Predicting the Size and Age of Smallmouth Bass (*Micropterus dolomieu*) Consumed by Double-Crested Cormorants (*Phalacrocorax auritus*) in Eastern Lake Ontario, 1993-1994.

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Smallmouth bass (*Micropterus dolomieu*) are an important recreational fishery in the New York waters of the eastern basin of Lake Ontario (Stone et al 1951, Jolliff and LeTendre 1967, Panek 1981 and Anonymous 1984). The quality of the fishery, as measured by catch rates, was among the best in New York State during the 1970s (Panek 1981). Local accounts from older guides and anglers suggest that the bass fishing in the eastern basin of Lake Ontario remained healthy and productive throughout periods of substantial change in the fish community during the 20th century. In recent years, however, smallmouth bass relative abundance has declined and is currently at the lowest level measured since sampling began in 1976 (Eckert 1998); concurrently, estimated mortality rate of young smallmouth bass has also increased (Chrisman and Eckert 1998). Moreover, similar declines in smallmouth bass relative abundance were noted in Canadian waters of the eastern basin of Lake Ontario (Hoyle 1997) and in the St. Lawrence River (McCullough and Klindt 1997).

At the same time smallmouth bass numbers were declining, abundance of double-crested cormorants (*Phalacrocorax auritus*) nesting on Little Galloo Island in the eastern basin of Lake Ontario expanded exponentially; starting from a few birds in the early 1980s and peaking at over 8,000 pairs in 1996, but have since declined to 5,839 pairs in 1998 (NYSDEC 1998). Based on an examination of pellets (regurgitated undigested fish remains), estimates of smallmouth bass consumption by cormorants in eastern Lake Ontario ranged from approximately 200,000 to 1.25 million fish, annually (Ross and Johnson 1995, In press). Although cormorant population increases and smallmouth bass losses to cormorant predation are well documented, there is no information regarding the size and age composition of smallmouth bass consumed by cormorants. This information is important for evaluating any link between cormorant predation and smallmouth bass abundance, because if cormorants feed principally on older, legal-size smallmouth bass (12 inch [305 mm] minimum size limit), the impact would be more severe than if they feed on young-of-year fish. The most abundant age group of any fish species is usually young-of-year fish, and the greatest loss in any age group of fish occurs in the first year of life.

Any additional loss of young-of-year smallmouth bass from predation by cormorants would probably be a small proportion of total mortality and would likely not be detectable as a decrease in numbers of adult fish. In contrast, additional loss at older ages would represent a greater proportion of the population and, therefore, could reduce the size of both the population and the fishable stock.

The objective of this study is to describe the size and age composition of smallmouth bass consumed by cormorants. The U.S. Geological Survey – Biological Resource Division (USGS-BRD) has conducted fish consumption studies of cormorants since 1993 by examining pellets. This report describes the results of a detailed examination of archived otolith samples to evaluate the size and age of smallmouth bass consumed by cormorants.

Methods

This study focused on 374 smallmouth bass otoliths collected from pellets gathered from Little Galloo Island during the cormorant breeding season, from May 5 to July 8, during each year from 1993 through 1997. Most otoliths examined in this study were collected during 1993-1994. Otoliths, diagnostic bones and eye lenses were stored in 70% ethyl alcohol. Many of the otoliths were fragile,"dusty," or had their edges completely eroded[1] (due to the digestive process of cormorants). The degradation of the otoliths was recorded on an erosion index scale (least eroded [Level 1] to most eroded [Level 5], Table 1). Otoliths with little erosion (Level 1) were used as the standard to which other erosion levels were compared. The erosion level was evaluated subjectively by assessing the wear around the edges and overall thickness of the otolith, as well as whether the otolith had broken ends. Smallmouth bass otoliths are elongate and fairly thick, but they have a fragile rostrum, that presumably breaks off early in the digestive process of cormorants. Some otoliths were noticeably worn, but were measured for comparison with less eroded otoliths; these were classified Level 4 and Level 5. The maximum length of the smallmouth bass otoliths was taken along the longitudinal axis. These measurements were made with a *Manostat* Fiberglas Dial Caliper. Otoliths were not compressed since they can bend and break with only very slight pressure, especially when softened by storage in 70% ethyl alcohol. Length was recorded to the nearest 0.1 mm. All the measurements and classifications were done by the senior author to maintain consistency.

Total lengths of smallmouth bass were estimated from the regression of otolith length-to-total length, based on 11 smallmouth bass collected from Oneida Lake and 19 from the Bay of Quinte (data provided by John Casselman, Ontario Ministry of Natural Resources). Total lengths (TL) of Bay of Quinte fish were first converted from standard lengths (SL) from the following conversion relation derived from Oneida Lake smallmouth bass:

$$TL = 0.298\ SL + 2.393$$

The slope and intercept of the Bay-of-Quinte data fell within the 95% CI of the Oneida Lake regression, therefore, the two samples were combined. The resulting regression (Figure 1) was then used to estimate total lengths of smallmouth bass consumed by cormorants from otolith lengths of otoliths recovered from pellets:

$$Y = 40.81\ X - 29.49$$
$$R^2 = 0.871$$

Where:

Y = total length and X = otolith length

Estimated total lengths of smallmouth bass were then used to estimate age composition by using an age-length key calculated from smallmouth bass collected by NYSDEC in the eastern basin of Lake Ontario during 1993 and 1994 (Table 2,

[1] Otolith storage should be done dry, or if liquid storage is necessary, it should be done in 100% buffered ethyl alcohol (Roy Heidinger, So. Illinois University, personal communication).

T. Eckert, NYSDEC, Cape Vincent, NY, personal communication). Estimates of total lengths derived from otoliths were arranged into 25 mm size groupings and apportioned according to the distribution of ages within each size group. A non-parametric Mann-Whitney U test was used to establish differences in otolith lengths among the various levels of erosion.

Results

Of the 374 useable smallmouth bass otoliths collected from 1993 through 1997, 46 were assigned a Level 1 erosion index and 62, 90, 83, and 93 were assigned Levels 2 through 5, respectively. The means, ranges and 95% CI for otolith lengths for each of the erosion levels showed a decline in otolith size with higher levels of erosion (Figure 3). Tests of the otolith length distributions showed no significant difference between Levels 1 and 2 distributions ($p>0.05$), but otolith lengths for Levels 3-5 were significantly different from the least eroded otoliths (Level 1). The sample was restricted to 1993 and 1994, because most pellets were collected during this period. Level 1 and 2 otoliths were combined (n= 99 for 1993-94) and were considered the most reliable predictors of smallmouth bass lengths.

Level 1 and 2 otoliths were used to estimate total lengths of smallmouth bass using the otolith length-to-total length regression. Estimated lengths ranged from 112 mm to 335 mm (4.4 to 13.2 in), and the modal size groups were 229 mm and 254 mm (9.0 and 10.0 in, Figure 4). The estimated mean and median total lengths were both 256 mm (10.1 in); the 95% CI for the mean was 12 mm (0.5 in). Approximately 14% of the sample of smallmouth bass consumed by cormorants were at or above the minimum size that can be taken legally by anglers ($\geq$ 305 mm [12.0 in], Table 3). The numbers of smallmouth bass within each 25 mm (1 in) size grouping were apportioned to each of the ages corresponding to the age distribution outlined in the 1993-1994 smallmouth bass age-length key (Table 2). Four fish were smaller than the smallest size group in the age-length key (none collected with gillnets); one of these fish was arbitrarily assigned age 2 and three were assigned to age 1. Ages assigned from the age-length key ranged from 1 to 10 years; the modal age group was 5 years, and the mean age was 4.4 years (Table 3 and Figure 5).

Discussion

Initially, we intended to obtain a sample of smallmouth bass otoliths recovered from cormorant pellets and examine their structure to establish the age composition of smallmouth bass consumed by cormorants. Storage of these otoliths in 70% ethyl alcohol, however, precluded any determination of age, because the otoliths were too fragile and opaque to detect annular structures. This problem led to using otolith lengths to predict total length, and then using an age-length key to estimate the age composition. This modified approach required less effort and less elaborate equipment for processing and reading otoliths. Estimating total length from the otolith length appears to be a relatively accurate method for describing size composition, since 87% of the variation (R^2) was explained by the relationship of total length to otolith length. Using age-length keys for smallmouth bass taken in gillnet surveys in the same area and at the same time as the cormorant predation samples was an important requirement in this analysis.

The estimated sizes and ages of smallmouth bass consumed by double-crested cormorants corresponded with the smallmouth bass captured in gillnet surveys during 1993 and 1994. The modes of the age and length distributions were similar for both cormorant and gillnet samples. This suggests ages 3 and 5 dominated the smallmouth bass population of the eastern basin in 1993 and 1994, and that cormorant predation reflected the population structure of smallmouth bass. The 330 mm (13 in) size group of smallmouth bass probably represents the upper limit of predation by cormorants, since larger bass were captured in gill nets, but were not preyed upon by cormorants. Further, very young smallmouth bass were not an important component of cormorant diet in Lake Ontario.

The sizes of smallmouth bass consumed by cormorants in eastern Lake Ontario are in sharp contrast to those observed in Oneida Lake, where double-crested cormorants targeted mostly young-of-year smallmouth bass in the fall (C. M. Adams, unpublished data). The difference between the two lakes may be attributable to variation in smallmouth bass age composition, growth, availability of other prey, or seasonal variation in sizes of smallmouth bass eaten by cormorants.

Double-crested cormorants may prey on smaller bass in eastern Lake Ontario than are represented in the length frequency distribution (Figure 4). Stomach contents of cormorants collected in 1998 contained two yearling (< 100 mm) smallmouth bass (Schneider and Adams 1998). Otoliths extracted from these yearling smallmouth bass were virtually indistinguishable from yellow perch. By age 2, however, the otoliths showed the prominent hooked rostrum that is characteristic of smallmouth bass. This suggests that numbers of YOY and age-1 smallmouth bass eaten by cormorants during 1993-94 may have been under-estimated (Ross and Johnson 1995, In press).

The age composition of smallmouth bass consumed by cormorants is essential to assess the impact of cormorant predation on the smallmouth bass population in eastern Lake Ontario during 1993-94. Two findings of this study should be important for that analysis: 1) the majority of predation occurs at ages within a year or two of recruitment to the fishery, and 2) 14% of smallmouth bass consumed by cormorants were legal-size bass.

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Table 1. Ranking system used to evaluate level of erosion of smallmouth bass otoliths from Double-crested Cormorant pellets.

Index Level	**Description**
Level 1	Good condition, essentially unchanged by digestion
Level 2	Edges smoothed, little erosion evident
Level 3	Edges smoothed and ototlith thinned
Level 4	Noticeably reduced in size by erosion, perimeter eroded off
Level 5	One or both ends broken off

Table 2 Age-length relation for smallmouth bass captured in New York waters of the eastern basin of Lake Ontario during NYSDEC summer gillnet surveys, 1993-1994.

	Total Length (mm)													
Age	178	203	229	254	279	305	330	356	381	406	432	457	483	Total
1	2	0	0	0	0	0	0	0	0	0	0	0	0	2
2	9	5	0	0	0	0	0	0	0	0	0	0	0	14
3	40	57	44	15	1	0	0	0	0	0	0	0	0	157
4	7	22	27	26	23	5	1	1	0	0	0	0	0	112
5	0	18	26	70	69	34	10	0	0	0	0	0	0	227
6	0	0	3	20	52	47	57	40	14	0	0	0	0	233
7	0	0	0	1	3	15	18	24	17	5	0	0	0	83
8	0	0	0	0	0	0	0	0	11	11	1	0	0	23
9	0	0	0	0	0	0	0	3	14	19	7	0	1	44
10	0	0	0	0	0	0	0	1	6	23	11	0	1	42
11	0	0	0	0	0	0	0	0	3	16	11	2	0	32
12	0	0	0	0	0	0	0	0	0	1	8	2	0	11
13	0	0	0	0	0	0	0	0	0	3	2	0	0	5
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	58	102	100	132	148	101	86	69	65	78	41	4	2	986

Table 3. Estimated age (y) and length (in) composition of smallmouth bass consumed by double-crested cormorants from the eastern basin of Lake Ontario, 1993-1994. Legal size in the fishery is 12 inches (305 mm).

Age	Proportion	Length	Proportion
1	0.032	4	0.020
2	0.025	5	0.020
3	0.245	6	0.000
4	0.176	7	0.061
5	0.325	8	0.121
6	0.169	9	0.242
7	0.028	10	0.242
8	0.000	11	0.152
9	0.000	12	0.111
10	0.000	13	0.030
Mean Age=	**4.4 years**	**Mean Length=**	**256 mm (10.1 in)**
		Percent Legal=	**14.1%**

Figure 1. Length-to-otolith relation for smallmouth bass collected from Oneida Lake and Bay of Quinte

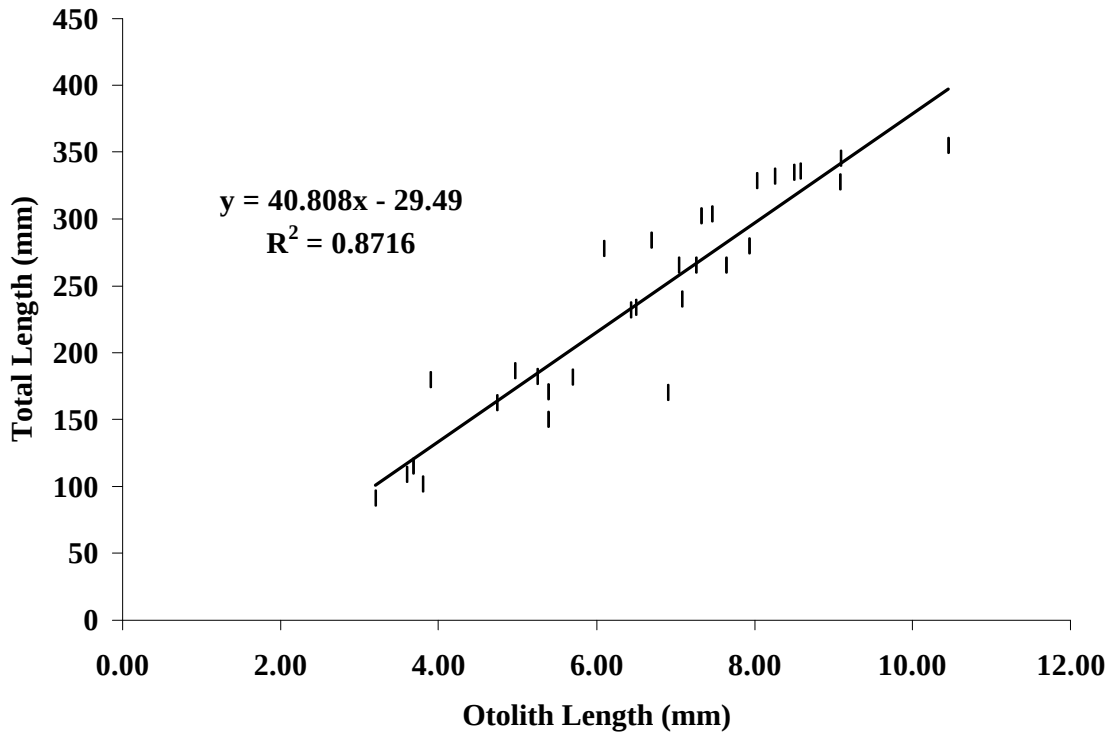


Figure 2. Smallmouth bass otolith length distributions (mm) for different erosion levels of otoliths recovered from double-crested cormorant pellets from eastern Lake Ontario.

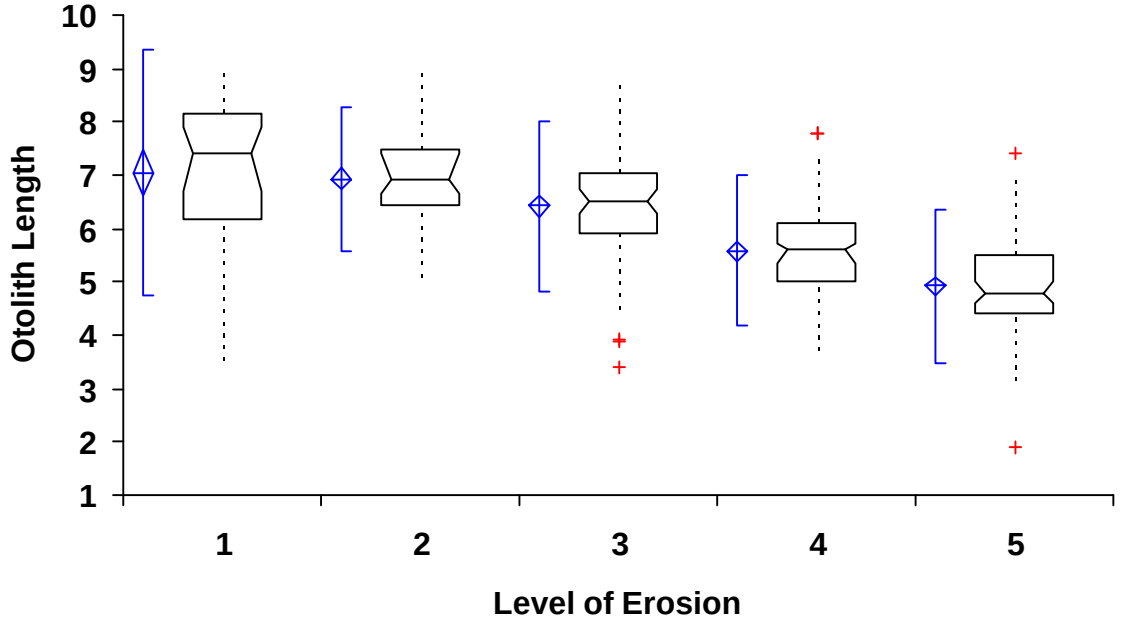
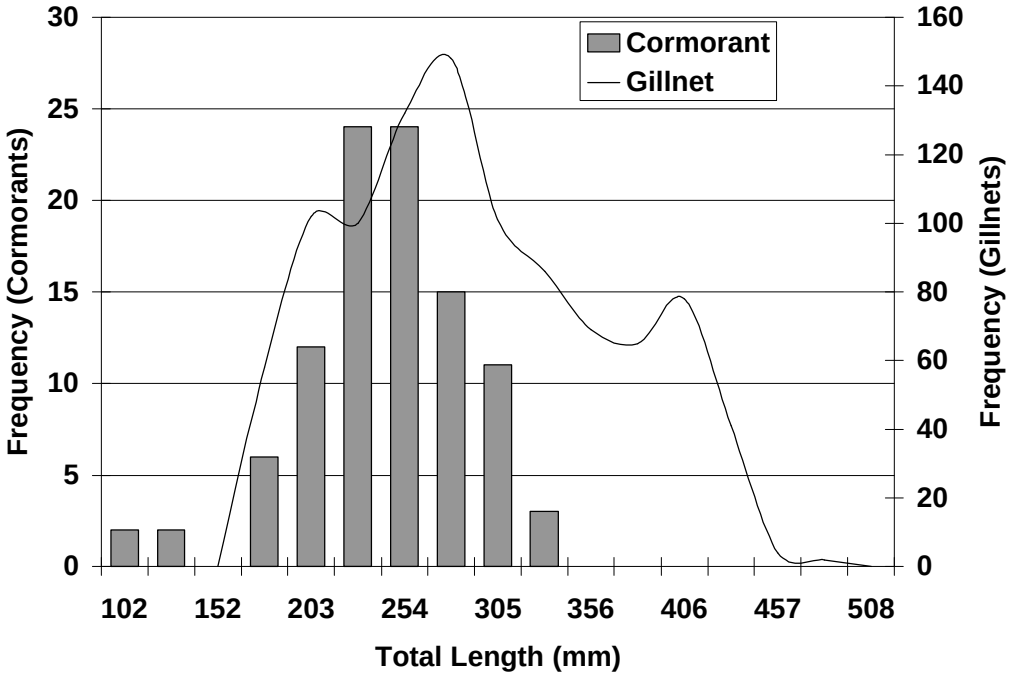
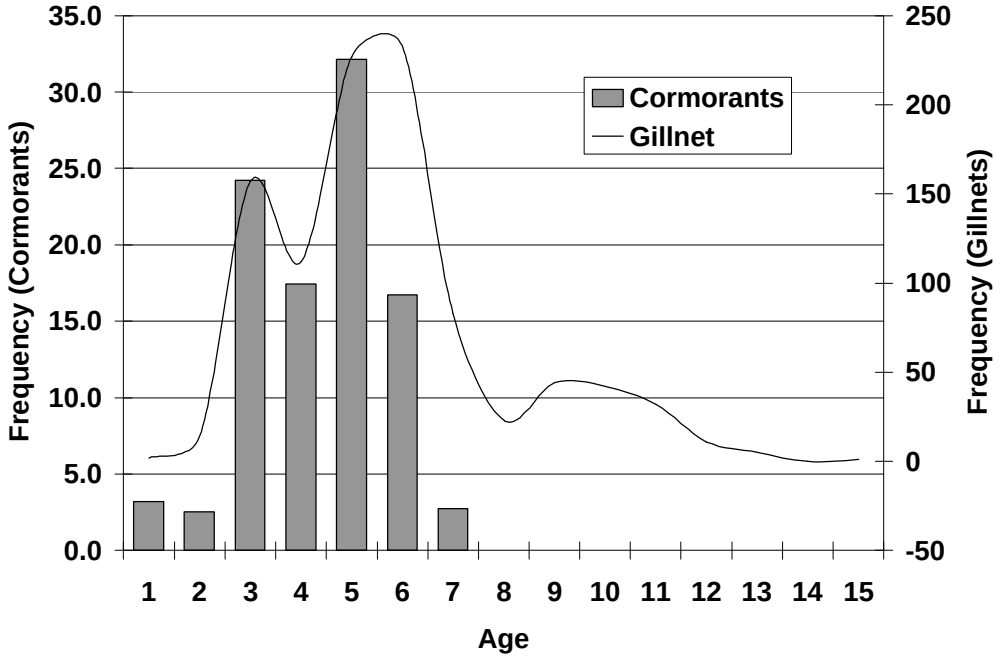


Figure 3. Length frequency distribution of smallmouth bass consumed by double-crested cormorants (99) and captured in gillnets (986) from the eastern basin of Lake Ontario, 1993-1994.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