Diet Composition and Fish Consumption of Double-Crested Cormorants from the Pigeon and Snake Island Colonies of Eastern Lake Ontario in 2001[1]

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Little Galloo (LGI), Pigeon (PI), and Snake (SI) islands are home to the largest colonies of double-crested cormorants (*Phalacrocorax auritus*) in the eastern basin of Lake Ontario. The proliferation of cormorant colonies in this area has created concern as to the effects that these piscivorous birds may have on local fish populations (Schneider et al. 1999). Although studies of the diet and fish consumption of the LGI colony, the largest eastern basin colony have been ongoing annually since 1992 (Johnson et al. 2002), prior to 1999 only a single year of diet information from a very small sample size existed for these two cormorant colonies (Neuman et al. 1997). Diet and fish consumption information has been collected annually since 1999 for the PI and SI colonies. These studies are moderate in their intensity compared to the more extensive efforts being carried out at LGI (Johnson et al. 2001a). Since 1999 the number of cormorant pellets collected on PI (2,319) and SI (2,159) have represented about 42% and 39%, respectively, of the total pellets examined for the LGI colony. This paper reports on the diet composition and fish consumption of cormorants from the PI and SI colonies in 2001.

Methods

Diagnostic prey remains recovered in regurgitated pellets were used to describe the diet of double-crested cormorants from the PI and SI colonies in 2001. Approximately 150 pellets were collected on each of 5 dates beginning in late May and ending in early September. The sample size (150) was determined using power analysis based on sample variability from earlier work that used pellets to describe the diet of cormorants on nearby Little Galloo Island (Ross and Johnson, 1999). In the laboratory, diagnostic bones, all otoliths, and representative scales were removed from the pellets and identified under magnification. Eye lenses were also enumerated since, although they could not be used in species identification, their total number (i.e., number of lenses 2) generated fish counts that exceeded those based on bones or otoliths in some pellets. For prey species identified, diagnostic fish material recovered from cormorant pellets were compared with bones, scales, and otoliths from known specimens defleshed in NaOH.

To estimate number of fish consumed by cormorants from the two cormorant colonies, we used a model similar to that of Weseloh and Casselman (unpublished report: Fish consumption by double-crested cormorants on Lake Ontario, Burlington, Ontario) to estimate the number of fish eaten by cormorants annually. This model incorporated cormorant age-class population size and seasonal residence time (time spent feeding in area) to estimate the number of cormorant feeding days, mean daily fish ingestion rates, a fecal pathway correction factor for fish not detected in pellets (Johnson and Ross, 1996), and several assumptions based on values from the literature or personal communication from colleagues. To estimate the number of cormorants feeding we used annual nest counts (all nests counted) provided by the Canadian Wildlife Service and assumed that (1) residence time for breeding adults, immatures, and young-of-year (YOY) was 158, 112, and 92 days, respectively (Weseloh and Casselman, unpublished report); (2) number of immatures was about 10% of adult population which was taken as twice the number of nests; and (3) the number of young-of-year (YOY) cormorants is the product of the fledgling productivity estimate for the year and the number of active nests. We did not account for bird mortality during the time of residence or the migrant double-crested cormorant population (transient birds that stay an unknown amount of time on Lake Ontario). Incorporating bird mortality estimates into the model would reduce fish consumption estimates whereas including migrant birds would increase estimated consumption. Although YOY cormorants are generally present for about 113 days, consumption by chicks during the first 3 weeks post-hatch is considered minimal, and for the remainder of the season their daily food intake approximates that of adults (Weseloh and Casselman, unpublished report). Immature cormorants are essentially fully grown but non-reproductive birds.

Because of the apparent differences in feeding patterns of cormorants over the season, we identified three separate feeding phases, pre-chick (prior to chick hatch), chick (chicks present and being feed by adults), and post-chick (cessation of feeding chicks by adult) feeding. These phases were characterized by differences in diet consumption and daily fish consumption (i.e., the number of fish per pellet). Pre-chick feeding was from early April to early June, the chick feeding period from early June to late July, and the post-chick feeding period from early August to late September. To examine cormorant fish consumption by feeding period (i.e., pre-chick, chick, and post-chick) we further broke down the number of cormorants feeding days by age-class as follows:

	Days			
	Pre-chick	Chick	Post-chick	Total
Adults	64	42	52	158
Immatures	18	42	52	112
YOY	0	42	50	92

To estimate the number of fish consumed by cormorants during each feeding period we multiplied the number of double-crested cormorant feeding days by mean daily ingestion rates for that period. For estimates of mean daily ingestion rates, we used the mean number of fish per pellet multiplied by a fecal correction factor of 1.042 (Johnson and Ross 1996). Although variation in pellet production rates have been observed in cormorants (Carss et al. 1997) some researchers consider that a single pellet is typically produced by adult cormorants each day (Craven and Lev 1987, Orta 1992, Derby and Lovvorn 1997). Pellet production rates greater than one per day would increase our fish consumption estimates whereas rates less than one per day would reduce our estimates. Fish consumption estimates for each of the three feeding periods were summed to provide an annual fish consumption estimate. Specific fish consumption was estimated by multiplying the percent composition by number for a species in the diet for each feeding period by the total fish consumption estimate for that period. Consumption estimates were then summed for all three periods to provide annual consumption estimates for each species or taxon. The use of the Weseloh and Casselman model, which did not include variance estimates associated with the number of feeding days for each life stage, precluded us from generating standard error estimates for fish consumption estimates. To estimate the biomass of fish eaten, we assumed that cormorants consumed 0.47 kg fish per day (Schramm et al. 1984, 1987; Weseloh and Casselman 1992), representing about 25% of their body weight (Dunn 1975). We estimated the size of yellow perch (*Perca flavescens*), rock bass (*Ambloplites rupestris*) and pumpkinseed (*Lepomis gibbosus*) consumed during each cormorant feeding period by measuring at least 100 (in a few cases <100 were in a sample) randomly selected otoliths from each feeding period to the nearest 0.1 mm with calipers. Broken or chipped otoliths were not considered for measurement. For smallmouth bass (*Micropterus dolomieu*), we measured all unbroken otoliths from each feeding period even if the total exceeded 100. We used otolith-length fish-length relationships derived for smallmouth bass (Adams et al. 1999), yellow perch (Burnett et al. 2000), and rock bass and pumpkinseed (Ross and Johnson in review) to estimate the length of these species eaten by cormorants. To estimate the weight of these species consumed by cormorants we used length-weight regressions for eastern Lake Ontario populations (unpublished data).

Spatial and temporal variation in diet composition for the PI, SI, and LGI colonies was determined by using the equation of Morisita (1959) as modified by Horn (1966). Overlap values can range from 0, when samples contain no food in common, to 1, when there is identical representation of food between samples. When using this formula, overlap values (Cë) $ 0.60 are considered biologically significant (Zaret and Rand 1971).

Results

In all, 1,474 cormorant pellets were examined from PI (744) and SI (730) in 2001. Similar to previous years, three distinct cormorant feeding periods were apparent, i.e. pre-chick feeding, chick feeding, and post-chick feeding, and were characterized by differences in diet composition and daily fish consumption (fish/pellet). Daily fish consumption for the PI colony declined from 18.5 during the pre-chick feeding period, to 15.8 during the chick feeding period, to 9.1 during the post-chick feeding period, and averaged 15.2 for the season (Table 1). Decreased daily fish consumption at the SI colony over the season was not as dramatic as that at PI. Fish consumption decreased from 14.2 fish per pellet to 10.1 fish per pellet from late May to early Sept. and averaged 12.4 for the season (Table 2).

<u>Diet Composition</u>

The diet of cormorants from the PI colony consisted mostly of alewife (29.4%), three-spine stickleback (19.5%), yellow perch (16.7%), rock bass (11.6%), cyprinids (9.8%), slimy sculpin (6.3%), and smallmouth bass (3.5%) (Table 1). Alewife were the major component of the diet at PI during the chick (58.9%) and post-chick (27.0%) feeding periods whereas three-spine stickleback dominated the diet during the pre-chick (51.0%) feeding period. The contribution of three species in the diet, yellow perch, rock bass and smallmouth bass, increased as the season progressed. Slimy sculpin were more frequently consumed early (10.1%) in the season, whereas cyprinids contributed more to the diet late (17.5%) in the season (Table 1). For the entire season forage fish (i.e. alewife, three-spine stickleback, cyprinids, slimy sculpin, etc.) comprised 65.9% of the diet, panfish (i.e. yellow perch, rock bass, pumpkinseed, ictalurids etc.) composed 31.4%, and gamefish (mostly smallmouth bass) contributed 3.6% of the diet of PI cormorants (Table 1).

Yellow perch (43.9%), cyprinids (14.5%), alewife (13.2%), rock bass (10.6%), pumpkinseed (6.8%), three-spine stickleback (4.5%), and slimy sculpin (3.1%) were the main prey of SI cormorants (Table 2). Yellow perch were the principle components in the diet during each feeding period (34.8%-51.7%). The contribution of three-spine stickleback (9.4% to 0) and slimy sculpin (4.9% to 1.9%) in the diet declined over the season, whereas rock bass increased (5.1% to 17.1%). Panfish (yellow perch, rock bass, pumpkinseed, ictalurids) made up 63.1% of the diet of SI cormorants, forage fish (cyprinids, alewife, three-spine stickleback, slimy sculpin) 35.8%, and gamefish (smallmouth bass and esocids) 1.1%, (Table 2).

<u>Diet Overlap</u>

Diet overlap between cormorants from the PI and SI colonies was low (least similar) during the pre-chick feeding period but was high thereafter (Table 3). For the entire season, diet overlap between the two colonies was significant (i.e. Cë=0.699) (Table 3). Significant temporal variation in diet composition occurred at PI. Diet overlap between the three feeding periods averaged 0.422 and was high (0.773) only between the chick and post-chick feeding periods (Table 4). Temporal variation in diet composition was minimal at SI (CëΘ =0.845, range 0.777-0.939) (Table 4).

Fish Consumption

Based on nests counts of 1,180 on PI and 1,160 on SI and fledgling productivities of 1.3 chicks per nest (pers. comm. James Farquhar, NYSDEC, Watertown), we estimated 0.54 and 0.53 million cormorant feeding days for these colonies, respectively, in 2001. Fish consumption for the PI colony was estimated at 7.5 million fish and 0.54 million pounds, and for the SI colony at 6.6 million fish and 0.53 million pounds (Table 5). Cormorants from PI consumed 4.9 million forage fish (including 2.2 million alewife, 1.5 million three-spine stickleback, 0.7 million cyprinids and 0.5 million slimy sculpin), 2.3 million panfish (1.3 million yellow perch, 0.9 million rock bass, 0.1 million pumpkinseed and 0.1 million ictalurids), and 0.3 million gamefish (mostly smallmouth bass, 0.26 million) (Figure 1). Cormorants from the SI colony consumed 4.2 million panfish (2.9 million yellow perch, 0.7 million rock bass, 0.4 million pumpkinseed and 0.1 million ictahurids), 2.3 million forage fish (1.0 million cyprinids, 0.9 million alewife, 0.3 million three-spine stickleback and 0.2 million slimy sculpin) and 0.1 million gamefish (0.05 million smallmouth bass and 0.03 million esocids) (Figure 1).

Size of fish consumed

Temporal changes in the size of some species consumed by cormorants was apparent. At PI the size of yellow perch and pumpkinseed consumed by cormorants increased over the season (Table 6). At SI the size of smallmouth bass increased over the season and smaller pumpkinseed were consumed earlier in the season (pre-chick feeding period). Spatial differences between colonies in the size of fish consumed was also evident. The smallmouth bass consumed by cormorants at PI in 2001 were larger than at SI during each feeding period whereas the size of pumpkinseed consumed was generally larger at SI (Table 6).

The average weight of smallmouth bass, yellow perch, rock bass, and pumpkinseed (computed from length-weight regressions) for each feeding period is provided in Table 6. We determined the biomass of each of these four species consumed by cormorants during each feeding period at the colony. For the entire feeding season, cormorants from PI and SI colonies consumed 20,000 and 2,000 pounds of smallmouth bass, 45,000 and 108,000 pounds of yellow perch, 25,000 and 20,000 pounds of rock bass, and 3,000 and 20,000 pounds of pumpkinseed, respectively.

Discussion

Johnson et al. (2001b) reported substantial annual variation in the diet of cormorants at PI and minimal annual variation in diet at SI between 1999 and 2000. These trends continued in 2001 with the diet of cormorants from PI being different from earlier years. For the third year in a row a different fish was the main prey species at PI (i.e. 1999-yellow perch, 2000-three-spine stickleback, 2001-alewife). Since 1999 the contribution of these three species in the diet of PI cormorants has ranged from 13.5% to 29.4% for alewife, 9.3% to 45.5% for three-spine stickleback, and 15.8% to 38.4% for yellow perch. At SI yellow perch was the primary prey of cormorants for the third consecutive year (Johnson et al. 2000, 2001b).

Johnson et al. (2001b) speculated that temporal variation in diet composition at LGI and PI was due to the seasonal occurrence of alewife and three-spine stickleback in the diet. Of these three large eastern basin colonies LGI and PI appear to be most alike in terms of diet composition and seasonal feeding trends. Diet overlap between LGI and PI in 2001 was by far the highest (Cë =0.892) observed among the three colonies (Table 3). However, there were some differences in the consumption of alewife in 2001 between the LGI and PI colonies. Although alewife consumption by the PI colony increased sharply following the pre-chick feeding period, increasing from 4.0% to 58.9%, total dominance of alewife in the diet during each feeding period (30.3% to 63.0%) occurred only at LGI. This reduced temporal variation in diet composition at LGI thereby increasing diet overlap among feeding periods (i.e., Θ=0.855) (Table 4). Because of the dominance of alewife in the diet of LGI cormorants throughout the season in 2001, temporal feeding patterns at LGI were more similar to those at SI where yellow perch dominated during each feed period then those at PI. In 2000, Johnson et al. (2001b) found that temporal feeding patterns by LGI cormorants were more similar to cormorants at PI than at SI.

Fish consumption by the PI colony has declined for the past three years, from 15.3 million fish and 1.06 million pounds in 1999 to 7.5 million fish and 0.54 million pounds in 2001 (Johnson et al. 2000, 2001b). Fish consumption by the SI colony has remained fairly stable since 1999. Over the past three years we estimate that cormorants from PI and SI have consumed about 56.6 million fish weighing 3.9 million pounds. In 2001, cormorants from LGI (Johnson et al. 2002), PI and SI consumed 35.5 million fish weighing 2.94 million pounds. Since 1999, we estimate that cormorants from these three colonies have eaten approximately 116 million fish weighing about 9.5 million pounds.

There was no apparent difference in the size of smallmouth bass, yellow perch and pumpkinseed consumed by PI and SI cormorants between 2000 and 2001 (Johnson et al. 2001b). However, the size of rock bass consumed at both colonies declined in 2001 from a mean of 123 mm to 90 mm. This decline in the size of rock bass consumed between years was also evident at the LGI colony although the size of rock bass eaten at LGI were larger, on average (104 mm to 90 mm) than those at PI and SI (Johnson et al. 2002). For the second consecutive year the size of pumpkinseed consumed by cormorants at PI were smaller than those at the other two eastern basin colonies.

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Table 1. Seasonal and total percent diet composition of double-crested cormorants from Pigeon Island, 2001. Sample dates for the pre-chick, chick and post-chick feeding periods were 5/24/01 and 6/6/01, 7/11/01, and 8/8/01 and 9/5/01, respectively.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	300	150	294	744
Fish/pellet (adjusted)	18.5	15.8	9.1	15.2
Alewife	4.0	58.9	27.0	29.4
Three-spine stickleback	51.0	0.6	0.5	19.5
Yellow perch	12.0	13.3	24.0	16.7
Rock bass	7.8	13.2	15.6	11.6
Cyprinid	9.9	4.6	17.5	9.8
Slimy sculpin	10.1	3.2	5.3	6.3
Smallmouth bass	0.7	5.0	5.6	3.5
Pumpkinseed	2.6	0.7	0.9	1.4
Ictalurid	1.6	0.3	2.4	1.3
Catostomid	<0.1	0.2	0.3	0.2
Freshwater drum	---	---	0.7	0.2
Esocid	<0.1	---	0.1	<0.1
Trout-perch	0.2	---	---	<0.1
Rainbow smelt	<0.1	---	---	<0.1
Lake herring	<0.1	---	---	<0.1
White perch	<0.1	---	---	<0.1
Burbot	---	---	0.1	<0.1
	100.0	100.0	100.0	100.0

Table 2. Seasonal and total percent diet composition of double-crested cormorants from Snake Island, 2001. Sample dates for the pre-chick, chick and post-chick feeding periods were 5/3/01 and 6/6/01, 7/11/01, and 8/8/01 and 9/5/01, respectively.

	Pre-chick	Chick	Post-chick	Total
No. of pellets	300	138	292	730
Fish/pellet (adjusted)	14.2	13.3	10.1	12.4
Yellow perch	51.7	34.8	45.7	43.9
Cyprinids	13.4	11.0	19.4	14.5
Alewife	2.2	31.2	5.0	13.2
Rock bass	5.1	9.8	17.1	10.6
Pumpkinseed	11.4	3.8	5.4	6.8
Three-spine stickleback	9.4	4.1	----	4.5
Slimy sculpin	4.4	2.9	1.9	3.1
Ictalurid	1.1	0.7	3.6	1.8
Smallmouth bass	0.2	1.1	1.0	0.8
Catostomid	0.3	0.2	0.5	0.3
Esocid	0.6	---	0.4	0.3
Trout-perch	0.2	0.4	<0.1	0.2
Rainbow smelt	<0.1	---	---	<0.1
Freshwater drum	<0.1	---	---	<0.1
	100.0	100.0	100.0	100.0

Table 3. Spatial diet overlap (Cë) among three eastern Lake Ontario cormorant colonies, 2001.

Feeding period	Colonies L. Galloo I.-Pigeon I.	Colonies L. Galloo I.-Snake I.	Colonies Pigeon I.-Snake I.
Pre-chick	0.565	0.659	0.353
Chick	0.988	0.773	0.791
Post-chick	0.897	0.593	0.786
Entire season	0.892	0.692	0.699

Table 4. Temporal diet overlap (Cë) among feeding periods at each of the three eastern Lake Ontario cormorant colonies, 2001.

Feeding period	Little Galloo I.	Pigeon I.	Snake I.
Pre-chick - Chick	0.754	0.177	0.777
Pre-chick - Post-chick	0.881	0.315	0.939
Chick - Post-chick	0.931	0.773	0.818
0 =	0.855	0.422	0.845

Table 5. Fish consumption estimates (in millions) for cormorants from the Pigeon and Snake Island colonies in eastern Lake Ontario, 2001.

	Pigeon Island		Snake Island	
Period	Number	Pounds	Number	Pounds
Pre-chick feeding	2.9	0.16	2.2	0.15
Chick feeding	2.7	0.17	2.3	0.17
Post-chick feeding	1.9	0.21	2.1	0.21
Total	7.5	0.54	6.6	0.53

Table 6. Estimated total length (TL, mm), average weight (Wt, g), number examined (No.), and standard error (SE) of smallmouth bass, yellow perch, rock bass and pumpkinseed consumed by double-crested cormorants during each feeding period on Pigeon Island and Snake Island in 2001.

	Pigeon Island				Snake Island			
Pre-chick								
Species	TL	Wt.	No.	SE	TL	Wt.	No.	SE
Smallmouth Bass	177	69	44	7.7	118	18	7	18.2
Yellow perch	109	14	100	2.9	125	21	100	3.0
Rock bass	84	11	100	4.1	92	15	100	4.0
Pumpkinseed	76	8	100	2.5	98	19	100	3.6
Chick								
Species	TL	Wt.	No.	SE	TL	Wt.	No.	SE
Smallmouth Bass	133	27	54	7.2	119	19	19	16.8
Yellow perch	117	17	100	2.6	108	14	100	2.7
Rock bass	94	16	100	3.3	85	12	100	3.4
Pumpkinseed	79	9	15	2.8	106	25	92	3.5
Post-chick								
Species	TL	Wt.	No.	SE	TL	Wt.	No.	SE
Smallmouth Bass	152	43	49	6.4	134	28	17	12.4
Yellow perch	131	24	100	2.7	123	20	100	3.0
Rock bass	89	13	100	2.9	93	15	100	3.3
Pumpkinseed	106	25	28	5.2	106	25	100	2.2

Figure 1. Estimated number (in millions) of fish consumed by cormorants from the Pigeon (a) and Snake (b) Island colonies in eastern Lake Ontario 2001.