Seasonal Feeding of Carp, *Cyprinus carpio*, in the Bay of Quinte Watershed, Ontario

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Observations from three areas and three seasons in 1977-78 suggest that Carp resident in the waters of the Bay of Quinte watershed are omnivorous, but primarily ingest invertebrate organisms. Feeding is curtailed but does not cease during the autumn and winter months. Plant materials make up a small part of digestive tract contents in the fall, changing to seeds in the winter. The presence of considerable debris during summer and fall suggests an active scouring of the substrate during feeding. A low incidence of plant materials in the digestive tract contents at any time of the year indicates a low nutritional dependence on aquatic plants. This suggests that, at present population densities, Carp are not a threat (in terms of direct ingestion) to indigenous aquatic plants though they may still act the role of a control species for many native macrophytes.

Key Words: Carp, *Cyprinus carpio*, feeding, macrophytes, benthos, invertebrates, seasonal, polyphagous, Wild Rice

Carp, *Cyprinus carpio*, became naturalized in the Bay of Quinte watershed early in the present century likely as a result of a combination of easterly movements of the species through the Trent Canal system from Lake Simcoe, and invasions from plantings made in New York State where Carp had been introduced into the Lake Ontario watershed as early as 1890 (Smith 1892). Presence of the Carp was first reported from the Bay of Quinte in 1907 and from most of the Kawartha Lakes by 1915 (McCrimmon 1968; MacCrimmon and Skobe 1970).

There is a longstanding concept, and some evidence, that the feeding habits of alien Carp may be detrimental to pristine aquatic ecosystems, especially indigenous vegetation and dependent fish and wildlife species (Cahn 1919; Gerking 1950). Early Canadian evidence of their deleterious effects on aquatic resources is limited historically to a relationship observed between Carp overabundance and the destruction of rooted aquatics, in particular, Wild Rice (*Zizania aquatica*), Wild Celery (*Valisneria americana*), and Water Milfoil (*Myriophyllum excalbens*), in marsh habitats in the lower Great Lakes basin (McCrimmon 1968; MacCrimmon and Skobe 1970). Other negative relationships between the Carp and the environment are speculative and, in fact, the presence of this species may prove to be beneficial to eutrophifying waters (Uhler 1944; McCrimmon 1968; and others).

Despite concern over potential negative effects of Carp populations on the aquatic resources of waters such as those in the Bay of Quinte watershed, no comprehensive investigation of the feeding and diet of the species has been undertaken in Canadian waters. This paper, therefore, records just such information on the Carp by reporting on the gastrointestinal contents of the species taken from three Bay of Quinte watershed locations over a 12-month period.

Materials and Methods

Carp were collected in the Bay of Quinte watershed from the Indian River, Bay of Quinte itself, and Sturgeon Lake (Figure 1). A detailed description of the watershed is provided by Johnson and Owen (1971).

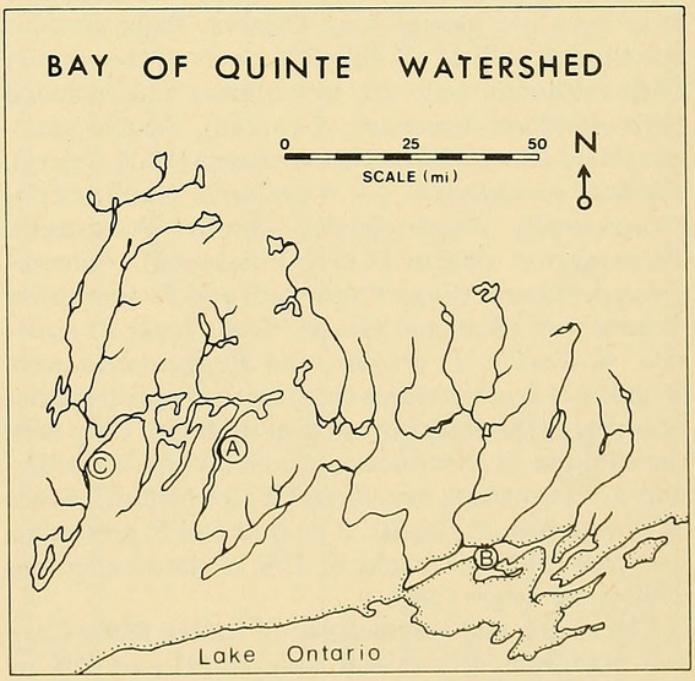

FIGURE 1. Bay of Quinte Watershed showing the Kawartha Lakes District and sampling areas: A, Indian River; B, Bay of Quinte; C, Sturgeon Lake.

Collections from the Indian River were made during the spring and summer of 1977 by seine and fyke net. The Carp were transported to the Trent University laboratory for routine examination. Fish were sorted into two size groups and the entire gastrointestinal tract preserved in 10% formalin for later study. Samples also were taken from Carp caught commercially by gill nets during the fall of 1977 from the Bay of Quinte, and during the winter from Sturgeon Lake, in 1978.

The volumes of digestive tract contents up to 10 ml were measured in graduated cylinders to the nearest 0.1 ml. If the total volume was greater than 10 ml, a mixed 10% subsample was taken from larger samples. Food items were recorded by frequency of occurrence and relative volume (Ricker 1968). Because of the macerated nature of much of the material in the digestive tracts of most fish, some animal life was classified only to order or group, such as plants, (green fragments and seeds), debris (sediments and dead plant material), or unidentified invertebrates. Statistical differences between- and within-group were examined using a "student t-test" (Steel and Torrie 1960).

Results

Indian River Carp specimens collected during the spring and summer months contained food in 92% of the digestive tracts with a mean volume of 12.9 ml/kg body weight (Table 1). Separation of the fish into two size groups showed a higher percentage of animal organisms (91%) in the diet of the younger fish. The dominant invertebrates in relative importance (Table 2) in both size groups were Diptera. Plant remains occurred in 39% of all digestive tracts of the smaller Carp (although only 2% by volume) and included *Ceratophyllum demersum* (Coontail), *Zizania aquatica* (Wild Rice), *Valisneria americana* (Wild Celery), *Elodea canadensis* [= *Anacharis canadensis*] (Waterweed), *Najas flecilis*, (Bushy Pondweed), *Potamogeton crispus* (Curly Pondweed), *Potamogeton pectinatus* (Sago Pondweed) and *Potamogeton richardsonii* (Redhead Grass). Seeds from *Z. aquatica, N. flexilis, P. crispus*, and *P. pectinatus* were found in 25% of the stomachs. The above plant species occurred in the digestive tracts of the larger Carp with the addition of *Nymphaea odorata* (White Waterlily) and *Myriophyllum excalbens* (Water Milfoil). Seeds of *Z. aquatica, N. flexilis, P. crispus* and *P. pectinatus* occurred in the stomachs of 25% of the smaller and 27% of the larger Carp.

The spring and summer diet of Indian River Carp was predominantly animal material (91 and 82% by volume, Table 2). Debris was the second most important food category. Statistical analysis (P = 0.05) revealed no significant difference in food item prefer-

TABLE 1. Vital statistics and contents of digestive tracts of Carp taken from three waters in the Bay of Quinte Watershed, Ontario, 1977 and winter of 1978.

Location	Number of Specimens	Age Range (Years)	Length Range (mm)	Weight Range (g)	Volumetric Diet Composition			Tracts with food (%)	Mean Volume (ml/kg body weight)
					Animal	Plant	Debris (%)		
Spring/Summer									
Indian River	56	1 to 3	135-256	40-700	91	2	7		
Indian River	48	4 to 9	257-377	726-4210	82	8	10	92	12.9
Autum									
Bay of Quinte	128	8 to 16	600-860	3985-9024	74	8	18	86	5.6
Winter									
Sturgeon Lake	120	8 to 17	625-910	3900-9325	97	2	1	74	1.4

ence by prey group with sex or size at this location.

Adult Bay of Quinte Carp specimens collected during the autumn months contained food in 86% of the digestive tracts with a mean volume of 5.6 ml/kg fish (Table 1). Diptera dominated the invertebrate forms (Table 2) with their larvae and pupae making up 38% by volumetric proportion. Debris was the second highest level of relative importance at 18% by volume. The plant component was only 7% by volume (Table 2), principally green fragments and consisting of the same species identified in the Indian River samples. The autumn diet of the Bay of Quinte Carp was dominated by animal material with debris and plant items making up 18 and 8% respectively (Table 1). There were no significant differences between the presence of major food groups and the sex or two size categories.

Mature Sturgeon Lake Carp specimens collected by large mesh (over 18 cm) gill nets during the winter months contained food in 74% of the digestive tracts with a mean volume of 1.4 ml/kg body weight (Table 1). Diptera made up 43% and Cladocera 29% of their diet by volume (Table 2). The plant component, which occurred in 32% of the digestive tracts, made up only two percent of the diet by volume and consisted almost entirely of seeds of *Zizania aquatica, Najas flexilis, Potamogeton crispus*, and *Potamogeton pectinatus*. The winter diet of Sturgeon Lake Carp was found to consist almost entirely of animal items (98% by volume, Table 1). There was no significant difference between food items ingested and either size or sex (t-test, P = 0.01).

Discussion

Analysis of the Carp digestive tract contents between sites revealed no significant difference (P = 0.05) between categories or volumes of ingested groups. Thus comparison of the data by water body or season was simplified. This finding was rather surprising, since some authors have clearly related Carp size to food preference (Bailey and Harrison 1945; Alikunhi 1958). It is possible that clear food/fish size relationships were inconsistent because sampling sites were different over the seasons. It was necessary, however, to use Carp specimens when available from several waters, to round out data in the annual feeding cycle. From this study there is no evidence that available food items varied appreciably within the three waters that were essentially warmwater and eutrophic (Johnson and Owen 1971; R.W. Lewies 1976. The fisheries of the Kawartha Lakes. *In:* Kawartha Lakes Water Management Study/Water Quality Assessment (1972-1976). Ontario Ministry of the Environment and Ministry of Natural Resources, MS pp. 83-106), but future studies should focus on one site

TABLE 2. Incidence of occurrence of mean volumes of materials in digestive tracts of Carp from the Bay of Quinte Watershed, by area and principal food grouping.

	Indian River Spring/Summer, 1977				Sturgeon Lake Autumn/Winter, 1978				Bay of Quinte Autumn, 1977	
	Small Fish 256 mm		Large Fish 257 mm		Large Fish 600 mm		Large Fish 625 mm			
Food Category	% Occurrence	% Volume	% Occurrence	% Volume	% Occurrence	% Volume	% Occurrence	% Volume		
Cladocera	63	26	69	7	43	29	77	7		
Copepoda	63	20	65	4	43	12.5	66	4		
Trichoptera	41	4	69	12.5	0	0	73	9.5		
Diptera	86	28	81	32.5	49	43	79	38		
Mollusca	32	1	72	10.5	23	6.5	71	8.5		
Other Invertebrates	24	11	25	15	0	5.5	30	8		
Plant Material	39	2	71	8	32*	2*	84	8		
Debris	88	7	81	10	27	1	67	18		
Number of Stomachs	56		48		120		128			

*Seeds only

over a season, to confirm our preliminary observations.

The omnivorous nature of the digestive tracts' contents is typical of Carp generally (McCrimmon 1968; Scott and Crossman 1973; McAllister and Coad 1974), and suggests that most littoral plant items are likely to be ingested either by choice or incidentally. The presence of substantial amounts of debris (2 to 8% by volume) in fish from all waters confirms that considerable sucking and digging activity by the Carp may occur while feeding (Vass 1957; Moen 1953). However, the items ingested by each Carp population were principally invertebrates (74 to 97% by volume) although a review of the literature (Table 3) shows that the relative amount of animal and plant materials in Carp from various waters is extremely variable (19 to 98% by volume).

Only during the winter period of ice cover, when macrophyte production would be minimal, did plant material not make up an appreciable percentage (7 to 18%) of the volume of ingested items by the Carp.

Seeds were found in 32% of the Carp in winter, and would represent high caloric-value food. Another noteworthy observation was that Carp did, in fact, feed under the ice in winter. This finding is new, and has not been reported for the Carp in European waters. Opinions differ on the dietary importance of vegetable matter, and there is some question whether feeding on aquatic plants if obligatory, as asserted by Gaevskaya (1969). While some authors (Cole 1905; Tracey 1910) reported direct grazing, other authors (Eder and Carlson 1977) concluded that the presence of plant materials in the digestive tract are a consequence of intensive searching for invertebrates. Others (Summerfelt et al. 1971) argue that there may be no nutritional reward because of the inability of the species to digest cellulose. On the other hand, Carp are known to feed strictly on vegetation in rice fields (Gaevskaya 1966); and Gunn et al. (1976) have clearly demonstrated that Bullhead (*Ictalurus nebulosus*) can assimilate algae. If we add to this the findings of Kevern (1966), who showed that yearling carp ingest and assimilate both detritus and algae, we must also support the argument on the side of herbivory, with the addition of seeds to the winter diet.

With more eutrophic conditions in recent years in the Quinte region, both Carp and plant production have increased noticeably (J. Christie, personal communication). One impact on aquatic vegetation would seem to be uprooting of macrophytes by scouring activity, and there is no doubt (McCrimmon 1968) that high Carp populations can cause marked ecological change by uprooting vast areas of more susceptible rooted aquatics, especially Wild Rice, Wild Celery, and Water Milfoil. Accompanying such activity, the turbidity may reduce photosynthesis. However, population levels of Carp in the Bay of Quinte drainage would seem to be substantially below levels which cause vegetative devastation, perhaps because a significant commercial fishery is maintained, thus keeping the Carp populations within reasonable size.

To maintain primarily an animal diet, as judged by volume (which may or may not be a legitimate method), the Bay of Quinte Carp ingested a wide variety of invertebrate organisms, with Diptera, Cladocera, Trichoptera and Copepoda the dominant categories in Carp from the three sites (Table 2). The considerable variations in dominant invertebrate organisms ingested by Carp (Moen 1953; Nakamura 1955; Sigler 1958; Rehder 1959; Walberg and Nelson

TABLE 3. Food of Carp as reported by various authors, expressed in % of total volume of digestive tract contents, showing the relative importance of plant and animal contingents.

Reference	Region/Habitat	Size	% Animal	% Plant
Birznek (1962) *in* Gaevskaya 1966	Russian Rice Fields	All	Mainly Plants and seeds	
Ewers and Boesel 1935	Buckeye Lake, Ohio	Young	88	12
Egereva (1958) *in* Gaevskaya 1966	Volga River	All	22	78
Harrison 1950	Iowa Lakes	Adult	63	32
Moen 1953	Iowa Lakes	Adult	75	25
Pearse 1918	Wisconsin Lakes	Adult	90	6
Rehder 1959	Des Moines River Iowa	Adult	23	77
Sibley 1929	Lake Erie	Young	62	14
Sigler 1958	Utah Lakes	Adult	23	77
Struthers 1929	Erie-Niagara System	Adult	44	56
Struthers 1930	St. Lawrence Watershed, New York	Adult	50	50
Present Study	Bay of Quinte Watershed	Young	91	8
		Adult	74-98	1-8

1966; Summerfelt et al. 1970; Eder and Carlson 1977) would seem to be explained largely by the local abundance and relative seasonal availability of aquatic invertebrates. A greater prevalence of chironomids in Bay of Quinte Carp than occurred in the two Kawartha waters, for example, may be related to the high abundance of such benthic organisms in the Quinte region (Johnson and Brinkhurst 1971). On the other hand, a high chironomid component could reflect a seasonal or site-specific bias.

While fish eggs, including those of the Carp themselves, have been recorded as infrequent constituents of Carp stomachs elsewhere (Cole 1905; Leach 1919), predations by Quinte Carp on fish eggs or fish was also of negligible consequence in this study. Conversely, Carp are in permanent co-existence with various piscivorous fishes, including esocid and centrarchid species in the Bay of Quinte watershed (MacKay 1963) and juvenile Carp are known to contribute to the diet of these species (McCrimmon 1968). Carp may, therefore, be an amenity to local sport fisheries at this time.

Seasonal variability in feeding activity, or intensity of feeding (Table 1), is apparent from mean volumes of digestive tract contents in the Carp stomachs. The most active feeding seems to occur in the spring and summer months (12.9 ml/kg fish body weight) when the water is warmest, and the least intensive during the cold winter months (1.4 ml/kg fish body weight), when metabolic rates are the highest and lowest, respectively. Similarly, the numbers of Carp containing food are greatest in the spring and summer, and least in the winter. Also, the decreased abundance of debris and plant materials in their diet during the winter suggests a lesser foraging among vegetation. Macrophyte production at the time of sampling under a thick ice-cover, would have been at its lowest annual level.

There is no evidence from the present study that Carp in the Bay of Quinte watershed, at present population levels, are deleterious to either indigenous aquatic vegetation or preferred fish species. Any substantial increase in the Carp populations in these waters may, however, lead up to possibly severe environmental impact, such as has occurred historically in other Canadian waters when Carp become too numerous (McCrimmon 1968).

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