The Relationship Between the Abundance of Smallmouth Bass and Double-crested Cormorants in the Eastern Basin of Lake Ontario.

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The smallmouth bass (*Micropterus dolomieui*) fishery of the eastern basin of Lake Ontario was one of the premier smallmouth bass fisheries in New York State (Brown 1975; Krester and Klatt 1981). In recent years anglers and business owners have complained that the quality of smallmouth bass fishing in the eastern basin has deteriorated. Recent creel surveys corroborated the declines in fishing quality (Eckert 1998a; McCullough and Einhouse 1999). Chrisman and Eckert (1998), using index gillnet data, also documented that during the 1990's the eastern basin smallmouth bass population declined to the lowest level recorded in over two decades.

At the same time the smallmouth bass population was declining, the double-crested cormorant (*Phalacocorax auritus*) population on Little Galloo Island was increasing (Weseloh and Collier 1995). Furthermore, from 1993 to 1997, United States Geological Survey (USGS) biologists reported that double-crested cormorants were consuming between 200,000 to 1.25 million smallmouth bass annually from eastern Lake Ontario (Ross and Johnson 1995; in press). Although the declines in smallmouth bass abundance and predation on smallmouth bass by double-crested cormorants were clearly documented, two important pieces of information were not well understood: 1) the size and age of smallmouth bass consumed by double-crested cormorants; and 2) whether losses to double-crested cormorant predation increased the rate of smallmouth bass mortality. Recently, two studies have shown that double-crested cormorants were targeting age-2 to 5 smallmouth bass in the eastern basin of Lake Ontario (Adams et al. 1998; Schneider and Adams 1998). With this new information the link between double-crested cormorant predation and smallmouth bass mortality could be examined. The objectives of this report were to establish whether or not double-crested cormorant predation significantly increased mortality of smallmouth bass in the eastern basin of Lake Ontario and if this mortality could cause the declines recorded in the smallmouth bass population and fishery.

Trends in Eastern Basin Smallmouth Bass Fishery

Anecdotal accounts of the eastern basin smallmouth bass fishery from anglers, charter boat operators, local business owners, and Environmental Conservation law enforcement officers all indicated that fishing quality and participation had declined over the last several years. Recently, two studies were completed which documented long term trends in angling quality for smallmouth bass fisheries in Lake Ontario.

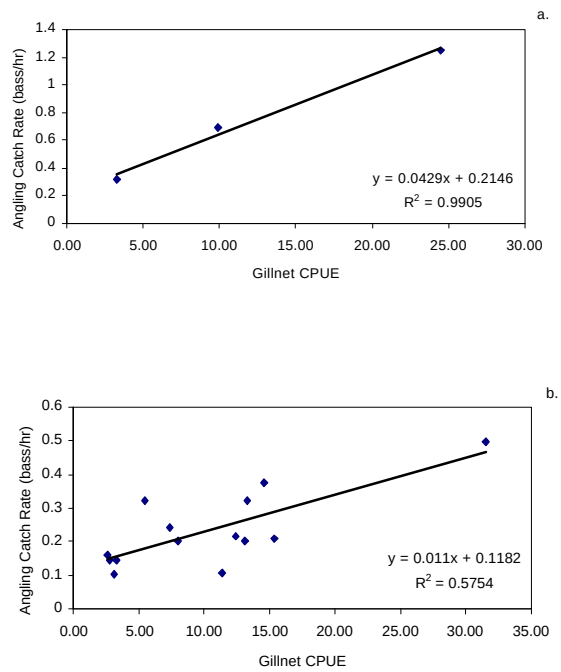
McCullough and Einhouse (1999) performed a creel survey aimed at assessing effort, catch and harvest for the eastern basin warmwater fishery. This study further documented the importance of smallmouth bass in the eastern basin fishery with 48% of all anglers surveyed specifically pursuing smallmouth bass. Results from this survey found that total harvest, harvest rate and catch rate of smallmouth bass were down 54 to 80% from previous surveys completed in 1978 (Panek 1981) and 1984 (Anonymous 1989). McCullough and Einhouse (1999) found no indication of a decline in fishing effort between the three surveys, however, they indicated that comparison of fishing effort between years should be approached with caution because of differences in methodology between the studies. McCullough and Einhouse (1999) also stated “the eastern basin smallmouth bass fishery

may have exhibited a higher quality and greater effort between the late 1980s and early 1990s when bass were more abundant".

Eckert (1998a, 1998b) analyzed smallmouth bass fishing data collected annually since 1985 from the NYSDEC Lake Ontario Fishing Boat Census, a creel survey aimed at assessing the fishery for trout and salmon. Survey data was collected along the US shore from the Niagara River eastward to Association Island Cut near Henderson. Results indicated that while trends in effort have increased steadily lake-wide, catch rate has fluctuated without trend for the west, west central and east central areas of the lake, but has declined recently in the east. Survey data were further divided into a finer geographic scale made up of nine locations grouped by proximity of access channels and concentrating on specific shoreline areas with significant smallmouth bass fisheries. Results from analysis of the data from these nine locations indicated that the only site which showed a significant decline in harvest rate was Henderson in the eastern basin. Each year since 1990, the Henderson site catch and harvest rates were below the lake-wide average. Two other sites also showed a decline in catch rates, Sodus / Port Bay and Little Salmon River. There were, however, no associated declines in harvest rate at these sites and the catch rates there were still above lake-wide averages. Catch and harvest rates at all other sites varied without trend or trended upward. Eckert (1998a) indicated that if the decline in smallmouth bass stocks in the eastern basin was solely related to lake productivity, then downward trends in the fishery would be expected from sites lake-wide. These trends were not apparent from creel survey data.

We used the data from these studies to further examine the relationship between harvest and stock abundance. We plotted separately, the harvest rate data for the Henderson site from the Fishing Boat Census (Eckert 1998a, 1998b) and the data for the eastern basin creel surveys (Panek 1981; NYSDEC 1989; McCullough and Einhouse 1999) against the catch-per-unit-effort (CPUE) summed within years for smallmouth bass age-5 and older from the NYSDEC Warm-water Fishery Assessment (Figures 1a and b). We included CPUE data for age-5 smallmouth bass because as many as 30% or more were legal sized (305 mm, 12 inches) at this age (Chrisman and Eckert 1998). Also, the mean length of age-5 smallmouth bass for all years since 1976, except 1979, was greater than 279 mm (11 inches) and the long term mean was about 295 mm (11.6 inches). Simple linear regression analysis of the harvest rate and abundance data indicated a direct significant relationship for both creel survey types (Fishing Boat Census: $r^2 = 0.58$ and $p = 0.005$; eastern basin creel survey: $r^2 = 0.99$ and $p = 0.022$, respectively). While the high r^2 value for the eastern basin creel survey is based only on three data points, these relationships do demonstrate that the creel survey data is comparable to index gillnetting data.

Figure 1. The simple linear regressions between

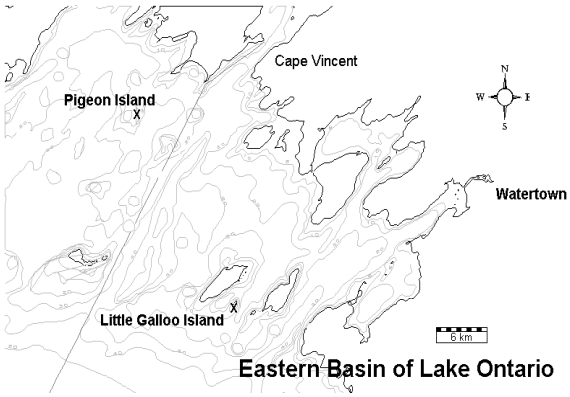


catch rate (smallmouth bass per hr) from creel surveys and the catch-per-unit-effort (CPUE) data from index gillnets. Catch rates are from the eastern basin creel surveys (panel a; Panek 1981; NYSDEC 1989; McCullough 1999) and the Henderson site from the Lake Ontario Fishing Boat Census (panel b; Eckert 1999a, 1999b). CPUE data is from index gillnets set during the annual NYSDEC warmwater fish community assessment (Eckert 1999c).

Double-crested Cormorant Population Trend

Double-crested cormorants were first observed on Lake Ontario in the 1930s, but populations declined to low levels in the 1960s and 70s, most likely due to contaminant induced eggshell thinning and subsequent reproductive failure (Weseloh and Collier 1995). The number of double-crested cormorant nests on Little Galloo Island has since increased steadily from 22 in 1974 peaking at 8410 in 1996 and declining to 5839 in 1998 (Weseloh and Collier 1995; NYSDEC 1998). In addition to Little Galloo Island in US waters, Pigeon Island, just across the international border in Canadian waters, had 1818 nests in 1998. Double-crested cormorants can dive to depths in excess of 22 m (72 ft; Palmer 1962) and in eastern Lake Ontario, typically feed within 15-20 miles of the colony making nearly all of the smallmouth bass habitat in the eastern basin accessible to this form of predation (Figure 2).

Figure 2. Locations of the Little Galloo Island



and Pidgeon Island Double-crested Cormorant colonies in the eastern basin of Lake Ontario.

Diet studies indicate that double-crested cormorants eat substantial numbers of smallmouth bass in eastern Lake Ontario. Based on examination of pellets, recent studies indicate that the percent composition of smallmouth bass in double-crested cormorant diets ranged between 0.2 and 5.8% from 1992 to 1998 (Ross and Johnson 1995; in press; Johnson et al. 1998). During that time, estimated total annual double-crested cormorant predation on smallmouth bass for the Little Galloo and Pigeon islands colonies ranged from about 132,000 to 748,000 bass with inter-annual fluctuations in diet composition linked to prey availability (Table 1; Ross and Johnson 1995; in press; Johnson et al. 1998).

Table 1. Annual totals of smallmouth bass consumed by double-crested cormorants colonies on Little Galloo and Pigeon Islands. Data courtesy of J.H. Johnson and R.M. Ross, US Geological Survey Cortland, NY and Wellsboro, PA.

Year	Little Galloo	Pigeon	Total
1993	320,000	55,000	375,000
1994	355,000	58,000	413,000
1996	114,000	18,000	132,000
1997	672,000	76,000	748,000
1998	464,000	144,000	608,000

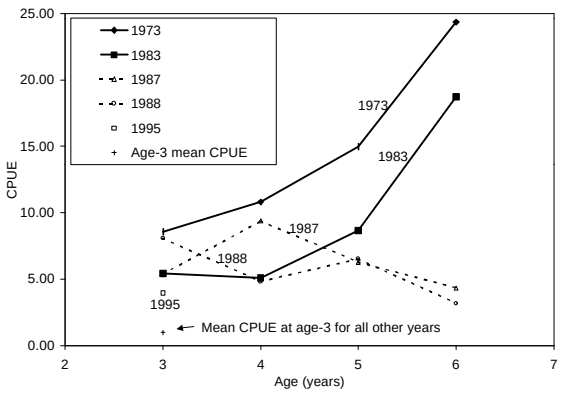
Smallmouth Bass Population Trend

Lake Ontario eastern basin smallmouth bass abundance and demographics were monitored annually as part of the warm water fishery assessment each August from 1976 to 1998 (Chrisman and Eckert 1998; Eckert 1998c). In those surveys, standard index gillnets were set overnight, parallel to contours at depths from about 4 to 20 m. CPUE data were stratified for depth and area, and coverage included all of the inshore US waters of the eastern basin. Fish collected were measured for length and weight, sexed, and had scales removed for aging.

The CPUE of smallmouth bass sampled in August from index gillnets indicated a cyclic abundance pattern for the Lake Ontario eastern basin population. Most individuals within the population were produced from a few strong year-classes with relatively low production of young smallmouth bass between those cohorts. Recruitment of smallmouth bass in the eastern basin is thought to be strongly influenced by weather during the spawning season with indications of density dependent mortality between strong year classes. Since the survey began in 1976 the population has been dominated by two year-classes, the 1973 and the 1983 cohorts. Recently two consecutive large year-classes were formed, 1987 and 1988. They had the second and third largest CPUEs in index

gillnetting at age-3 and 4 of the 23 year data set. These year-classes, however, recruited to the adult population at rates 4 to 5 times lower than the previous strong year-classes (Figure 3). The CPUEs for the last four years (1995 - 1998) for smallmouth bass age-6 and older also were the lowest observed since data collection began in 1976.

Figure 3. Catch-per-unit-effort (CPUE) from index gillnets of strong year-classes of



smallmouth bass at ages-3 through 6. CPUE data is from bass collected from the eastern basin of Lake Ontario during the annual NYSDEC warmwater fish community assessment (Eckert 1999c). Strong year-classes of bass have a CPUE at age-3 of 4 or greater.

Smallmouth bass do not become fully recruited (completely vulnerable to capture) to the index gillnets until they reach about age-6 in the eastern basin of Lake Ontario (Chrisman and Eckert 1998). Typically catch curves for eastern basin smallmouth bass peak at age-5, 6 or 7 and then show a smooth decline thereafter indicating a nearly constant mortality for adults of the same cohort. From 1976 to 1989 mortality of adult smallmouth bass varied about a mean of 25.4%, with no apparent trend except that less abundant cohorts had higher mortality rates. After 1989, the mean annual mortality of adult smallmouth bass increased to 41.7%. While mortality of adult smallmouth bass increased, the change was not great enough to cause the age-class structure currently being observed. Mortality from the fishery would be expected to shift the peak of catch curves to age-5, the age smallmouth bass first enter the eastern basin fishery. Beginning with the 1987 cohort, however, the peak CPUE in catch curves (modal age) from index nets shifted toward younger ages (ages-3 and 4). While age-3 and 4 smallmouth bass in the eastern basin population are not fully recruited to index gillnets they are consistently caught each year. Also, catches of age-3 and 4 bass have provided a consistent measure of year class strength. The CPUE for all cohorts of bass at ages-3 and 4 has generally varied without trend about means of 0.98 and 1.34, respectively, except for the four strong year-classes (1973, 1983, 1987, and 1988). The lack of an increase in CPUE for these young bass indicates that catchability has not changed for these ages and hence is not driving the shift in modal age of catch curves. There is no evidence of current sources of additional mortality on adult smallmouth bass, hence the trend of declining modal age in index gillnetting seems to be driven by young smallmouth bass not reaching adult ages. Since 1989, age-3 to 7 bass showed no trends in growth, but age-8 and older bass all showed an increasing trend (Chrisman and Eckert 1998), somewhat discounting the probability that food limitation is causing increased mortality. Because of incomplete vulnerability to capture in index gillnets, however, catch curve analysis cannot be used to compute mortality for smallmouth bass aged-2 to 5.

Changes in Mortality of Young Bass

Throughout the 23 year index gillnetting data set (Eckert 1998c), CPUEs for smallmouth bass age-3, 4 and 5 do provide a consistent measure of year-class strength and relative abundance. To assess the mortality of smallmouth bass below the age appropriate for catch-curve analysis (age-3 to 5) we used an index of relative mortality. The relative mortality index is a ratio equivalent to the CPUE of smallmouth bass at a young age (e.g. age-3) divided by the CPUE of smallmouth bass in the same cohort at some older age (e.g. age-6). Because relative mortality is a measure of death rate within a cohort, CPUEs of the ages used in the ratio must be staggered through time. For example the relative mortality of age-3 to age-6 would be calculated from the CPUE of smallmouth bass age-3 at time *t* divided by the CPUE of smallmouth

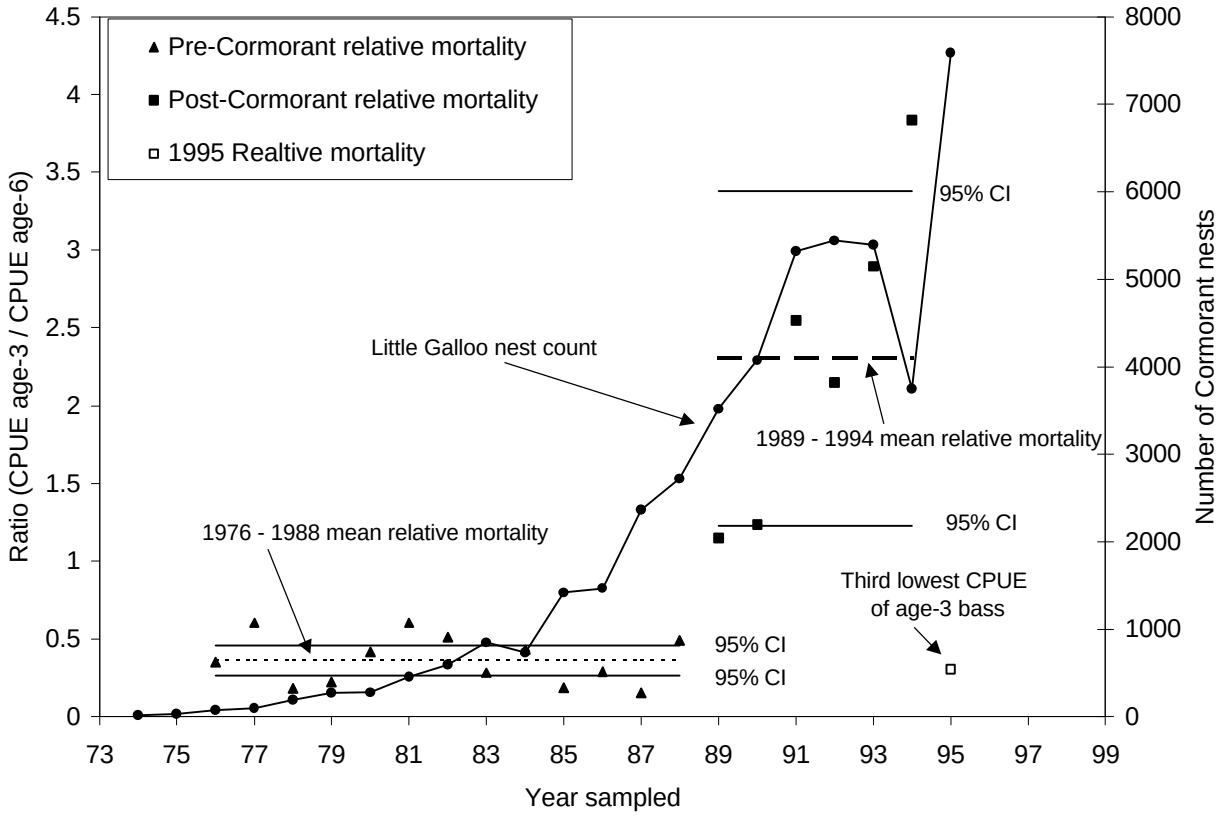


Figure 4. The relative mortality of smallmouth bass from the eastern basin of Lake Ontario between ages-3 and 6 versus the number of cormorant nests on Little Galloo Island. Relative mortality is equivalent to the CPUE of age-3 bass divided by the CPUE of age-6 bass within the same cohort three years later. Relative mortalities are plotted for the year in which the age-3 bass were sampled. Dotted lines represent estimates of the means of relative mortality data for years 1976 to 1988 and 1989 to 1994 and are extended to cover each time interval. The 95% CIs are the confidence limits for each mean again extended to cover each time interval.

bass age-6 at time *t+3*.

We analyzed the relative mortality of smallmouth bass at successive ages from age-3 to 6, and between pre-recruits (ages-3 to 5) and smallmouth bass fully recruited to the sport-fishery (age-6 and older). Because of low CPUEs from weak year-classes, year-to-year variability in catch rates, and because age-3 to 5 smallmouth bass were not fully recruited to the gear, relative mortality between successive ages was variable and trends were difficult to detect. Relative mortality of pre-recruits and fully recruited smallmouth bass did, however, show clear trends. Single factor analysis of variance of the relative mortalities between age-3 and 6 and those between age-4 and 6 detected significant differences between the time periods from 1975 to 1988 and from 1989 to 1996 ($p <$

0.001 and p = 0.033, respectively). Relative mortality of smallmouth bass between ages-3 and 6 increased after 1989 when double-crested cormorant nest counts on Little Galloo Island exceeded 3000 (Figure 4). For the time period 1976 to 1994, simple linear regression analysis of the relationship between the relative mortality of smallmouth bass from age-3 to 6 (*RM*) and the number of double-crested cormorant nests on Little Galloo Island (*CN*) produced a direct significant relationship:

$$RM = 0.000435 * CN + 0.0825$$
$$(r^2 = 0.62,\ p < 0.0001).$$

The relative mortality of smallmouth bass from age-3 to age-6 from the 1992 year-class (age-3 in 1995) dropped to pre-cormorant levels, but this was the third weakest year-class recorded with CPUE near zero.

The Effect of Increased Mortality on the Smallmouth Bass Population

The recent persistent declines in CPUE of smallmouth bass in index gillnetting (Chrisman and Eckert 1998; Eckert 1998c) and the total annual consumption of smallmouth bass by double-crested cormorants (Ross and Johnson 1995; in press) led to a previous examinations of the impact of this new source of smallmouth bass mortality. Schneider et al. (1997) used mark-recapture estimates of smallmouth bass densities (McCullough 1988) to estimate that double-crested cormorants could consume between 21 and 79% of all age-2 to 5 smallmouth bass available in the eastern basin. Predation mortality of this sort, however, will have a greater impact on older age classes of fish. Additional mortality on relatively abundant young-of-the-year and yearling fish would be a small component of their total mortality and these ages may have the ability to compensate to increased mortality through increases in growth and size-related survivorship.

Knowing the size and age of smallmouth bass that most often appeared in double-crested cormorant diets was a critical aspect missing from earlier diet studies. Two studies were conducted to determine the size and age of smallmouth bass eaten by double-crested cormorants. In one study smallmouth bass otoliths were recovered from archived samples of double-crested cormorant pellets collected on Little Galloo Island in 1993 and 1994 (Adams et al. 1998). In another study smallmouth bass and smallmouth bass otoliths were recovered in 1998 from collections of pellets and chick regurgitate sampled on Little Gallo Island and from double-crested cormorant stomachs taken from birds shot over water less than 10 m deep between Gull Island and the Hardscrabble area (Schneider and Adams 1998). Ages of consumed smallmouth bass were estimated from otolith lengths and scale annuli. Results from these studies indicated that smallmouth bass from 33 mm to 335 mm (1.3 to 13 in.) were routinely eaten and most predation was concentrated on age-2 to 5 fish. Estimated from pellet examinations, the mean size of smallmouth bass consumed by double-crested cormorants in 1993 - 94 was 256 mm (age-4.4 years) and declined to 211 mm (age-2.9 years) in 1998. For all years studied, the modes of the age and length distributions were similar for smallmouth bass in both double-crested cormorant diets and gillnet samples indicating that double-crested cormorant consumption was influenced by the availability of smallmouth bass at the larger end of the size range that they could handle. Simply put, double-crested cormorants seemed to prefer to eat the largest smallmouth bass that they could handle. Schneider and Adams (1999) also indicated that otoliths from yearling smallmouth bass were indistinguishable from those extracted from yellow perch suggesting the possibility that double-crested cormorant predation on smallmouth bass may be under reported.

We used the new diet composition data to recalculate the impacts of double-crested cormorant predation on the smallmouth bass population in US waters of the eastern basin of Lake Ontario. The 1986 mark - recapture population estimate for adult smallmouth bass, ages-5 to 13 years, in the Hardscrabble area was 72,850 (95% confidence limits: 38,339 to 163,900) or 11.8 bass / ha (McCullough 1988). The area in the eastern basin between the 0 to 20 m depth contours is about 37650 ha. Expanding McCullough's (1988) density estimate yields a total of 444,270 adult smallmouth bass for this

Table 2. Numbers and biomass of smallmouth bass per hectare for water depths of 0 - 20 m in the eastern basin of Lake Ontario. Numbers of adult bass ages 5 to 13 are from McCullough's (1988) population estimate ($11.8 \cdot ha^{-1}$) and are partitioned between ages using a survivorship of 0.75 (Chrisman and Eckert 1998). Numbers of young bass age-1 to 4 were calculated using a survivorship of 0.38 (Carlander 1977). Biomass of bass is equivalent to the numbers at age multiplied by mean weight at age data collected during the annual NYSDEC warmwater fish community assessment (Chrisman and Eckert 1998; Eckert 1999c).

	Age	Weight (g)	Number / ha	Standing crop (kg /ha)
	1	93	153.00	14.23
	2	108	58.14	6.28
	3	160	22.09	3.53
	4	265	8.40	2.22
	5	351	3.19	1.12
	6	488	2.39	1.17
	7	632	1.79	1.13
	8	799	1.35	1.08
	9	941	1.01	0.95
	10	995	0.76	0.75
	11	1092	0.57	0.62
	12	1155	0.43	0.49
	13	1190	0.32	0.38
Total age 2-4			88.63	12.04
Total age 5-13			11.80	7.69
Total age 1-13			253.43	33.96

depth range. To partition the smallmouth bass population estimate into adult age groups we used a mean annual survivorship value of 0.75 calculated from catch curves of CPUE data collected annually from 1976 to 1989 during the NYSDEC warm water gillnet survey (Chrisman and Eckert 1998). To back project the population estimate to ages-1 to 5 we used a mean annual survivorship value of 0.38 calculated from values for young smallmouth bass published on page 187 in Carlander (1977). This yielded a density of 91.82 age-2 to 5 smallmouth bass per ha (Table 2). Using the weight-at-age data from index gillnetting (Chrisman and Eckert 1998) we calculated a standing crop from the population estimate of 33.96 kg/ha without including age-0 smallmouth bass. This is within the center of the mean standing crop range for smallmouth bass in lakes (20 - 40 kg/ha) reported in Carlander (1977). In 1986 when the mark - recapture estimate was done, however, the CPUE for adult smallmouth bass was 1.5 times greater than the 1993-94 mean and almost 5 times greater than the 1998 value. Hence, this smallmouth bass population estimate should provide a conservative description of the impact of cormorant predation.

We calculated double-crested cormorant predation on smallmouth bass in the eastern basin using data for Little Galloo and Pigeon islands (Table 1) and the age-structured diet data for 1993-94 and 1998 (Schneider and Adams 1998; Adams et al. 1998). A mean predation level for 1993-94 of 394,000 smallmouth bass distributed between ages-1 to 7 according to the 1993-94 cormorant diet data yielded a 23% reduction in bass ages-3 to 5. The 1993-94 level of consumption of age-5 and 6 smallmouth bass by double-crested cormorants exceeded population estimates for those year-classes. The 1998 predation level of 608,000 smallmouth bass distributed between ages-1 to 5 according to the 1998 cormorant diet data yielded a 36% reduction in age-3 to 5 fish and reduced age-3 numbers alone by 40%. While it is not likely that double-crested cormorant predation would remove entire cohorts from the smallmouth bass population, the loss rates induced by this new source of mortality could severely limit recruitment to the adult stock. The affects of successive years of cormorant predation on a single cohort could be a recruitment bottleneck similar to that suggested by the shift in modal age in gillnet catches and increased mortality of young fish shown in Figure 4.

Summary

Previous lows in smallmouth bass population abundance (mid 1980s) and subsequent recovery (late 1980s to early 1990s) led to the perception by resource managers that the low CPUEs of smallmouth bass observed prior to 1995 was another trough in the cycle. Fish managers became concerned in 1996 when, for the second consecutive year, the smallmouth bass CPUE was below the previous low observed in 1985 (Schneider et al. 1997), and the angling community was becoming increasingly alarmed with the poor fishing. These events precipitated additional studies in 1997 and 1998 to determine the cause of the declines in smallmouth bass. In depth examination of the population data collected over

the last 23 years lead to two very important observations (Chrisman and Eckert 1998). First, the 1987 and 1988 year-classes were the second and third strongest at age-3 and 4 but recruited to the population at rates 4 to 5 times lower than previous strong year-classes. Second, the peak CPUE in catch curves drawn from index gillnet catches had shifted from ages-5, 6 or 7 to age-3. Both of these observations can be indicative of a population with a mortality bottleneck prior to recruitment. There are a number of reasons to expect that additional mortality was occurring on smallmouth bass in between sensitive early life stages (YOY and yearling) and the adult stages that are fully recruited to the fishery.

1) If the fishery was responsible for the decline of smallmouth bass in the eastern basin of Lake Ontario, the expected value for the peak CPUE in catch curves would be age-5 (the age when these fish first begin to reach a legal size of 305 mm or 12 inches). Currently, catch curves reach a peak with CPUEs for age-3 smallmouth bass. Also, there is no other evidence of additional mortality sources on the adult stock.

2) Smallmouth bass catch and harvest rates by anglers in the eastern basin have declined substantially below levels measured in all previous surveys (Eckert 1998a; McCullough and Einhouse 1999).

3) The CPUE of adult fish from index gillnetting has declined steadily since the 1983 year-class hit the fishery in 1989. Currently, CPUEs of smallmouth bass over the last four years have been the lowest recorded in the 23 year NYSDEC data set (Chrisman and Eckert 1998; Eckert 1998c).

4) There is a highly significant direct relationship between smallmouth bass catch rates from creel surveys and CPUEs from index gillnetting, establishing a foundation for comparison between the two data types.

5) Results from the NYSDEC Fishing Boat Census (Eckert 1998a, 1998b) indicate that catch and harvest rates for smallmouth bass from the eastern basin are below lake wide averages and have been declining since the dramatic increase in double-crested cormorants in the late 1980s in the eastern basin. Results from this study also indicate that sites along the rest of the US shore westward do not show consistent trends and recent catch rates at many locations have improved discounting declines in lake productivity as a driving vector in eastern basin smallmouth bass declines.

6) Double-crested cormorants eat smallmouth bass in substantial numbers (Ross and 1995, in press; Johnson et al. 1998).

7) Numbers of double-crested cormorants in the eastern basin have increased dramatically since their counts began in 1974 (Weseloh and Collier 1995; NYSDEC 1998).

8) Poor recruitment of the strong 1987 and 1988 year-classes of smallmouth bass coincided with a dramatic rise in cormorant numbers in eastern Lake Ontario. These year-classes reached age-2 in 1989 and 1990, when the number of double-crested cormorant nests on Little Galloo Island reached levels over 3000.

9) The greatest proportion of smallmouth bass found in double-crested cormorant diets were age-3 to 5 fish (Adams et al. 1998; Schneider and Adams 1998).

10) Relative mortality of smallmouth bass between age-3 and age-6 was directly related to number of double-crested cormorants on Little Galloo Island. Mortality of smallmouth bass between age-3 and 6 increased dramatically after 1989 when double-crested cormorant nests counts on Little Galloo exceeded 3000.

11) The total number of smallmouth bass consumed by double-crested cormorants annually can remove large proportions of year-classes from the smallmouth bass population.

12) The CPUE of age-3 smallmouth bass during the last ten years since 1989 has exceeded the long term mean four times and has been about equal twice. Also, the 1995 year-class of smallmouth bass was the fifth most abundant on

record indicating that production and survivorship of YOY and yearling smallmouth bass is still favorable for the production of strong year-classes.

13) The lack of decline in growth rates of smallmouth bass age-3 to 7 and increased growth of bass age-8 and older may indicate that the eastern basin stock was not resource limited during the recent declines in adult abundance (Chrisman and Eckert 1998).

The recent increase in mortality can be explained from declining recruitment of age-3, 4 and 5 smallmouth bass to the fishery. The information presented in this study furnishes strong support for the existence of a cause / effect relationship between increased abundance of double-crested cormorants and declines in the smallmouth bass population and the quality of the fishery in the eastern basin of Lake Ontario. The main results from this study were that mortality of age-3 to 5 smallmouth bass increased substantially after 1988 and double-crested cormorant predation on these age-classes was substantial enough to cause the observed declines in the smallmouth bass population.

Implications

Production of strong year-classes of smallmouth bass in the eastern basin of Lake Ontario has occurred at intervals from 4 to 10 years and is thought to be related to environmental conditions during spawning. Because of the relatively long periods between these year-classes, the population in the basin is dependent upon high survivorship of young smallmouth bass age-2 to 5 years. The data presented in this report indicate that increased mortality of smallmouth bass age-3 to 5 has directly lead to the declines in the population and in the quality of the fishery. The ability of double-crested cormorant predation to effectively suppress bass cohort abundance at successive ages may compromise the ability of the smallmouth bass population to respond and possibly compensate to this relatively new form of predation. Currently the 1995 year-class of smallmouth bass, sampled as age-3 fish in 1998, is the fifth strongest on record. Cormorant diet studies for 1998, however, indicate that predation was particulary intense on the 1995 smallmouth bass cohort removing an estimated 340,480 individuals. Results of this study indicate that current levels of cormorant predation on the 1995 smallmouth bass cohort at age-4 and 5 could be enough to remove much of this year-class before it recruits to the fishery.

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