster and Weathers 1989), which involves recapturing the same birds twice, an onerous task when dealing with shy cormorants. Were this method attempted, the sample size would almost necessarily be limited to less than ten birds and probably less than five. Another accepted method is to use time budget data. However, this is extremely time-consuming, somewhat inaccurate (see Weathers et al. 1984), and requires estimates of metabolic rates for various behaviors such as foraging, swimming, and flying, which to my knowledge have not been made for cormorants, although they have been estimated for other seabirds (Kendeigh et al. 1977). A third method involves recording stomach temperatures of cormorants over the course of a few meals and using cormorant body temperature and the specific heat of fish to calculate meal mass (Grémillet and Plös 1994). However, temperature loggers, which must be force-fed to cormorants, are prohibitively expensive and are not easy to recover. Because all empirical methods were not feasible for this study, daily caloric intake of cormorants was estimated from published information on seabird metabolic rates.

Daily caloric intake for nestlings was taken directly from Dunn (1975), who determined consumption by directly observing nestlings. For my calculations, nestling numbers and intake were estimated as functions of the numbers of adult breeders. A brood size range of 3 to 3.5 was used (Chapter 3). Furthermore, breeding asynchrony was incorporated into this analysis by assuming six cohorts of breeders, each beginning egg incubation at 10-day

intervals starting the first week of May, corresponding roughly to observations made at the colonies. For mature and immature birds older than one year, daily caloric intake was estimated from Nagy (1987), who regressed field metabolic rate (FMR) against body weight for several different seabird species, and Hennemann (1983), who determined basal metabolism (BM) for cormorants by holding them in closed containers and measuring oxygen depletion within the container. From Hennemann's equation I estimated BM from body weight and then multiplied by 2.7 (as suggested by Nagy 1987) to obtain FMR. Ultimately, only estimates from Hennemann (1983) were used, because estimates from Nagy (1987) appeared unreasonably low, resulting in daily consumption rates of only 16% of body weight per day. Nagy's equation did not include any species from the order Pelicaniformes, to which cormorants belong, which may explain the discrepancy.

Daily caloric intake (DCI) was derived from FMR by (1) assuming that the birds were not gaining or losing body mass, and (2) assuming an assimilation efficiency of 0.85 (Dunn 1975, Nagy 1987). DCI was estimated separately for mature and immature birds, but differences between the two groups were based only on differences in body weight. The mean body weights of mature and immature birds, as well as the proportion of each group in the population and the change in proportion over time, were estimated from sampled birds. Immature birds are easily distinguished by their mottled brown or silvery plumage, whereas mature birds possess solid brownish black plumage. For simplicity, I further assumed that metabolic rates did not vary through the year (but see Masman et al. 1988).

Finally, daily consumption (g) was calculated by dividing DCI (kcal) by the caloric density of fish (kcal/g). Although there is significant interspecific and seasonal intraspecific variation in fish caloric density (Flath and Diana 1985, Strange and Pelton 1987, Hartman and Brandt 1995), for simplicity I assumed that all fish species had a caloric density of 1.2 kcal/g (Haas and Schaeffer 1992).

Yellow Perch Mortality from Cormorant Predation

The biomass of perch consumed by cormorants is:

$$biomass =$$

$$\left(\frac{P_{yp}}{d}\right)(CE)\left[(C_b)(D_b + N_y D_y) + C_n D_n\right] \quad (2)$$

P_{yp}:   proportion by mass of perch in the cormorant diet
d: caloric density of fish (constant)
CE: cormorant equivalents
C_b: proportion breeding cormorants in population
C_n: proportion nonbreeding cormorants in population
N_y: average number of young per breeding adult
D_b: daily caloric intake for breeders
D_n: daily caloric intake for nonbreeders
D_y: daily caloric intake for young

The biomass consumed was estimated by allowing all involved parameters to vary independently with time, calculating biomass consumed on a daily basis using the above equation, and summing over the time period of interest. Biomass consumed was calculated separately for the perch spawning season (Period 1, Day 1 to 30) and the rest of the year (Periods 2 to 6, Day 31 to 173) for two reasons. First, most perch (60 to 70%) consumed by cormorants were eaten during perch spawning, and the size frequency of perch in the cormorant diet was slightly but crucially different during this time, in that no young-of-the-year (YOY) perch were consumed. Second, yellow perch grow most rapidly after spawning, and so size structure of the perch population is very different during spawning than after spawning. The separation of these two time periods became important when size-specific mortality rates were calculated for perch. For each parameter in the above equation, the lowest and highest reasonable estimates were used to

calculate an overall range for biomass consumed.

Biomass of perch consumed was then converted to number of perch of different sizes consumed. First the average weight of perch for each size class was determined from the following equation:

$$\overline{w} = \frac{\int_{x_1}^{x_2} \left(aL^b\right)dL}{x_2 - x_1} \qquad (3)$$

where x_1 and x_2 are the lower and upper limits for each size class, respectively, and a and b are empirically determined parameters from the length-weight relationship. The size classes used were 25-mm classes. Using the size frequency of perch in the diet during the period of interest, the unique relationship between number of perch consumed and biomass of perch consumed was quantified, allowing determination of number from biomass. The size-specific numbers of perch consumed were converted to age-specific numbers consumed using a key developed from size-age data for yellow perch in bays de Noc, northern Lake Michigan (Chapter 4), an area similar to Les Cheneaux Islands in latitude and climate.

Size- and age-specific mortality rates were estimated by dividing the number of perch consumed by the estimated population size (Chapter 4). Size-specific mortality from cormorant predation was determined separately for the perch spawning season and the rest of the year. This required the application of two separate length-at-age keys, one for April and one for May to October, to the perch population age structure (Chapter 4), in order to yield two distinct size distributions for the perch population. Both keys were derived from data for yellow perch in bays de Noc, Lake Michigan. The population estimates for mid-May through October do not reflect mortality that occurred prior to period 2 (mid-May). Mortality from cormorant predation for mid-May through October was compared with mortality from angling over the same time period (Chapter 4). The MDNR's creel census showed no angler harvest between 1 May and the conclusion of perch spawning, and therefore mortality from angling is included only in the later part of the year. However, any perch caught immediately after ice-out in late April would not have been included in the MDNR's creel census (see Chapter 4 for methods). Age-specific mortality rates from cormorant predation were also calculated and compared with age-specific rates from angling. Mortality rates from cormorant predation and angling were compared with total annual mortality of yellow perch (see Chapter 4).

Results

Of 212 sexed adults collected during the first four dietary periods (17 April through 19 August), 124 were females and 88 were males. This sex ratio of 1.41 females per male sampled is significantly different from an even sex ratio ($\chi^2 = 6.11$, df = 1, P = 0.013), which implies that either the population sex ratio was female-biased, females fed more frequently than males and were therefore more likely to be sampled, or females foraged more frequently in Les Cheneaux Islands area, while males foraged elsewhere. The sex ratio of birds feeding in the study area appeared to change slightly through the year from more strongly female-biased in periods 1 and 2 (1.52 females per male), which roughly corresponds to the egg-laying and brooding stage, to slightly less strongly female-biased in periods 3 and 4 (1.22 females per male), the nestling stage. Given cormorant life histories and lack of sexual dimorphism, the population sex ratio is not likely to be female-biased. Females may have higher energetic requirements than males during egg-production, and are therefore likely to be feeding more frequently. This difference is probably restricted to the time of egg-laying, because males and females have been shown to share other parental responsibilities, including egg brooding, almost equally (Léger and McNeil 1985). Behavioral differences between sexes may also contribute to the observed female bias. Males may take on initial responsibility of nest building and guarding (J.P. Ludwig, personal communication). Therefore, during the courting and egg-laying stages, males may choose to forage close to the

colonies to protect eggs from predators and nest material from thieves (Siegel-Causey and Hunt 1986, McNeil and Léger 1987), whereas females may travel further to forage in more profitable habitats.

Regardless of stomach content weight, mean body weight was 2,080 g (n = 124) for females and 2,340 g (n = 87) for males. Females weighed significantly less than males, whether comparing adults with negligible stomach content weight (t = 6.42, df = 81, P < 0.001), or all birds regardless of stomach content weight (t = 8.88, df = 209, P < 0.001). The overlap in weight distributions for males and females is substantial (Figure 6-1), and therefore weight alone is not a reliable indicator of sex. However, when coupled with other measures, such as culmen length, culmen depth and wing length, in a discriminant analysis, weight can aid in distinguishing between sexes (Glahn and McCoy 1995). In general, exposed culmen lengths are known to be smaller for females than for males (Johnsgard 1993). In this study, exposed culmen lengths were compared for a small subset of 8 males and 5 females, and mean female culmen length (x_f = 55.1 mm) was significantly shorter than male culmen length (x_m = 58.1 mm; t = 3.20, df = 11, P = 0.008). Shorter culmen length may be one reasons why females have been found to consume slightly smaller prey than males (Campo et al. 1993); however, this study found no significant difference between the lengths of yellow perch consumed by males and females (t = 1.22, df = 87, P = 0.22).

A total of 30 taxonomic groups, encompassing one invertebrate and 14 fish families, was found in the cormorant diet (Table 6-1). Anumber of other small invertebrates thought to be fish prey items were also found but not identified. In addition, stomach parasites, especially roundworms, were found in 64% of the stomachs. Also, gizzard stones ranging from 3 to 25 mm in diameter were found in 14% of the stomachs. The dates and qualitative descriptions of the six dietary periods (Table 6-2) included abrupt shifts in diet composition between periods 1 and 2, occurring over 3 to 5 days, while transitions between other dietary periods were much more gradual and not easily distinguishable without a computer program (see Appendix 5).

The three-way loglinear analysis (results in Table 6-3a, b) revealed that although there was a highly significant interaction between consumption of yellow perch and season, the interactions between sex of cormorant and perch consumption and between sex of cormorant and season did not explain the frequencies observed. The three-way interaction among sex, season, and perch consumption was significant (G = 5.19, df = 1, P = 0.023); however, closer examination revealed that the significance of this interaction probably relates to a weak (C = 0.18) dependence of perch consumption on sex during the second season (periods 2 to 4; χ^2 = 5.02, df = 1, P = 0.025), when males were slightly more likely to consume perch than were females. However, I am skeptical that this analysis has uncovered a general trend in cormorant foraging behavior. During periods 2 to 4 perch were not concentrated for spawning and only composed about 1% of the diet by biomass. Very few sampled birds had perch in their stomachs. The capture of perch by cormorants and the subsequent sampling of cormorants are two random and relatively infrequent events that have perhaps produced spurious results in this case. The weakness of the relationship and its dubious reliability as a real biological phenomenon lends more credibility to the simpler model (Model 3 in Table 6-3b) selected as the best model, which explains variation in levels of perch consumption as relating to season only. I assumed that trends in consumption of other prey species were similar to those for yellow perch and were not related to sex. All further analyses and calculations were conducted with sexes pooled.

Seasonal diet composition of cormorants indicated that many of the primary diet species were spawning at the time they were consumed (Table 6-4): yellow perch, northern pike, rock bass, and pumpkinseed in period 1, sticklebacks and some alewife in period 2, and alewife in period 3 (Table 6-4, Figure 6-2). Alewife were by far the most important diet item, dominating diet biomass during periods 3 to 6 (4 July to 6 October). During periods 2 to 4, most alewife

consumed were spawning adults or yearling fish, but during periods 5 to 6, approximately 80% of the alewife captured were YOY. Consumption of perch was highly variable with time. Yellow perch was 48% by biomass of the cormorant diet during period 1, then dropped substantially during periods 2 to 5 and rose again to 14% during period 6.

The size frequency of perch in the cormorant diet did not vary much when comparing perch spawning season to the rest of the year (Figure 6-3), except that a few YOY yellow perch were found in stomachs later in the year, whereas no YOY could be consumed during perch spawning. The two distributions depicted in Figure 6-3 were not significantly different ($\chi^2 = 0.72$, df = 2, P = 0.70). Because of the obvious biological difference concerning presence of YOY perch later in the year, size frequency distributions were kept separate for all calculations. Interestingly, size frequencies of alewife in the diet changed very dramatically over the seasons (Figure 6-4), probably in response to changing densities of different year classes within the study area.

The aerial counts of cormorants (Figure 6-5) reveals an increase in the number of birds in Les Cheneaux Islands area through approximately day 60 (mid-June), followed by 40 days of relative stability in numbers, then 70 days of drastic fluctuations and an overall downward trend in numbers. There were essentially no cormorants remaining in the area after the first week of October 1995. Some of the fluctuations were most likely related to migrating birds stopping briefly in Les Cheneaux Islands area before traveling further north (spring) or south (fall). Fluctuations later in the year were probably also due to the 1995 year class fledging and then leaving the area, perhaps in large groups. At the time of aerial counts, very few birds were actually feeding in the study area relative to the number of birds on colonies (Figure 6-5). The study area usages (Table 6-5) were therefore employed in estimating the number of colony-residing birds that fed in the study area. St. Martins Shoal, the largest colony, is located furthest from the study area and had the lowest usage (26%), whereas Goose and Crow Islands, both within the study area, had

higher usages (57% and 67%, respectively). When these usage estimates were combined with the raw aerial counts (Equation 1), the resulting cormorant equivalents (CE, Figure 6-6) showed the same general trends over time as the raw aerial counts. Values for CE were approximately half to two-thirds values of raw counts.

Values of daily caloric intake for nestlings (Table 6-6), breeders and nonbreeders (Table 6-7) were used to calculate total consumption of prey by cormorants. Although a few stragglers breed into late September (J.P. Ludwig, personal communication), most breeding is terminated by the end of August. After day 155 (mid-September), no distinction was made between breeders and nonbreeders. The proportion of breeders and nonbreeders among the sampled birds changed dramatically through the year (Table 6-8), in that there were very few nonbreeders present in the area through day 78 compared with the rest of the year.

The biomass of perch consumed by cormorants was estimated (using Equation 2) at 7,100 kg of yellow perch consumed during perch spawning (period 1) and 4,300 kg consumed during the remainder of 1995, for a total of 11,400 kg consumed. By substituting reasonable ranges for all parameters in Equation 2, a consumption range of 6,600 to 17,500 kg was calculated. Given the size frequencies of perch in the diet and mean weights for each size class, these biomass estimates correspond to a range of 270,000 to 720,000 individual perch consumed, with a best estimate of 470,000. Only about 5% (24,000) of these perch were of legal size (length > 175 mm) when consumed, with a range of 14,000 to 37,000 fish. Cormorants also consumed an estimated 7,000 to 17,000 YOY perch during periods 2 to 6. No estimates of YOY perch abundance were made during 1995, and so the exact effect of cormorant predation on recruitment is unknown. However, recruitment of YOY to yearling perch is highly variable throughout the Great Lakes and does not appear to be correlated with the presence of avian predators. Furthermore, given the size of other year classes for Les Cheneaux Islands perch (Chapter 4), it seems reasonable to assume that removal of up to 17,000 YOY

would have no substantial effect on recruitment. The calculations of mortality rates that follow do not include YOY perch.

Mortality of legal-size perch due to cormorant predation and summer sport fishing in 1995 was low, when compared with all other sources of mortality combined. There appeared to be 2.76 million yellow perch of legal size in Les Cheneaux Islands area in 1995 (Chapter 4), so by consuming 24,000 legal-size perch, cormorants removed only 1% of the population. Angler catch was estimated at 66,500 (Chapter 4), which gives a summer angler exploitation rate of only 2.4%. The total annual mortality rate for the yellow perch population was estimated at 45% (Chapter 4). Other sources of mortality must then remove roughly 40% of legal-size perch to give a total annual mortality of 45%.

Examination of size-specific mortality rates (Table 6-9) reveals that mortality from cormorant predation is heaviest at smaller sizes (75 to 175 mm in early spring and 75 to 100 mm during the rest of the year), while angling mortality is greatest at 175 to 200 mm. It is not surprising that cormorants and anglers remove different sizes of perch, since anglers are restricted to larger fish by the 175-mm size limit and cormorants have been shown to consume smaller fish even when larger fish are available (Campo et al. 1993). Neither cormorant predation nor angling is a significant source of mortality at any size or time of year, when compared with total annual mortality (45%).

Examination of mortality rates by ages (Table 6-10) reveals that even the highest estimate for cormorant consumption of perch yields mortality rates that are less than 10% for all ages, which accounts for about one-fifth or less of the total annual mortality (45%). Mortality from summer angling is less than 3% for all age classes, which is less than one-fifteenth of total annual mortality. Because cormorants and anglers consume different sizes of perch, they affect different ages as well (Figure 6-7), although the overlap is greater for ages than for sizes. In general, cormorant predation accounts for a greater proportion of mortality at younger ages (1 to 3), whereas anglers impact essentially age 3 and older perch.

Discussion

Although the cormorant diet contained approximately 48% yellow perch by weight during the perch spawning season, the results for this study suggest that cormorant predation of perch in 1995 was, on the whole, not substantial. Other sources of mortality, including predation by piscivorous fish, accounted for the majority of yellow perch deaths. Little data exist on the consumption rates of perch by other fish in Les Cheneaux Islands area; however, burbot, northern pike, and splake are common large fishes in the area that have been reported to feed on yellow perch (Scott and Crossman 1973) and could consume moderate to large perch. Furthermore, many medium-sized fish in the area, such as smallmouth bass, rock bass, brown bullhead, and pumpkinseed, may prey on juvenile perch. Native American commercial gill netting, common in Les Cheneaux Islands area, is another possible source of mortality; however, most effort takes place south of the main islands in deeper water, where perch are likely to be scarce. There were no reports of tagged perch recovered by Native American fishermen, which suggests that mortality from gill netting was minimal.

An important consideration in interpreting the results of this study is year-to-year variation in cormorant consumption of perch and its effect on perch population dynamics. Specifically, the timing of perch spawning relative to cormorant migration may affect the number and sizes of perch that are vulnerable to heavy cormorant predation. In 1995, northern Michigan experienced a warm spring and as a result, perch spawning occurred earlier than usual. Many of the larger spawning fish may not have been susceptible to cormorant predation because they had spawned and dispersed before cormorants arrived in the area. However, in 1996 spawning was late and peaked after many cormorants had already migrated into the study area. Perch may have composed a greater proportion of the cormorant diet or may have been represented by a different size distribution in 1996 compared with 1995.

To determine possible impacts of increased predation or altered size selectivity during perch spawning, two calculations were made using the best 1995 estimates for all input variables, changing first only the proportion of perch in the cormorant diet during spawning, then also altering the size distribution to include more large fish. Allowing perch to compose 90% of the diet during the first 30 days, the estimated number of perch consumed was increased by 66% (780,000 perch consumed, compared with 470,000). However, the highest mortality rate was 11.3% (age 3), still small compared with total annual mortality. Allowing the proportion of perch 150 mm and larger to increase from 0.24 (as in 1995) to 0.50 for perch consumed during spawning, the estimated total number consumed fell back to 580,000. Under this scenario, cormorants eat fewer but larger perch. The cormorant-caused mortality rates declined for ages 1 to 3 and increased for ages 4 and older compared with mortality rates from the first 1996 simulation. The highest mortality rate still occurred at age 3 and was 10.7%.

I conclude that reasonable year-to-year variation in cormorant predation of perch during perch spawning does not appear to drastically alter age-specific mortality rates, provided perch and cormorant population sizes are comparable to 1995 estimates. Over the long term, changes in predatory behavior of cormorants, ecological plasticity in the timing or location of perch spawning, and population fluctuations for either cormorants or perch may influence the importance of cormorant predation on perch survival. The cormorant population in Les Cheneaux Islands area is predicted to continue to expand for at least the next few years (Chapter 3), and depending on the type of functional response involved, this may result in greater consumption of perch.

The relative contributions of different sources of mortality of perch, as well as total annual mortality, may also vary annually. Lucchesi (1988) and Schneeberger and Scott (Chapter 4) used comparable techniques to estimate total annual mortality in 1986 and 1995, respectively. Total mortality was 55% in 1986 and 45% in 1995. These differences may represent a gradual decline in mortality over the last decade, substantial yearly fluctuations in mortality rates, or differences in sampling bias. The composition of these morality rates has changed substantially, in that Lucchesi (1988) estimated that in 1986 fishing mortality for adult perch may have been as high as 40%, whereas in 1995 fishing mortality was estimated to be no greater than 5%. Furthermore, although cormorant predation has not been shown to cause high mortality rates in 1995, in 1986 Les Cheneaux cormorant population was two orders of magnitude smaller and therefore accounted for a negligible amount of perch mortality. The larger, more important, question underlying these issues regards the additivity of sources of mortality on perch. In other words, does mortality from cormorant predation or angling occur in addition to other sources of mortality (additive) or does it replace other sources (compensatory)? The comparison of only two years of mortality data is not sufficient to answer this question.

There may also be variation in total annual mortality of perch across ages. Since different factors affect mortality at different ages, it seems likely that age-specific total mortality rates will differ. Catch curve analysis (Chapter 4), a standard fisheries technique, only examines mortality for older fish and assumes that mortality rates do not differ by age. This assumption may not be unreasonable for older fish, which are less size differentiated, less affected by physical factors, and more uniformly susceptible to predation, all of which may result in similar and stable mortality rates. Mortality for younger perch is likely to be higher, more variable, or both. Cormorants may occasionally be a more prominent source of mortality for these ages, depending on their density and the relative additivity of all sources of mortality. All of these questions regarding variability in mortality of perch will be addressed in a forthcoming mathematical model of Les Cheneaux Islands yellow perch and cormorant interaction.

We know little about the indirect or higher order effects that cormorants have on target populations (such as perch) or on other components of these aquatic systems. For example, cormorants prey on northern pike

(18% of the diet by biomass in period 1), a known predator of yellow perch, thereby introducing an indirect positive effect on perch. Alewife are widely abundant throughout lakes Huron and Michigan and have been the object of numerous control strategies; they are also the primary prey for cormorants nearly everywhere the two species are found together (Belonger 1983, Christie et al. 1987, Ludwig et al. 1989, Karwowski et al. 1992, Ross and Johnson 1994). Predation on alewife may alleviate competition with yellow perch, as well as predation by alewife on perch larvae. In fact, based on the same bioenergetics approach used above to estimate consumption of perch, I estimate that in 1995 cormorants consumed approximately 123,000 kg of alewife in Les Cheneaux Islands. Because no population or total biomass estimates were made for alewife in this area, the impact of this level of cormorant predation cannot be known. Cormorant reproductive success may be intimately linked to the alewife populations and fluctuations therein (Weseloh and Ewins 1994), which suggests that (1) abundant alewife have contributed to widespread cormorant population growth, and (2) if food limitation is to occur for cormorants, it may be controlled by the alewife population. Cormorants may be indirectly benefiting yellow perch and many other components of the ecosystem by preying heavily upon the exotic alewife.
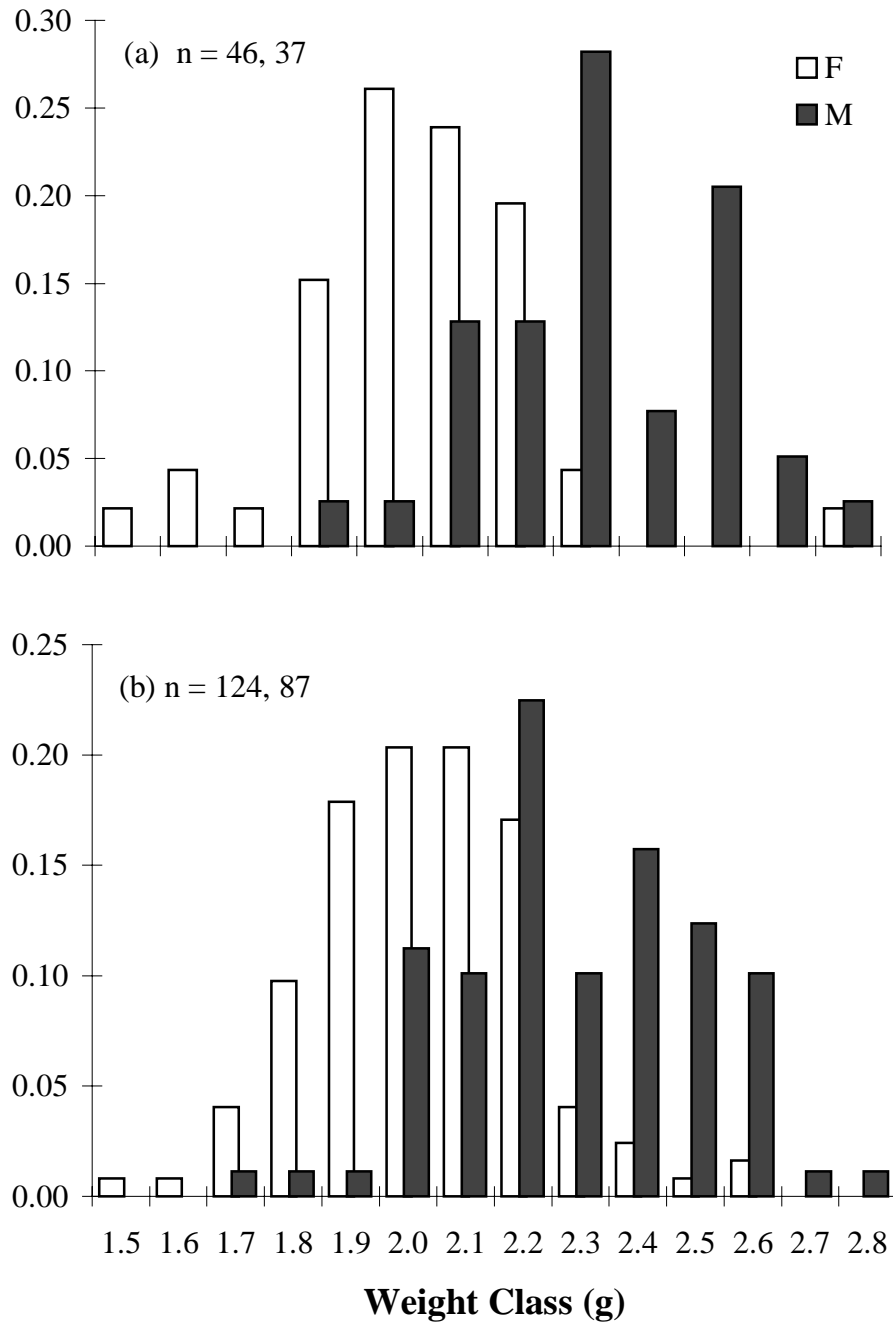
Figure 6-1.–Histograms of adult female and male cormorant body weights (kg) for birds with stomach content weight less than 30 g (a) and all birds (b). Y-axis is proportion of adult cormorants per weight class. Sample sizes are for females and males, respectively.
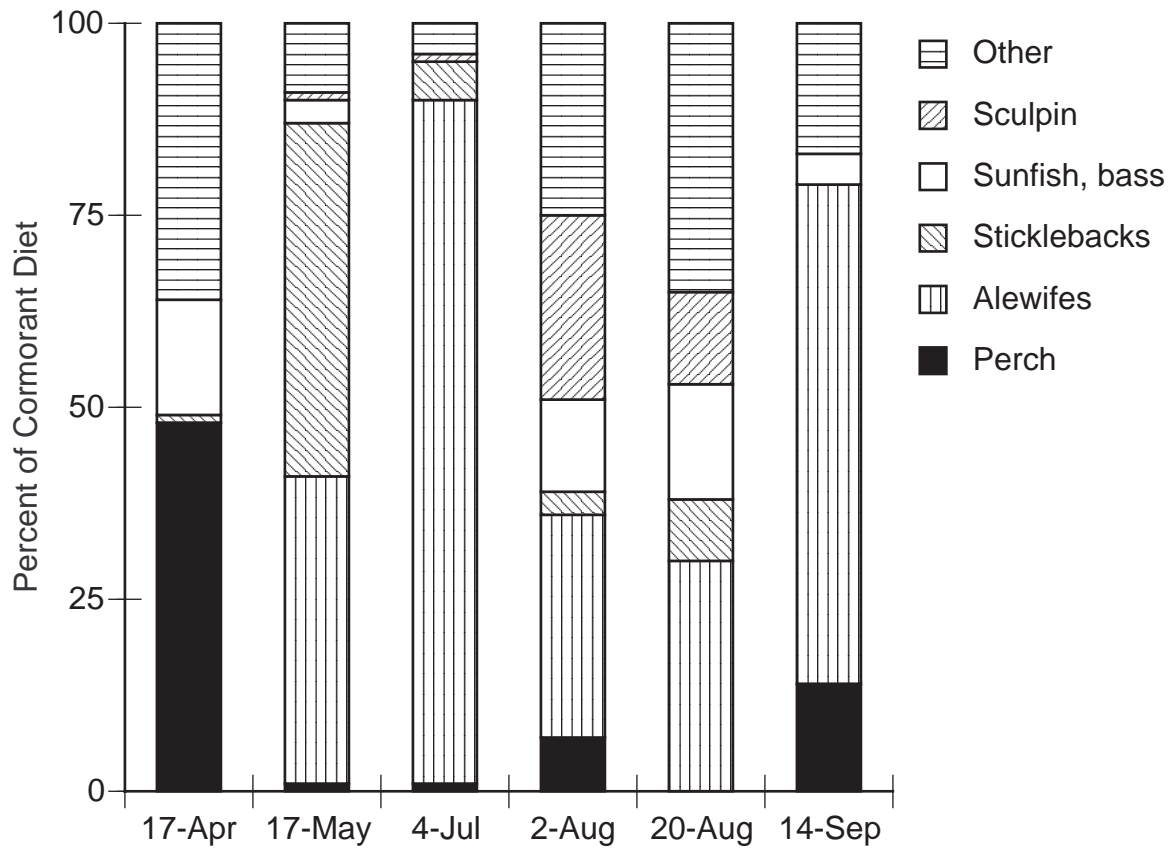
Figure 6-2.–Cormorant diet composition by biomass for 1995. Dates are start dates for the six dietary periods. The last day of the last period is 6 October.
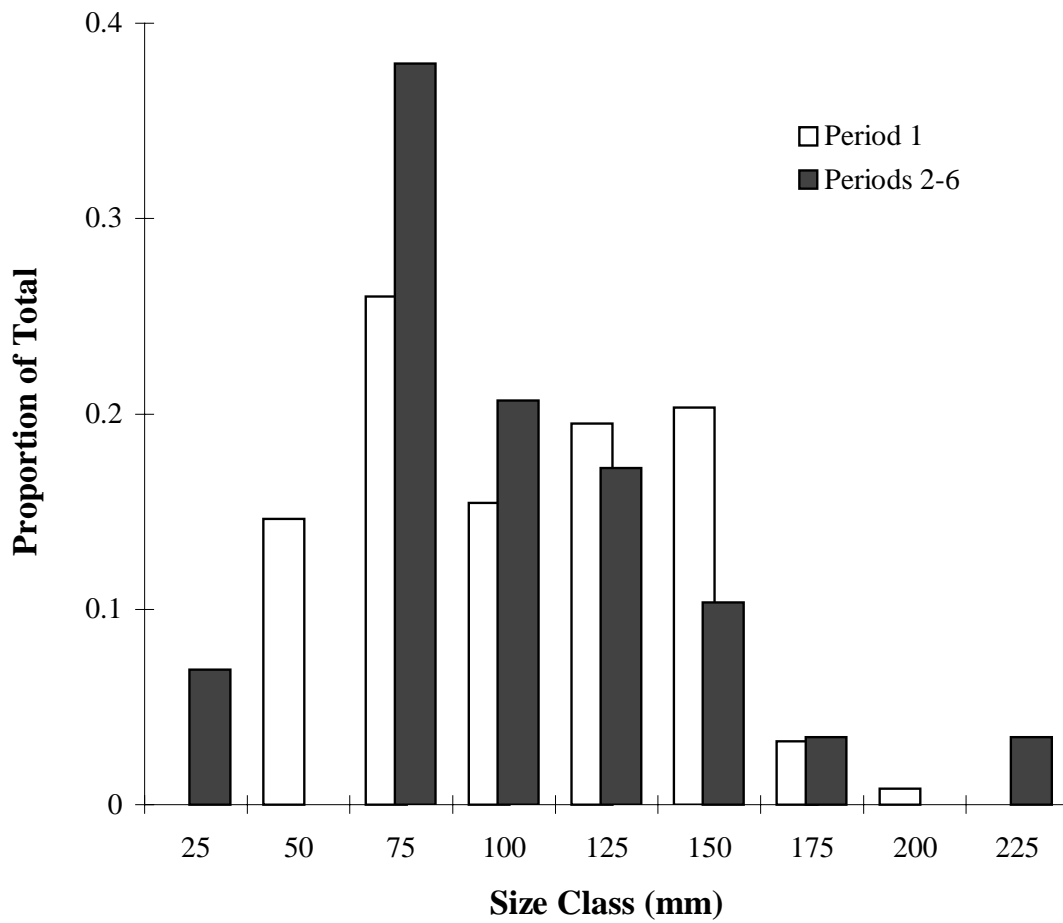
Figure 6-3.–Size frequencies of perch in the cormorant diet in 1995. The distributions are not statistically different; however, young-of-the-year perch were consumed only in periods 2 to 6 (the 25 mm size class).
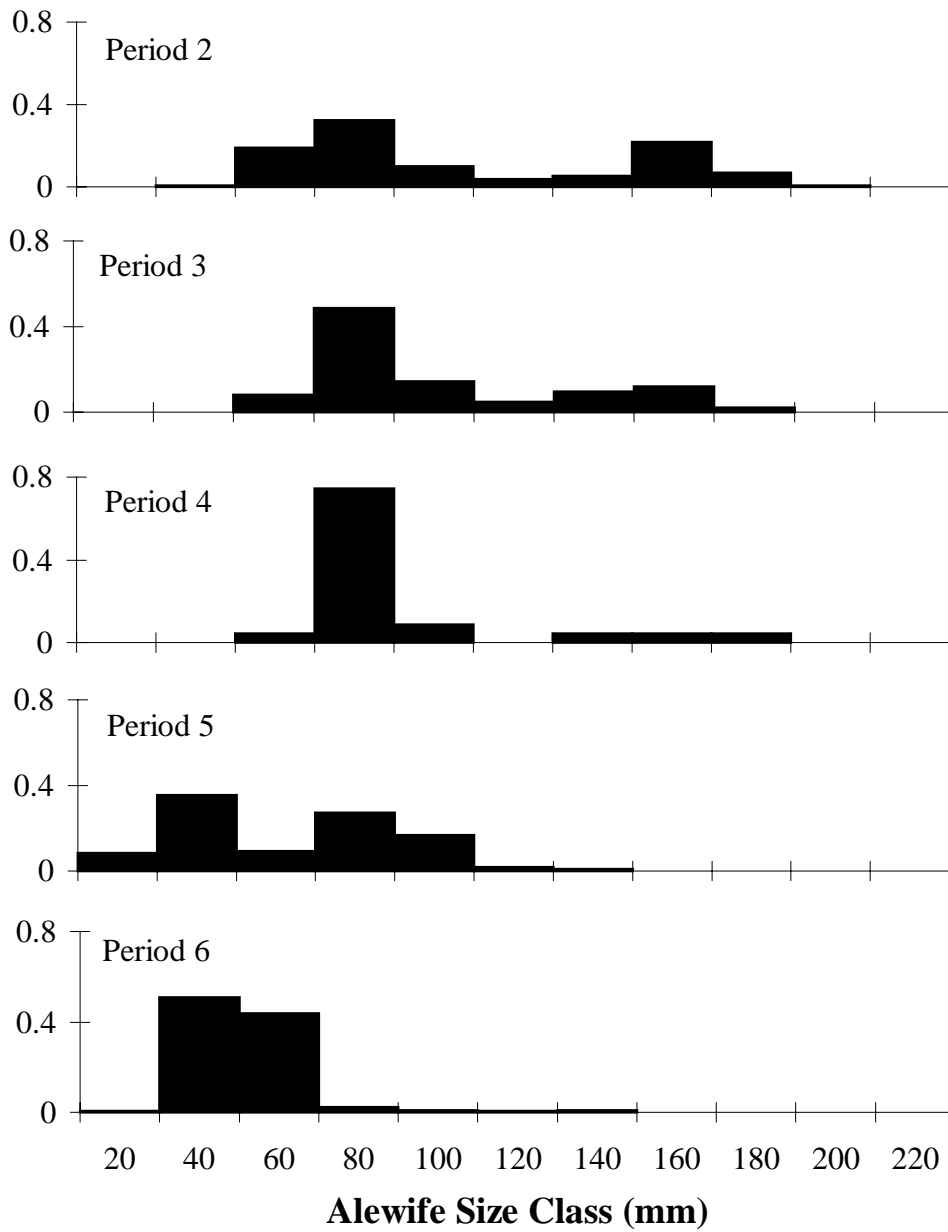
Figure 6-4.–Size frequencies of alewife in the cormorant diet during the periods 2 to 6. There were no alewife in the diet during period 1. Y-axis is proportion of alewife in each size class.
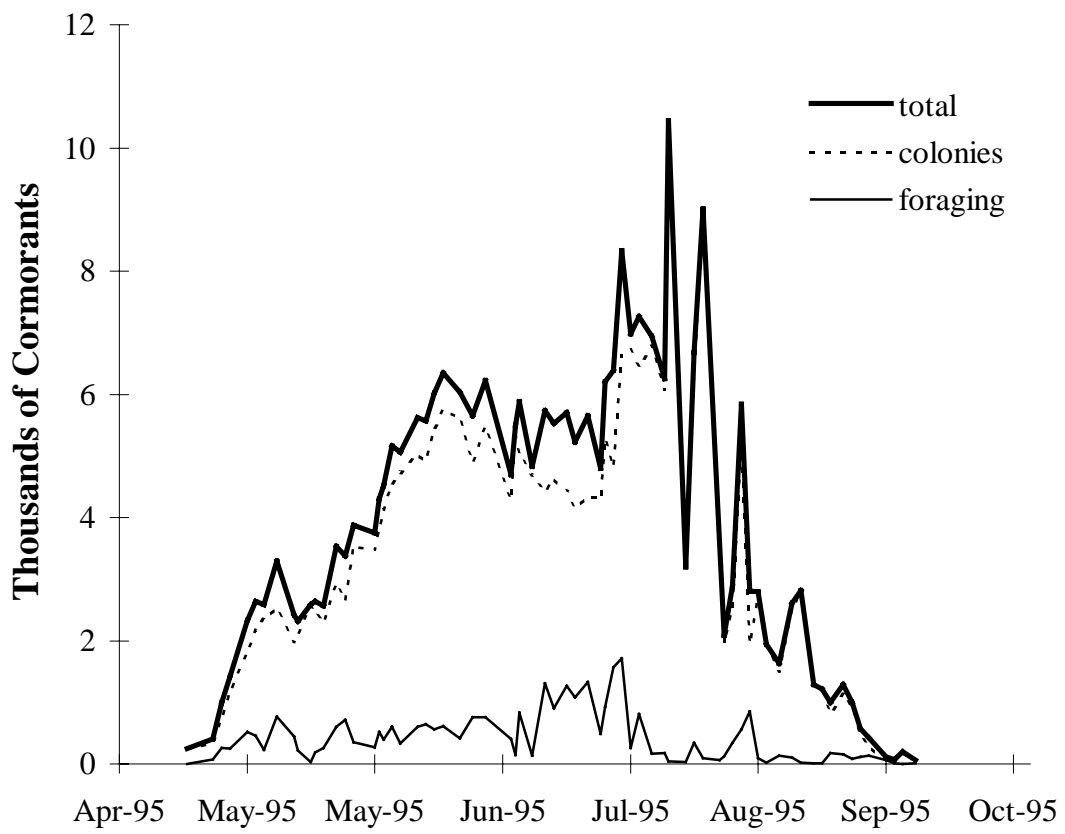
Figure 6-5.–Aerial counts of cormorants foraging within the study area or residing on colonies in Les Cheneaux Islands area.

Figure 6-6.–Cormorant equivalents (CE) for birds foraging in Les Cheneaux Islands area in 1995. See Equation 1 for the definition of CE.

Figure 6-7.–Mortality of different age classes of yellow perch in Les Cheneaux Islands area in 1995 caused by cormorant predation and by angling.

Table 6-1.–Prey items found in cormorant stomachs.

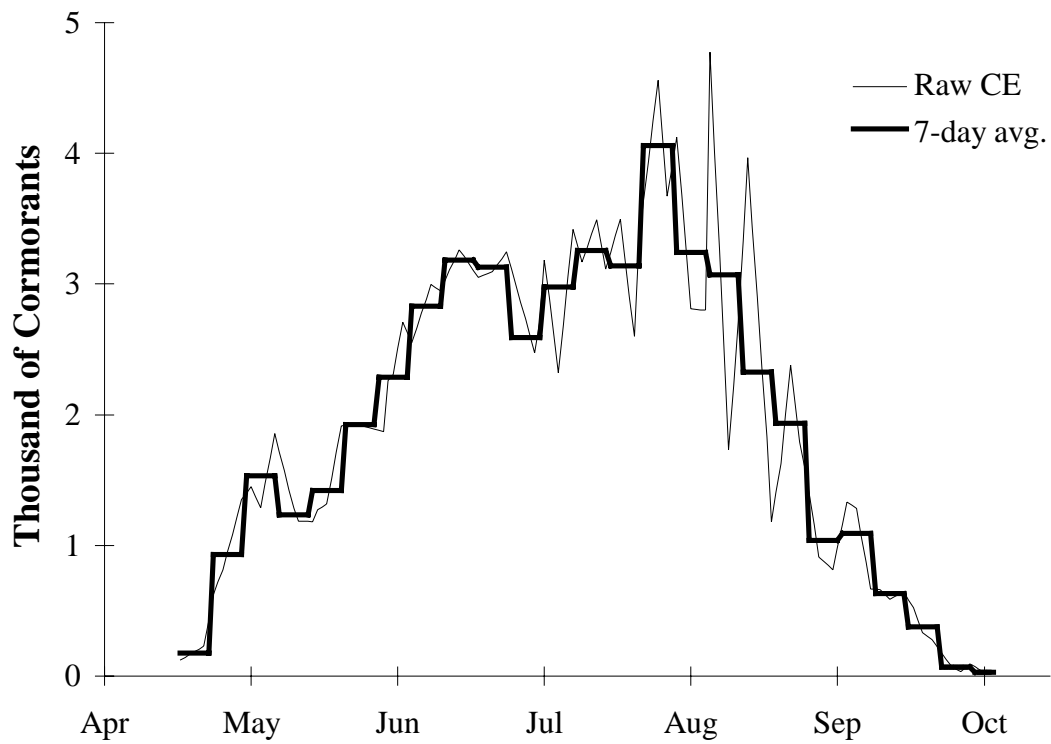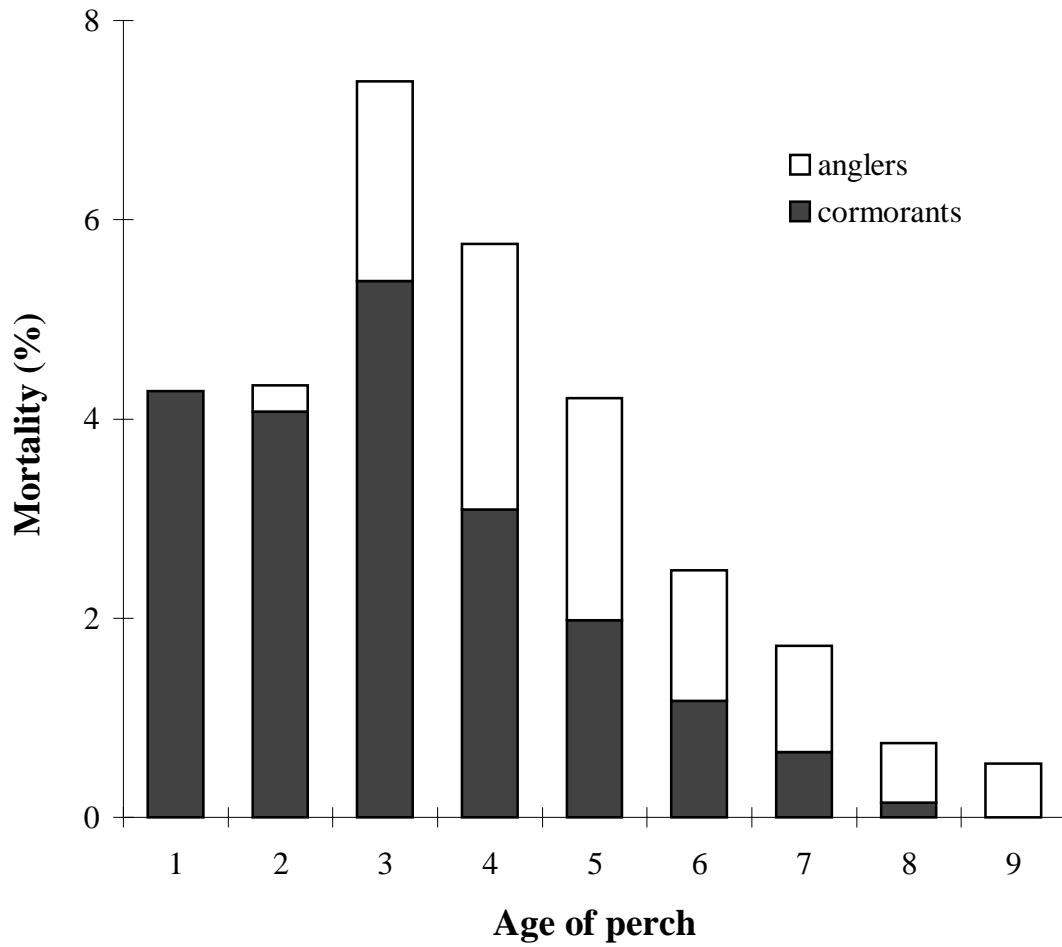| Family	Common name	Scientific name
Astacidae	Crayfish	
Catostomidae	Longnose sucker	*Catostomus catostomus*
	White sucker	*C. commersoni*
Centrarchidae	Pumpkinseed	*Lepomis gibbosus*
	Rock bass	*Ambloplites rupestris*
	Smallmouth bass	*Micropterus dolomieu*
Clupeidae	Alewife	*Alosa pseudoharengus*
	Gizzard shad	*Dorosoma cepedianum*
Cottidae	Mottled sculpin	*Cottus bairdi*
	Slimy sculpin	*C. cognatus*
	Spoonhead sculpin	*C. ricei*
Cyprinidae	Bluntnose minnow	*Pimephales notatus*
	Creek chub	*Semotilus atromaculatus*
	Longnose dace	*Rhinichthys cataractae*
	Shiner	*Notropis* spp.
Esocidae	Northern pike	*Esox lucius*
Gasterosteidae	Brook stickleback	*Culaea inconstans*
	Ninespine stickleback	*Pungitius pungitius*
	Threespine stickleback	*Gasterosteus aculeatus*
Ictaluridae	Brown bullhead	*Ameiurus nebulosus*
Lotidae	Burbot	*Lota lota*
Osmeridae	Rainbow smelt	*Osmerus mordax*
Percidae	Johnny darter	*Etheostoma nigrum*
	Yellow perch	*Perca flavescens*
Percopsidae	Trout-perch	*Percopsis omiscomaycus*
Petromyzontidae	Sea lamprey	*Petromyzon marinus*
Salmonidae	Bloater	*Coregonus hoyi*
	Lake whitefish	*Coregonus clupeaformis*
	Round whitefish	*Prosopium cylindraceum*
	Splake	*Salvelinus namaycush x S. fontinalis*

Table 6-2.–Dates and qualitative descriptions of the six dietary periods for cormorants in Les Cheneaux Islands area, Lake Huron, 1995.

Period	Dates	# days	# samples	Description
1	4/17 to 5/16	30	85	Perch spawning; pike and sunfish also important
2	5/17 to 7/3	48	97	Stickleback and larger (age > 1 yr.) alewife
3	7/4 to 8/1	29	67	Alewife spawning; many yearling alewife in diet
4	8/2 to 8/19	18	44	Diet highly diverse; alewife, sculpin, other prey
5	8/20 to 9/13	25	53	Young of year alewife, bullhead, and sunfish
6	9/14 to 10/6	23	27	Young of year alewife, yellow perch

Table 6-3a.–Frequencies for three-way loglinear analysis. Each adult bird was classified according to season sampled: perch spawning (period 1) or other (periods 2 to 4); sex: male (M) or female (F); and presence (+) or absence (-) of yellow perch in the stomach.

Season	Sex	Yellow perch	No. of birds
Period 1	F	+	22
Period 1	F	-	7
Period 1	M	+	11
Period 1	M	-	7
Periods 2 to 4	F	+	4
Periods 2 to 4	F	-	84
Periods 2 to 4	M	+	9
Periods 2 to 4	M	-	50

Table 6-3b.–Summary results of three-way loglinear analysis of season (T), sex (S), and yellow perch consumption (P) using the likelihood ratio statistic (G). The best model, selected using a combination of partitioning and stepwise procedures, is Model 3 (bold).

Model no.	Model $[\ln(E_{TSP}) =]$	df	G	P
1	$\mu + \mu_T + \mu_S + \mu_P$	4	73.52	<0.005
2	$\mu + \mu_T + \mu_S + \mu_P + \mu_{TS}$	3	73.47	<0.005
3	$\boldsymbol{\mu + \mu_T + \mu_S + \mu_P + \mu_{TP}}$	**3**	**6.13**	**0.106**
4	$\mu + \mu_T + \mu_S + \mu_P + \mu_{SP}$	3	73.16	<0.005
5	$\mu + \mu_T + \mu_S + \mu_P + \mu_{TS} + \mu_{TP}$	2	6.08	0.048
6	$\mu + \mu_T + \mu_S + \mu_P + \mu_{TS} + \mu_{SP}$	2	73.11	<0.005
7	$\mu + \mu_T + \mu_S + \mu_P + \mu_{TP} + \mu_{SP}$	2	5.77	0.056
8	$\mu + \mu_T + \mu_S + \mu_P + \mu_{TS} + \mu_{TP} + \mu_{SP}$	1	5.19	0.023

Table 6-4.—Diet composition of cormorants collected from Les Cheneaux Islands area in 1995. Values are percents by number (N) and biomass (B) of prey items from each prey category for each dietary period. A dash (-) represents less than 0.1 percent.

Prey Group	Period 1		Period 2		Period 3		Period 4		Period 5		Period 6		Total	
	N	B	N	B	N	B	N	B	N	B	N	B	N	B
Alewife	-	-	6.2	40.0	61.1	88.9	25.1	28.5	35.1	29.8	91.8	65.1	29.2	46.8
Stickleback	13.5	0.8	91.4	46.0	33.8	5.4	21.3	3.3	38.4	8.4	0.7	0.2	57.9	15.1
Yellow perch	42.1	47.7	0.2	1.2	0.4	0.9	1.6	7.0	-	-	0.4	13.9	2.1	10.5
Centrarchid	9.4	14.7	0.2	2.7	0.1	0.2	1.1	11.9	1.7	15.1	0.6	3.8	0.8	6.3
Sculpin	0.3	-	0.6	1.0	1.4	0.6	41.7	23.6	15.3	11.8	-	-	5.0	4.0
Northern pike	2.8	18.1	-	2.5	0.2	-	0.3	0.3	-	-	-	-	0.2	3.9
Minnow	24.0	4.1	-	-	0.3	0.2	1.6	1.1	3.7	2.3	4.7	9.2	2.1	1.6
White sucker	1.7	11.7	-	-	0.1	1.9	0.8	12.0	0.2	8.5	-	-	0.2	4.8
Brown bullhead	0.8	2.4	-	-	-	-	0.8	9.7	1.0	19.4	-	-	0.2	3.4
Smelt	0.8	-	0.5	0.4	1.8	0.4	-	-	0.5	-	0.1	-	0.7	0.2
Salmonid	-	-	0.1	1.3	0.2	1.4	-	-	0.2	0.7	-	-	0.1	0.9
Crayfish	3.3	0.2	0.4	0.2	0.2	-	4.4	0.8	1.7	0.4	-	-	0.9	0.2
Unidentified	0.6	-	-	0.1	0.2	-	0.8	0.4	0.5	0.3	0.1	0.1	0.2	0.1
Other	0.8	0.1	0.1	4.5	-	-	0.2	1.5	1.6	3.2	1.5	7.5	0.4	2.1

Table 6-5.–Study area usages for the three colonies of cormorants in Les Cheneaux Islands area, 1995. Number of nests are to the nearest hundred, taken from Chapter 3. Location is relative to the bounded study area (Figure 2-1).

Colony	No nests	Location	Study area usage
St. Martins Shoal	2000	~ 5 km W	0.26
Goose Island	1800	within	0.57
Crow Island	300	within	0.67

Table 6-6.–Daily caloric intake for cormorant nestlings as measured by Dunn (1975).

Age (days)	Mean DCI (kcal/day)
1 to 10	70
11 to 20	280
21 to 30	540
31 to 40	560
41 to 50	490

Table 6-7.–Daily caloric intake for cormorant breeders (B) and nonbreeders (NB), taken from Hennemann (1983).

Group	Days	Mean body weight (g)	DCI (kcal/day)
B	1 to 155	2200	550
NB	1 to 78	2100	540
NB	79 to 155	2000	520
All	156 to 173	2000	520

Table 6-8.–Relative proportions of breeding and nonbreeding cormorants in Les Cheneaux Islands area in 1995, as estimated from sampled birds. Distinctions were based on plumage characteristics.

Time period (days)	Proportion breeders	Proportion nonbreeders
1 to 30	0.99	0.01
31 to 78	0.92	0.08
79 to 107	0.77	0.23
108 to 125	0.54	0.46
126 to 155	0.40	0.60
156 to 173	0.00	1.00

Table 6-9.–Number of yellow perch from each size class (in thousands), and percent by size class of yellow perch age 1 and older consumed by cormorants (under low, best, and high estimates of cormorant consumption) and caught by anglers during 1995 for period 1, the period of perch spawning, and periods 2 to 6, the remainder of the year. Population estimates are in thousands. For population and angling data see Chapter 4.

Size (mm)	Population estimate	Consumed by cormorants						Caught by anglers	
		Low		Best		High			
		#	%	#	%	#	%	#	%
(a) Period 1 (17 April to 16 May 1995)									
25 to 50	8	0	0.0	0	0.0	0	0.0		
50 to 75	2,232	25.1	1.1	43.6	2.0	68.7	3.1		
75 to 100	2,234	44.8	2.0	77.7	3.5	122.3	5.5		
100 to 125	847	26.7	3.2	46.3	5.5	72.9	8.6		
125 to 150	1,717	33.6	2.0	58.2	3.4	91.8	5.3		
150 to 175	1,134	35.0	3.1	60.6	5.3	95.5	8.4		
175 to 200	640	5.7	0.9	9.9	1.5	15.5	2.4		
200 to 225	459	1.4	0.3	2.4	0.5	3.8	0.8		
225 to 375	529	0	0.0	0	0.0	0	0.0		
Totals:	9,800	172.3		298.7		470.5			
(b) Periods 2 to 6 (17 May to 16 October 1995)									
50 to 75	39	0	0.0	0	0.0	0	0.0	0	0.0
75 to 100	1,097	38.3	3.5	64.6	5.9	95.1	8.7	0	0.0
100 to 125	3,210	20.9	0.7	35.3	1.1	51.9	1.6	0	0.0
125 to 150	1,337	17.4	1.3	29.3	2.2	43.2	3.2	0	0.0
150 to 175	1,760	10.4	0.6	17.6	1.0	25.8	1.5	0.2	0.0
175 to 200	874	3.5	0.4	6.0	0.7	8.8	1.0	46.4	5.3
200 to 225	623	0.0	0.0	0.0	0.0	0.0	0.0	11.8	1.9
225 to 250	401	3.5	0.9	6.0	1.5	8.8	2.2	5.4	1.3
250 to 275	181	0	0.0	0	0.0	0	0.0	1.8	1.0
275 to 300	104	0	0.0	0	0.0	0	0.0	0.4	0.4
300 to 325	101	0	0.0	0	0.0	0	0.0	0.4	0.4
325 to 350	53	0	0.0	0	0.0	0	0.0	0.1	0.2
350 to 375	20	0	0.0	0	0.0	0	0.0	0	0.0
Totals:	9,800	94.0		158.8		233.6		67	

Table 6-10.–Number of yellow perch from each age class (in thousands), and percent by age class of the perch population age 1 and older eaten by cormorants (low, best, and high estimates) and taken by anglers in 1995. Size ranges are for April, prior to period of fastest growth. Totals for cormorant consumption do not include young-of-the-year. Population estimates are in thousands. For population and angling data see Chapter 4.

Age class	Approx. size range (mm)	Population estimate	Consumed by cormorants						Caught by anglers	
			Low		Best		High			
			#	%	#	%	#	%	#	%
1	25 to 150	4,416	127.6	2.9	218.9	5.0	335.1	7.6	0	0
2	50 to 200	2,429	66.9	2.8	115.0	4.7	177.5	7.3	6.4	0.3
3	75 to 225	1,336	48.7	3.6	83.9	6.3	130.1	9.7	26.8	2.0
4	100 to 275	735	15.3	2.1	26.4	3.6	41.1	5.6	19.6	2.7
5	125 to 350	404	5.4	1.3	9.3	2.3	14.2	3.5	9.0	2.2
6	150 to 350	222	1.7	0.8	3.0	1.4	4.5	2.0	2.9	1.3
7	150 to 350	122	0.6	0.5	1.0	0.8	1.5	1.2	1.3	1.1
8	175 to 350	67	0	0	0.1	0.1	0.1	0.1	0.4	0.6
9	225 to 350	37	0	0	0	0	0	0	0.2	0.5
10	300 to 350	20	0	0	0	0	0	0	0	0
11	300 to 375	11	0	0	0	0	0	0	0	0
	Totals:	9,799	266.2		457.6		704.1		67	

CHAPTER 7

SUMMARY AND CONCLUSIONS

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Cormorant Predation

The food habits of cormorants were estimated in 1995 by shooting 373 birds and analyzing their stomach contents (Chapter 6). The stomach analysis indicated that yellow perch were a large component of the cormorant diet during the early spring (47% by weight), decreased in the diet in late spring and early summer (less than 2% by weight), and increased slightly in the late summer and fall (14% by weight; Table 6-4). Cormorants ate predominantly small to medium sized yellow perch in the range of 75 to 150 mm (Figure 6-3), even during perch spawning in early spring.

We also estimated the number of cormorants foraging in Les Cheneaux Island study area. We conducted aerial counts of birds foraging in the study area and on nesting colonies at Crow Island, Goose Island, and St. Martin's Shoal an average of three times per week. All flights were conducted in early morning, and weekly averages were computed. We determined the proportion of birds observed on colonies during the flight count that were likely to forage in the study area at some other time of day, an important calculation since these birds represented the greatest contribution to our estimate of cormorant usage. The proportions were estimated from ground observations of cormorant movements at each colony at different times of day. Data were collected only during May and June 1995, and constant proportional usage of the study area was assumed throughout the year (Table 6-5). In general, total cormorant usage increased over the summer and peaked in July, consistent with cormorant migration and reproductive behavior. In 1995 cormorant use days numbered approximately 280,000 to 370,000 (Figure 6-6).

Total consumption by cormorants was estimated by combining cormorant usage with estimates of energetic requirements for cormorants. For the latter, separate estimates were made for breeding birds, non-breeding birds, and nestlings. In early spring, about 99% of the birds were breeding adults; this number gradually declined over the following weeks as more immature birds arrived in the area. By the end of the breeding season in August, there was no distinction between breeding and nonbreeding birds. The estimated daily caloric intake for breeding and non-breeding adult cormorants, as well as nestlings, was based on published allometric equations. Brood size was assumed to range from 3 to 3.5, and asynchronous breeding was incorporated into the calculation. Total calories required by the cormorant population was then the product of the number of cormorants foraging in the study area from each category and daily caloric intake. Calories were converted into weight of perch consumed using the percent by weight of perch in the cormorant diet (Table 6-4) and the estimated caloric density of fish (1.2 kcal per gram wet weight). Finally, we converted the weight of perch consumed into number consumed for each size group, using the size distribution of perch in the diet (Figure 6-3) and the average weight of perch in each size class.

Several methods were employed for estimating each input variable. Three estimates were made for daily caloric intake (low, medium, and high). The proportion of perch in the diet was determined using a linear regression of weight. The simulations were also run with low and high estimates ($\pm$ 10%, approximately) of the proportion of perch in the cormorant diet and cormorant usage to yield a lowest and highest reasonable estimate of perch consumption, a sort of "confidence interval". The best estimate of weight of perch eaten by cormorants was 11,400 kg, with a range of 6,600 to 17,500 kg. The number of perch eaten ranged from 270,000 to 720,000, with a best estimate of

470,000. The number of perch larger than 175 mm eaten ranged from 14,000 to 37,000, with a best estimate of 24,000.

Angler Catch and Perch Population Size

We acquired data on the status of the yellow perch population and fishery. According to the 1995 creel census, total catch from May through October 1995 was 66,469 (V=18,000), which is somewhat low compared to other years creel surveys were conducted. Catch per hour was fairly good at about 0.92 (Table 4-4). The estimate of catch excludes the winter fishery and will therefore be an underestimate of total catch for the year; however, we have anecdotal evidence to suggest that the winter fishery for 1995-1996 was negligible. The low summer catch in 1995 was due predominantly to relatively few angler hours, indicating low effort.

Mark-recapture analyses were performed on 8,463 tagged in April 1995. The size of the yellow perch fishery in 1995, estimated from tag returns, was about 2,760,000 (Table 4-7). This estimate includes perch 150 mm and larger at the time of tagging (April), all of which were expected to be recruited into the fishery (175 mm and larger) during the summer. Population size for younger fish and mortality rates were estimated from a catch curve obtained from the fall gill netting survey. Because data on small perch collected in Les Cheneaux Islands area were sparse, we used length-at-age data from Bays de Noc, Lake Michigan, since these two populations experience similar climatic conditions and show comparable growth rates. We estimated the total number of fish per size and age group using the measured total mortality rate (Table 4-8). Numbers per size group reflect the population size distribution in April, prior to the main growth period for perch. Total population size for perch age 1 and older was 9.8 million. Total mortality rate from the 1995 fall gill net data was estimated at 45% (compared with 55% in 1986), and the 1994-95 tagging data yielded a similar total mortality rate of 47% using the Brownie Model formulae.

Evaluation

The following evaluation pertains to perch age 1 and older; however, cormorants consumed an estimated 7,000 to 17,000 YOY perch in 1995. Because recruitment of YOY into yearling perch is highly variable, the exact effect of cormorant predation on recruitment is unknown without a measure of YOY production. However, yellow perch recruitment is variable throughout the Great Lakes and does not appear to be correlated with the presence of avian predators. We presume that other sources of mortality are more important for this life stage.

Our estimate of the biomass of yellow perch age 1 and older in Les Cheneaux Islands is 417,800 kg (923,300 lb.). The study area contains roughly 11,860 ha (29,317 acres) of water, which yields a biomass density of 35.2 kg/ha. During May through October 1995, approximately 7,350 kg (16,250 lb.) or 1.8% of the biomass of perch was removed by anglers, and during all of 1995 a total of 11,400 kg (21,690 lb.) or 2.7% of the biomass was removed by cormorants.

In order to assess the size-specific mortality from cormorant predation, it was necessary to examine separately the perch spawning season and the rest of the year (Table 6-9). The perch population size structure is quite different early in the year before the period of yellow perch growth, and cormorant predation is also heaviest at that time, as 60 to 70% of perch consumed were eaten before mid-May. We applied two separate length-at-age keys developed from Bays de Noc data, one for April and one for May to October, to the perch population age structure determined from the catch curve, in order to yield two distinct size distributions for the perch population. The size-specific population estimates in periods 2 to 6 do not reflect mortality that had occurred prior to period 2 (mid-May). The creel census showed no angler harvest between 1 May and the conclusion of perch spawning, and therefore mortality from angling was included only in periods 2 to 6. Please note, however, that angler catch does not reflect any perch caught immediately after ice-out in late April. Our

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results (Table 6-9) show that mortality from cormorant predation is heaviest at small sizes, 75 to 150 mm in early spring and less than 75 to 125 mm during other times while angling mortality is greatest at 175 to 225 mm. Neither is a significant source of mortality at any size or time of year. Examination of mortality rates by age classes (Table 6-10) reveals that even the highest estimate for cormorant consumption of perch yields mortality rates that are less than 10% for any given age, which accounts for about one-fifth or less of the total annual mortality (45%). Mortality from summer angling is less than 3% for all age classes, which is less than one-fifteenth of total annual mortality.

Mortality of legal-size perch due to cormorant predation and summer sport fishing in 1995 was not significant, when compared with all other sources combined. With 2.76 million fish in the yellow perch fishery of Les Cheneaux Islands, a take of 24,000 by cormorants is a removal of only 0.9% of the population by number. A catch of 66,500 gives a summer angler exploitation rate of only 2.5%. For comparison, the exploitation rate from tag returns during the May to October 1995 fishing season amounted to 2.6% of all perch tagged, including those that were sublegal when tagged but larger than 175 mm when caught. Other sources of mortality must then remove roughly 40% of legal-size perch to give a total annual mortality of 45%.

A greater concern with cormorants may be their effect on small fish. In particular, fish 75 to 125 mm in length appeared to be more uniformly vulnerable to cormorants. However, it is not clear whether mortality on small perch caused by cormorants occurs in addition to other substantial sources of mortality (additive), or rather replaces these other sources (compensatory). If mortality from cormorant predation is additive to other sources of mortality at small sizes, the future abundance of large fish could possibly be reduced, although current predation rates suggest that this effect will not be substantial.

A final important consideration is how the year-to-year variation in cormorant consumption of perch will affect perch population dynamics.

Specifically, the timing of perch spawning relative to cormorant migration may affect the number and sizes of perch that are vulnerable to heavy cormorant predation. In 1995 perch spawning was early, and many of the larger spawning fish may not have been susceptible to cormorant predation because they had dispersed before cormorants arrived in the area. In 1996 spawning was late and peaked with cormorants present in the study area. However, we do not know whether perch composed a greater proportion of the cormorant diet or if the size distribution of perch consumed was different in 1996 compared with 1995. To determine possible impacts of increased predation or altered size selectivity during perch spawning, we conducted two simulations with the best 1995 estimates for all input variables, changing first only the proportion of perch in the cormorant diet during spawning, then also altering the size distribution to include more large fish. Allowing perch to compose 90% of the diet during the first 30 days, the estimated number of perch consumed was increased by 66% (780,000 perch consumed, compared with 470,000). However, the highest mortality rate, at age 3, was 11.3%, somewhat small compared with total annual mortality. Then allowing the proportion of 150-mm-and-longer perch to increase from 0.24 (as in 1995) to 0.50 for perch consumed during spawning, the estimated total number consumed fell back to 580,000. The cormorant-caused mortality rates declined for ages 1 to 3 and increased for ages 4 and older compared with mortality rates from the first 1996 simulation. The highest rate for all ages still occurred at age 3 and was 10.7%. We conclude that reasonable year-to-year variation in cormorant predation of perch during perch spawning will not drastically alter age-specific mortality rates, provided perch and cormorant population sizes are comparable to 1995 estimates. However, over the long term, changes in predatory behavior of cormorants, ecological plasticity regarding the timing or location of perch spawning, and population fluctuations for either cormorants or perch may influence the importance of yearly variation in predation.

Yellow Perch Population Trends

The depressed population of yellow perch is not unique to Les Cheneaux Islands, but has been observed in many other areas of the Great Lakes. Abundance of perch in Les Cheneaux Islands was low during 1985 to 1994, but fall gill net surveys indicate an increased catch-per-effort in 1994-1995 (Figure 4-1). There also appeared to be several strong year classes in the population (1989, 1991, and possibly 1993 year classes). However, preliminary 1996 gill net data indicate the lowest catch per effort in recent times. These results make it difficult to forecast perch population trends in Les Cheneaux Islands area.

Acknowledgments

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APPENDIX 1

LIST OF COMMON AND SCIENTIFIC NAMES OF ORGANISMS
USED IN THIS REPORT

Common name	Scientific name	Common name	Scientific name
Alewife	*Alosa pseudoharengus*	Mud puppy	*Necturus malculosus*
Bloater	*Coregonus hoyi*	Ninespine stickleback	*Pungitius pungitius*
Bluntnose minnow	*Pimephales notatus*	Northern pike	*Esox lucius*
Brook stickleback	*Culaea inconstans*	Pumpkinseed	*Lepomis gibbosus*
Brown bullhead	*Ameiurus nebulosus*	Rainbow smelt	*Osmerus mordax*
Burbot	*Lota lota*	Ring-billed gull	*Larus delawarensis*
Cape cormorant	*Phalacrocorax capensis*	Rock bass	*Ambloplites rupestris*
Caspian tern	*Sterna caspia*	Round whitefish	*Prosopium cylindraceum*
Crayfish	Family Astacidae	Shiner	*Notropis* spp.
Creek chub	*Semotilus atromaculatus*	Slimy sculpin	*Cottus cognatus*
Double-crested cormorant	*Phalacrocorax auritus*	Smallmouth bass	*Micropterus dolomieu*
Gizzard shad	*Dorosoma cepedianum*	Splake	*Salvelinus namaycush x S. fontinalis*
Herring gull	*Larus argentatus*	Spoonhead sculpin	*Cottus ricei*
Johnny darter	*Etheostoma nigrum*	Threespine stickleback	*Gasterosteus aculeatus*
Lake trout	*Salvelinus namaycush*	Trout perch	*Percopsis omiscomaycus*
Lake whitefish	*Coregonus clupeaformis*	Walleye	*Stizostedion vitreum*
Lamprey	Family Petromyzontidae	White pelican	*Pelecanus erythrorhynchos*
Longnose dace	*Rhinichthys cataractae*	White sucker	*Catostomus commersoni*
Longnose sucker	*Catostomus catostomus*	Yellow perch	*Perca flavescens*
Loon	*Gavia immer*	Zebra mussel	*Dreissena polymorpha*
Mottled sculpin	*Cottus bairdi*		

RETURNS OF BANDED CORMORANTS FROM THE FOOD HABIT STUDY

Glenn Y. Belyea

Of the 373 cormorants collected for the food habits study (Chapter 6), 53 (14.2%) were leg banded. These birds were banded at their respective nesting colony prior to fledging. Nearly every known nesting colony in northern Lake Huron, northern Lake Michigan and eastern Lake Superior was represented (Appendix Table 2-1). It is not surprising in a large and rapidly expanding population such as this to have a mixing of birds from various colonies. Some of the colonies represented were a surprisingly long distance away. The farthest colony represented was Sister Island, Green Bay, Wisconsin, which is approximately 235 km from the recovery location.

The oldest banded bird collected was 11 years old and 25 (47.2%) birds were 5 or more years old. Not including young-of-the-year birds, the average age of the banded cormorants was 5.9 years. The number of older birds would indicate that cormorants have high longevity and probably high survival. A number of the cormorants collected in late summer were young of the year. Most were from colonies within Les Cheneaux Islands area, but 3 were from Canadian colonies in the North Channel of Lake Huron. This demonstrates how early some young birds leave the nesting colonies to begin migrating south.

Appendix Table 2-1.–Data on banded cormorants collected in Les Cheneaux Islands area in 1995.

Band number	Banding location	Date banded	Date collected	Age (yr)
638-12629	St. Martins Shoal, Northern Lake Huron	7/13/91	6/19/95	3.9
767-82401	Middle Grant Island, North Channel, Lake Huron	6/23/95	8/23/95	0.2
767-82435	Middle Grant Island, North Channel, Lake Huron	6/23/95	9/14/95	0.2
768-80225	Pigeon Island, Lake Ontario	6/21/86	6/7/95	9.0
798-52160	West Island, North Channel, Lake Huron	6/29/87	5/7/95	7.9
798-53847	Wheeler Reef, Northern Lake Huron	6/24/88	6/16/95	7.0
937-62747	Black River Island, Lake Huron	7/7/88	7/24/95	7.0
977-57715	Sister Island, Green Bay, Wisconsin, Lake Michigan	6/23/88	5/16/95	6.9
1117-08850	St. Martins Shoal, Northern Lake Huron	6/22/86	6/11/95	9.0
1117-08982	St. Martins Shoal, Northern Lake Huron	6/22/86	5/5/95	8.9
1117-08998	St. Martins Shoal, Northern Lake Huron	6/22/86	6/3/95	9.0
1137-66197	St. Martins Shoal, Northern Lake Huron	7/10/84	7/1/95	11.0
1137-71098	Little Gull Island, Green Bay, Lake Michigan	7/15/87	8/23/95	8.1
1137-71166	Little Gull Island, Green Bay, Lake Michigan	7/15/87	6/1/95	7.9
1137-81263	Hat Island, Northern Lake Michigan	6/18/87	6/22/95	8.0
1137-81633	St. Martins Shoal, Northern Lake Huron	6/21/87	7/4/95	8.0
1137-81668	St. Martins Shoal, Northern Lake Huron	6/21/87	4/27/95	7.9

Appendix Table 2-1.–Continued.

Band number	Banding location	Date banded	Date collected	Age (yr)
1137-81700	St. Martins Shoal, Northern Lake Huron	6/21/87	7/20/95	8.1
1137-81800	St. Martins Shoal, Northern Lake Huron	6/21/87	6/15/95	8.0
1137-82344	St. Martins Shoal, Northern Lake Huron	7/14/87	8/6/95	8.1
1227-15252	St. Martins Shoal, Northern Lake Huron	6/15/88	6/21/95	7.0
1227-18430	St. Martins Shoal, Northern Lake Huron	7/2/88	5/9/95	6.9
1227-18810	Goose Island, Lake Huron	7/2/88	7/29/95	7.1
1227-18813	Goose Island, Lake Huron	7/2/88	5/9/95	6.9
1227-19098	Grape Island, Northern Lake Michigan	7/4/88	7/24/95	7.1
1227-37664	Tahquamenon Island, Lake Superior	6/15/94	8/13/95	1.2
1227-56269	St. Martins Shoal, Northern Lake Huron	6/17/90	6/22/95	5.0
1227-58383	Tahquamenon Island, Lake Superior	6/22/92	4/29/95	2.9
1247-10747	Africa Rocks, North Channel, Lake Huron	7/11/89	9/20/95	6.2
1247-15158	St. Martins Shoal, Northern Lake Huron	6/9/89	4/29/95	5.9
1247-21690	Tahquamenon Island, Lake Superior	6/19/91	5/15/95	3.9
1247-23371	Cousins Island, North Channel, Lake Huron	6/29/90	5/26/95	4.9
1247-25255	Tahquamenon Island, Lake Superior	6/19/91	6/19/95	4.0
1247-30318	Herbert Island, North Channel, Lake Huron	6/15/91	6/11/95	4.0
1247-33735	Doucet Rock, North Channel, Lake Huron	6/19/91	5/5/95	3.9
1247-33858	Doucet Rock, North Channel, Lake Huron	6/19/91	9/12/95	4.2
1247-34716	West Island, North Channel, Lake Huron	6/19/91	4/25/95	3.9
1247-39523	Goose Island, Northern Lake Huron	7/13/91	5/2/95	3.8
1247-45308	St. Martins Shoal, Northern Lake Huron	6/23/92	8/6/95	3.1
1247-65299	St. Martins Shoal, Northern Lake Huron	6/22/93	5/26/95	1.9
1247-65662	St. Martins Shoal, Northern Lake Huron	6/22/93	7/19/95	2.1
1247-66837	Naubinway Island, Northern Lake Michigan	7/4/95	9/6/95	0.2
1247-66844	Naubinway Island, Northern Lake Michigan	7/4/95	8/24/95	0.1
1247-67043	Crow Island, Northern Lake Huron	7/5/95	8/19/95	0.1
1247-67045	Crow Island, Northern Lake Huron	7/5/95	8/24/95	0.1
1247-67053	Crow Island, Northern Lake Huron	7/5/95	8/24/95	0.1
1247-67053	Crow Island, Northern Lake Huron	7/5/95	8/24/95	0.1
1247-67061	Crow Island, Northern Lake Huron	7/5/95	8/10/95	0.0
1247-67129	Crow Island, Northern Lake Huron	7/5/95	8/19/95	0.1
1247-67137	Crow Island, Northern Lake Huron	7/5/95	9/8/95	0.2
1247-67874	St. Martins Shoal, Northern Lake Huron	7/6/95	9/7/95	0.2
1247-86703	Elm Island, North Channel, Lake Huron	6/21/95	8/19/95	0.2
1247-88960	Crow Island, Northern Lake Huron	6/22/94	7/8/95	1.0
1247-88994	West Saddlebag Reef, Northern Lake Huron	6/22/94	7/8/95	1.0

RETENTION OF METAL JAW TAGS IN THE STOMACHS
OF CAPTIVE CORMORANTS

Glenn Y. Belyea

Monel metal jaw tags were placed on nearly 10,000 yellow perch in Les Cheneaux Islands area in the spring of 1994 and 1995 by MDNR fisheries personnel as part of a research study to determine the impact of cormorant predation on the yellow perch population. In an effort to determine retention time and rate of decay of jaw tags in cormorant stomachs, cormorants were fed tagged and untagged yellow perch in a captive situation. Three fledging age cormorants were captured on 2 August 1994 at West Saddlebag Reef, Chippewa County and transported to the Rose Lake Wildlife Research Center near East Lansing. The cormorants were housed in a 5-m diameter by 4-m high corn crib. The crib had a concrete floor, several high and low perch sites, and a 2-m diameter wading pool filled with water. The birds were individually marked with a colored leg band and they were hand fed 75 to 200 mm long captive-reared yellow perch twice daily. After a week of acclimation to this procedure, they appeared to be well adjusted and feeding trials with individually numbered tagged perch began on 9 August. Thus, jaw tags were easily identifiable to individual birds. Initially 2 tagged perch were fed to each of the three birds, then 2 more on the following day. Four tags per bird seemed to be a reasonable number to try to maintain in the stomachs. The floor of the pen was checked for expelled tags and then spray cleaned twice daily. Band numbers of expelled tags were recorded. An appropriate number of tagged perch were fed to birds that expelled the collected tags to maintain a total of 4 tags in each bird's stomach.

The feeding study continued until 2 September (24 days). After 24 days, enough tags had been recovered (Appendix Table 3-1) to conclude that tags were not damaged in cormorant stomachs and would be individually identifiable either in the stomachs of collected birds or in regurgitated pellets recovered at the nesting colonies. A total of 40 tagged perch were fed to the 3 birds. Individual birds received 6, 14, and 20 tags, respectively, depending upon the retention time and the replacement rate necessary to maintain a total of 4 in each stomach. All tags found expelled by cormorants were regurgitated in pellets; none were associated with excrement. While regurgitated tags were somewhat darkened and discolored, all were easily readable and no erosion of the metal was evident, even after a 23-day exposure in the stomach.

Initially this study was going to determine retention time and rate for decay of the tags, but only an assessment of tag damage was made. It was soon evident that a determination of tag retention time from captive cormorants would be very difficult and misleading. Retention time varied greatly among birds (even within a single bird), and it was obvious that much of this was caused by the captive situation which required twice daily disturbances to force-feed the birds and check for regurgitated tags. This disturbance sometimes caused the birds to prematurely regurgitate perch and perch tags. It appears that cormorants regurgitate tags often enough to prevent any real tag erosion in their stomachs.

During the initial portion of this feeding study, several of the birds were x-rayed to determine the fate of the tags. Three days had passed and no tags had been found in the regurgitant. There was concern that tags might have been missed on the pen floor or totally eroded in the stomach. The x-rays showed them to be fully intact in the bottom of the stomach. Eventually, these tags were all regurgitated or still present in the stomachs when the study was terminated and the birds were sacrificed and necropsied. Seven tags, however, could not be found. I believe these were overlooked in the search for regurgitated tags on the pen floor, but they may have been expelled outside of the pen into the surrounding grass. In either case, I do not believe they were digested since all other tags, even those retained for 23 days, showed no sign of erosion.

Appendix Table 3-1.–Retention time of fish jaw tags fed to cormorants.

Perch tag number	Date in	Date out	Total days in gut
Male 1			
543	8/10	9/1	21
548	8/10	[a]	–
550	8/9	9/2	23
554	8/9	8/30	21
555	8/11	8/30	19
556	8/11	[a]	–
Male 2			
544	8/10	8/16	6
546	8/10	8/16	6
549	8/9	8/16	7
552	8/9	8/16	7
557	8/11	8/16	5
560	8/11	8/16	5
561	8/17	8/26	9
562	8/16	8/23	7
563	8/18	8/23	5
564	8/17	8/26	9
565	8/18	[a]	–
566	8/16	8/23	7
567	8/29	9/1	3
568	8/29	9/1	3
579	8/25	[a]	–
581	8/25	8/26	1
584	8/25	8/26	1
597	8/26	8/28	2
598	8/26	[a]	–
600	8/26	[a]	–
Female			
545	8/10	8/18	8
547	8/10	8/23	13
551	8/9	8/23	14
553	8/9	8/31	22
558	8/11	8/29	18
559	8/11	8/18	7
569	8/29	Necropsy	
570	8/29	8/31	2
571	8/30	9/1	2
572	8/30	Necropsy	
580	8/25	8/29	4
582	8/25	[a]	–
583	8/25	8/29	4
599	8/26	8/29	3

[a] Tags not found.

APPENDIX 4

LOSS OF JAW TAGS BY YELLOW PERCH

Susan L. Maruca

Objective:

To estimate long-term loss rates for metal jaw tags from yellow perch.

Methods:

In late March and early April 1995, 500 adult yellow perch (length > 150 mm) were collected from Lake St. Clair using trap nets. Lengths and weights were measured for each fish, sexes and reproductive state were recorded when possible, and metal identification tags were placed in the jaw of each fish. The fish were then stocked in three drainable ponds at the Saline Fisheries Research Station in Saline, Michigan. The ponds were drained at intervals of approximately one month, six months, and one year. Weights, lengths, and tag retention were measured for all recovered perch. The large-sample normal approximation for the binomial distribution was used to calculate 95% confidence intervals for tag loss rate.

The relationship between perch size and probability of recovery was examined using 2-way χ^2 tests of independence for each pond. To assess differences in mean growth among ponds (and therefore length of time in ponds), an analysis of covariance (ANCOVA) was performed, with absolute growth as the dependent variable, pond as the independent variable, and length at stocking as a covariate. A regression analysis was performed separately for each pond to determine the relationship between length at stocking and growth.

Results:

All yellow perch recovered retained tags. The 95% confidence intervals were 0 to 3% tag loss for 40 days, 0 to 5% for 187 days, and 0 to 7% for 369 days (Appendix Table 4-1). Tag loss does not appear to be an important factor in estimating population size or angler exploitation rate from mark-recapture data when metal jaw tags are used.

There was no relationship between size of fish and probability of recovery for any of the three ponds (Appendix Table 4-2). Mortality in all three ponds appears to be size-independent.

Growth data for all fish in all ponds is displayed in Appendix Figure 4-1. For each pond, regression analysis showed that there was a significant linear relationship between growth and length at stocking (all $P < 0.005$) where smaller fish tended to grow more than larger fish. The ANCOVA results showed that although length at stocking accounted for a significant amount of variation in growth (F = 29.3; df = 1,174; $P < 0.001$), differences in growth among ponds were significant (F = 36.3; df = 2,174; $P < 0.00001$). Multiple comparisons (Bonferroni's method) of the adjusted means (Appendix Table 4-3) showed that growth for pond 1 was significantly different from ponds 2 and 3 (both $P < 0.00001$); however, growth for ponds 2 and 3 was not different (P = 0.64), indicating that most growth occurred between May 10 and October 4.
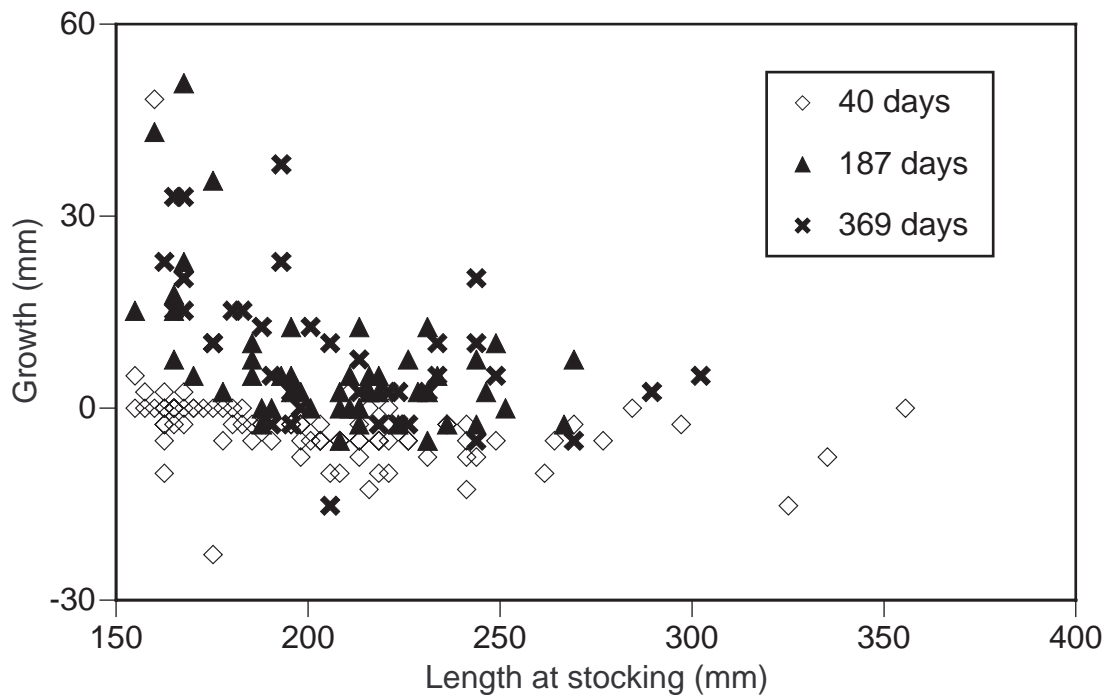
Appendix Figure 4-1.–Absolute growth (mm) for all perch recovered from ponds as related to length at stocking.

Appendix Table 4-1.–Estimated tag loss rate for yellow perch over intervals of about one month, six months, and one year.

Pond	Date stocked	Date recovered	Days in pond	Number stocked	Number recovered	Recovered w/ tags	Tag loss rate	95% CI for tag loss rate
1	4/3/95	5/10/95	40	166	89	89	0	0 - 0.030
2	3/30/95	10/4/95	187	167	51	51	0	0 - 0.050
3	3/30/95	4/4/96	369	167	38	38	0	0 - 0.066

Appendix Table 4-2.–Results of the χ^2 tests of independence for size of perch and the probability of recovery. For each pond, perch were classified as recovered or not recovered, and as small (150 to 190 mm), medium (190 to 225 mm), or large (>225 mm).

Pond	χ^2	d.f.	P-value
1	1.72	2	0.42
2	0.42	2	0.81
3	0.89	2	0.64

Appendix Table 4-3.–Adjusted mean growth (AMG) of yellow perch. AMG is the absolute growth (mm) adjusted for variation in growth related to variation in length at stocking. Differences in AMG are related only to ponds.

Pond	Adjusted mean growth (mm)	N
1	-3.30	89
2	6.60	51
3	8.89	38

APPENDIX 5

BASIC PROGRAM "SEASON.BAS" FOR ESTIMATING SEASONAL TIME PERIODS FOR PREY CONSUMPTION ANALYSIS

Susan L. Maruca

```
DECLARE SUB AGGREGATE ()
DECLARE SUB CHISQUARE (x2!)
'Program season

' This program is designed to calculate cutoff dates for my 1995
'   cormorant diet data.  User selects the number of cutoff dates
'   and gives ranges for each; the program selects dates such that
'   the Chi-square statistic is maximum.  This is an iterative
'   procedure, which continues until the dates converge.


'VARIABLES
DIM dietday%(2300)   'day numbers for diet data
DIM fishspec%(2300)  'species numbers
DIM nofish%(2300)        'number of fish per species (per stomach)
DIM cutoff1(10)      'first date in range for each cutoff
DIM cutoff2(10)      'last date in range for each cutoff
DIM cutofftemp(10)   'this round's cutoff dates
DIM cutoff(10)           'last round's cutoff dates (actual cutoffs upon
                     '   convergence)
DIM cutoffcalc(10)   'cutoffs to use in calculation
DIM table(11, 8)     'contingency table for season, prey group

'Global variables
COMMON SHARED dietday%(), fishspec%(), nofish%(), cutofftemp()
COMMON SHARED table()
COMMON SHARED arraysize, nocutoffs, noseasons, findate

arraysize = 0    'size of above arrays
nocutoffs = 0    'number of cutoff dates desired
noseasons = 0    'number of seasons
findate = 0      'the last date of interest


'Input data from file
CLS
INPUT "Input file name?"; infile$
OPEN infile$ FOR INPUT AS #1
i = 0
WHILE NOT EOF(1)
    INPUT #1, dietday%(i), fishspec%(i), nofish%(i)
    'PRINT dietday(i), stomach(i), fishspec(i), nofish(i)
    i = i + 1
WEND
CLOSE #1

arraysize = i - 1
findate = dietday%(arraysize)
PRINT : PRINT : PRINT "Array size is "; arraysize
PRINT

'INPUT "To continue, hit return", junk$
'get cutoff information
PRINT "Please input the following information on season cutoff dates."
INPUT "Number of cutoff dates desired (<=10)?"; nocutoffs
noseasons = nocutoffs + 1
FOR j = 1 TO nocutoffs
    PRINT "First date of range for season "; j; " cutoff?"
```

```
    INPUT cutoff1(j)
    PRINT "Last date of range for season "; j; " cutoff?"
    INPUT cutoff2(j)
    NEXT j
PRINT : PRINT "The last date of season "; noseasons; " is assumed to be "; findate


'Maximization of Chi-square

'Initializing cutoff
FOR k = 1 TO nocutoffs
    cutoff(k) = cutoff1(k)
    cutofftemp(k) = cutoff1(k)
    NEXT k

i = 0
j = 0
round = 0

'Iterative loop -- repeat until cutofftemp=cutoff
DO

    'next round
    round = round + 1

    'optimize each cutoff date
    FOR i = 1 TO nocutoffs

        chi2maxtemp = 0
        bestj = cutofftemp(i)

        FOR j = cutoff1(i) TO cutoff2(i)
            cutofftemp(i) = j
            CALL AGGREGATE
            CALL CHISQUARE(chi2)
            'IF chi2 = chi2maxtemp THEN
                'PRINT "Tie for cutoff # "; i; ", days "; bestj; j
                'PRINT "Keeping day = "; bestj; " as the optimum day so far."
                'PRINT
            IF chi2 > chi2maxtemp THEN
                chi2maxtemp = chi2
                bestj = j
                END IF
            NEXT j

        'save the maximum
        cutofftemp(i) = bestj

        NEXT i

    'save chi2maxtemp at end of a round
    chi2max = chi2maxtemp
    'check cutoff and cutofftemp
    flag = 0
    FOR i = 1 TO nocutoffs
        IF cutofftemp(i) <> cutoff(i) THEN
            flag = flag + 1
            cutoff(i) = cutofftemp(i)
            END IF
        NEXT i
    PRINT "round = "; round
    PRINT "flag = "; flag

    LOOP UNTIL flag = 0


'Print results
PRINT : PRINT
PRINT "Results:"
```

```
PRINT "---------"
PRINT
PRINT "Iterations:", round
PRINT "Chi-square:", chi2max
FOR i = 1 TO nocutoffs
    PRINT "Season "; i; " cutoff day:", cutoff(i)
    NEXT i
PRINT "Note: Cutoff days are the last days for each season."

END


SUB AGGREGATE
'Procedure to aggregate data

DIM beginon(10)         'beginning dates for all seasons
DIM endon(10)           'ending dates for all seasons

'Clear contingency table
FOR n = 1 TO noseasons
    FOR m = 1 TO 7
        table(n, m) = 0
    NEXT m
NEXT n

'set beginon and endon
FOR i = 1 TO noseasons
    IF i = noseasons THEN endon(i) = findate ELSE endon(i) = cutofftemp(i)
    IF i = 1 THEN beginon(i) = 1 ELSE beginon(i) = cutofftemp(i - 1) + 1
    NEXT i


FOR k = 1 TO arraysize

    'determine season
    FOR i = 1 TO noseasons
        IF dietday%(k) >= beginon(i) AND dietday%(k) <= endon(i) THEN season = i
        NEXT i

    'determine preygroup
    SELECT CASE fishspec%(k)
    CASE 1
        preygroup = 1    'alewives
    CASE 30
        preygroup = 2    'perch
    CASE 16, 18, 23, 33
        preygroup = 3    'centrarchid
    CASE 5, 14, 26, 31
        preygroup = 4    'sticklebacks
    CASE 22, 25, 34, 35
        preygroup = 5    'sculpin
    CASE 4, 9, 21, 36, 37
        preygroup = 6    'cyprinid
    CASE ELSE
        preygroup = 7    'other
    END SELECT

    'increment table
    LET table(season, preygroup) = table(season, preygroup) + nofish%(k)

    NEXT k

END SUB

SUB CHISQUARE (x2)

'procedure to calculate the chisquare value for table(n,m)

'imagine a chi-square table with n rows (seasons) and m columns (prey groups)
```

```
DIM rowtotal(10)
DIM coltotal(8)
DIM expected(10, 8)

CONST noprey = 7
total = 0
x2 = 0

'clear rowtotal and coltotal arrays
FOR n = 1 TO noseasons
    rowtotal(n) = 0
    NEXT n
FOR m = 1 TO noprey
    coltotal(m) = 0
    NEXT m

'clear expected array
FOR n = 1 TO noseasons
    FOR m = 1 TO noprey
        expected(n, m) = 0
        NEXT m
    NEXT n

'calculate row totals
FOR n = 1 TO noseasons
    FOR m = 1 TO noprey
        rowtotal(n) = rowtotal(n) + table(n, m)
        NEXT m
    NEXT n

'calculate column totals
FOR m = 1 TO noprey
    FOR n = 1 TO noseasons
        coltotal(m) = coltotal(m) + table(n, m)
        NEXT n
    NEXT m

'calculate total
FOR n = 1 TO noseasons
    total = total + rowtotal(n)
    NEXT n

'calculated expected values
FOR n = 1 TO noseasons
    FOR m = 1 TO noprey
        expected(n, m) = rowtotal(n) * coltotal(m) / total
        NEXT m
    NEXT n

'test tough and dirty rule
lessthan5 = 0
lessthan1 = 0
exps = noseasons * noprey
FOR n = 1 TO noseasons
    FOR m = 1 TO noprey
        IF expected(n, m) < 5 THEN lessthan5 = lessthan5 + 1
        IF expected(n, m) < 1 THEN
            lessthan1 = lessthan1 + 1
            nviol = n
            mviol = m
            END IF
        NEXT m
    NEXT n
perc5 = lessthan5 / exps
IF perc5 > .2 THEN PRINT "WARNING:  VIOLATION OF TOUGH AND DIRTY RULE (5)!!"
IF lessthan1 > 1 THEN
        PRINT "WARNING: VIOLATION OF TOUGH AND DIRTY RULE (1)!!"
        PRINT "n = "; nviol; " and m = "; mviol
        END IF
```

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```
'calculate chi-square statistic
FOR n = 1 TO noseasons
    FOR m = 1 TO noprey
        x2 = x2 + table(n, m) ^ 2 / expected(n, m) - 2 * table(n, m) + expected(n,
m)
        NEXT m
    NEXT n

PRINT x2
'INPUT "Hit return to continue", junk$

END SUB
```