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JAMES S. BULAK

Fisheries Research Laboratory and Department of Zoology
Southern Illinois University, Carbondale, Ill.
Present address: *South Carolina Wildlife and*
Marine Resources Department
P.O. Box 170, Bonneau, SC 29431

ROY C. HEIDINGER

Fisheries Research Laboratory and Department of Zoology
Southern Illinois University
Carbondale, IL 62901

FOOD OF AGE 1 AND 2 ATLANTIC TOMCOD, *MICROGADUS TOMCOD*, FROM HAVERSTRAW BAY, HUDSON RIVER, NEW YORK

Atlantic tomcod, *Microgadus tomcod* (Walbaum), are opportunistic feeders (Howe 1971; Grabe 1978) with amphipods *Gammarus* spp. and the decapod *Crangon septemspinosa* identified as primary prey (Howe 1971; Alexander 1971; Scott and Crossman 1973; Grabe 1978; Nittel[1]). Limited data are available on the biology of yearling and older Hudson River tomcod due to their low overall abundance and because they are most abundant during winter when ice cover restricts sampling. This note summarizes feeding data of 339 tomcod, ages 1 and 2, from the Haverstraw Bay area of the Hudson River (37.5-41.5 mi north of the Battery, New York City) on 19 dates, January 1973-June 1976, and supplements food preference data on juveniles (Grabe 1978). All fish were collected as part of an ecological monitoring program conducted by Lawler, Matusky & Skelly Engineers for Orange and Rockland Utilities, Inc.

Methods

Collections (Table 1) were made with a 9.1 m otter trawl (64 mm mesh cod end liner) towed against the tide at 1.5-2.0 m/s during both day and night. The data are likely to be biased towards daytime feeding preferences since almost twice as many tows were taken during daytime as at night. Diel differences in feeding could not be evaluated because day and night collections were often combined for other analyses. Fish were preserved in 10% buffered Formalin.[2] In the laboratory they were measured (±1 mm total length, TL) and weighed (±0.1 g), and the stomachs were removed and preserved in 70% ethanol. Prey were identified and counted, and the contents of 195 stomachs were dried at 103° C. The number of fish per sampling period whose stomach contents were analyzed were limited by contract and were randomly selected from the total catch. Whenever possible, I analyzed additional fish to increase both sample size and temporal coverage. Yearling and older tomcod collected during fall 1973 were separated from young-of-the-year by examination of length-frequency histograms drawn from larger samples (Lawler, Matusky & Skelly Engineers[3]); by this method age 1 and 2 fish were those ≥160 mm TL. On other sampling dates young-of-the-year were present only as larvae or as juveniles <110 mm TL.

TABLE 1.—Collections of age 1 and 2 Atlantic tomcod from Haverstraw Bay, Hudson River, 1973-76.

Season	Sample size	Total length (mm) Mean	95% confidence limits
Winter (Jan.-Feb.)	72	130.5	126.2-134.7
Spring (Apr.-June)	166	158.7	155.8-161.6
Summer (July-Aug.)	10	156.3	142.2-170.3
Fall (Oct.-Dec.)	91	182.6	178.3-186.8

Food preference data were classified seasonally and examined as percentage occurrence (number of fish in which prey item "a" occurred/total number of fish), percentage composition (number of prey item "a"/total number of prey), and as importance, I, the geometric mean of these two measurements (Windell 1971). This approach, however, may overestimate the utilization of smaller prey (e.g., copepods) but should provide a better indication of feeding preference than either percent occurrence or percent composition taken singly. An index of fullness (Windell 1971), I_f, was calculated to evaluate feeding intensity (dry

[1]Nittel, M. 1976. Food habits of Atlantic tomcod (*Microgadus tomcod*) in the Hudson River. *In* Hudson River Ecology. Fourth Symposium on Hudson River Ecology. Bear Mountain, N.Y., March 28-30 1976. Hudson River Environmental Society, Inc.

[2]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[3]Lawler, Matusky & Skelly Engineers. 1976. Environmental impact assessment—water quality analysis: Hudson River. Natl. Comm. on Water Quality. NTIS PB-251099.

weight of stomach contents × 10^4 as a percentage of wet weight of fish). Empty stomachs were included in seasonal measurements of feeding intensity. Statistical tests were from Sokal and Rohlf (1969).

Results and Discussion

Gammarus spp. were the most important prey during all seasons (Table 2). Secondary prey included copepods (winter), the oppossum shrimp, *Neomysis americana* (spring and fall) *Monoculodes* sp. (Amphipoda) (spring), *Cyathura polita* (Isopoda) (spring and fall), and sand shrimp, *Crangon septemspinosa* (fall). *Gammarus* spp., *N. americana,* and *Monoculodes* sp. are numerically important tychoplankters in this area of the Hudson River (Ginn 1977; Lauer et al.[4]). Abundant infaunal species in the Haverstraw Bay area include the polychaete *Scolecolepides viridis* the amphipod *Leptocheirus plumulosus,* and *Cyathura polita* (Ristich et al. 1977). Tychoplankton appears to be more important as prey of Hudson River tomcod than infauna. In other estuaries, however, infauna may be more important; e.g., Alexander (1971) found that polychaetes, even though

[4]Lauer, G. J., W. T. Waller, D. W. Bath, W. Meeks, R. Heffner, T. Ginn, L. Zubarik, P. Bibko, and P. C. Storm. 1974. Entrainment studies on Hudson River organisms. *In* L. D. Jensen (editor), Entrainment and intake screening. Proceedings on the second entrainment and intake screening workshop, p. 37-82. Johns Hopkins Univ. Edison Electric Inst. Rep. 15.

TABLE 2.—Seasonal prey of age 1 and 2 Atlantic tomcod from Haverstraw Bay, Hudson River, 1973-76.

	Percent occurrence[1]				Percent composition[2]				Importance[3]			
Taxon	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Nematoda		0.6		2.2		<0.1		0.1		0.1		0.5
Polychaeta:												
Scolecolepides viridis		2.4		2.2		0.1		0.1		0.5		0.5
Oligochaeta				1.1				0.4				0.7
Hirudinea		1.2		2.2		0.1		0.2		0.3		0.7
Glossiphoniidae	6.9			0.3					1.4			
Helobdella sp.		0.6				<0.1				0.1		
Theromyzon sp.		2.4				0.2				0.7		
Piscicola milneri		0.6				<0.1				0.1		
Mollusca:												
Amnicola sp.		1.2		1.1		<0.1		0.1		0.2		0.3
Crustacea:												
Ostracoda		0.6				<0.1				0.1		
Copepoda	45.8	4.8		2.2	47.7	1.3		0.3	46.7	2.5		0.8
Mysidacea:												
Neomysis americana	13.9	18.1	10.0	40.7	2.9	3.5	12.5	9.6	6.3	8.0	11.2	19.8
Isopoda:												
Chiridotea almyra		6.6				0.3				1.4		
Cyathura polita	2.8	18.7		14.3	0.1	0.9		2.3	0.5	4.1		5.7
Edotea triloba	1.4			5.5	0.1			0.5	0.4			1.7
Amphipoda:												
Corophium lacustre	1.4	1.8		2.2	0.1	0.1		0.1	0.4	0.4		0.5
Gammarus spp.	81.9	87.3	60.0	64.8	43.5	88.6	62.5	70.2	59.7	87.9	61.2	67.4
Leptocheirus plumulosus		6.6		1.1		0.3		0.1		1.4		0.3
Melita nitida				1.1				0.1				0.3
Monoculodes sp.	12.5	13.3		14.3	2.0	4.0		3.0	5.0	7.3		6.5
Decapoda:												
Callinectes sapidus				5.5				0.6				1.8
Crangon septemspinosa	1.4		30.0	49.1	0.1		18.8	7.2	0.4		23.7	18.8
Rhithropanopeus harrisii		1.2		20.9		0.1		2.3		0.3		5.7
Insecta:												
Odonata:												
Enallagma spp.		0.6				<0.1				0.1		
Trichoptera larvae		0.6		1.1		<0.1		0.1		0.1		0.3
Diptera:												
Chaoborus punctipennis larvae		1.8	10.0	1.1		0.1	6.2	0.1		0.4	7.9	0.3
Chironomidae larvae	2.8	4.8		4.4	0.1	0.2		0.7	0.5	1.0		1.8
Unidentified pupae		1.8				0.1				0.4		
Pisces:												
Alosa spp.				5.5				0.6				1.8
A. aestivalis				*								
A. pseudoharengus				*								
Anchoa mitchilli				2.2				0.1				0.5
Anguilla rostrata		0.6				<0.1				0.1		
Microgadus tomcod eggs	4.2				3.3				3.7			
M. tomcod larvae		1.2				0.1				0.3		
M. tomcod juveniles		1.8				0.1				0.4		
Unidentified	1.4	3.6		14.3	0.1	0.1		1.1	0.4	0.6		4.0

[1]Number of occurrences/total number of fish.
[2]Number of prey item "a"/total number of prey.
[3]Geometric mean of (percent occurrence × percent composition).

underestimated, ranked second to *Crangon septemspinosa* in the percent volume of stomach contents of tomcod from Montsweag Bay, Maine.

Feeding intensity showed significant differences between seasons by analysis of variance using arc-sine transformed I_f values ($F_{3,190} = 11.9$; $P<0.001$). A Student Newman-Keulls test showed that I_f was greatest during fall, and spring values were greater than winter and summer, which were similar ($P<0.05$) (Table 3). Percentage of empty stomachs was highest during winter, least during fall and spring. Feeding intensity, then, was greatest both prior to and subsequent to spawning, when, presumably, energy requirements were greatest. A similar seasonal cycle was described for juveniles (Grabe 1978).

A shift in importance of primary prey, from *C. septemspinosa* to copepods, occurred from fall to winter. A similar shift from the larger prey to smaller prey was noted for juveniles (Grabe 1978), and it was suggested that constriction of the alimentary canal by maturing gonads (Schaner and Sherman 1960) was a factor. To clarify this shift, predation on the primary species (*Gammarus* spp.) and large (*C. septemspinosa*) and small (copepods) secondary prey were examined for the period November 1974 through February 1975 (November and December fish were young-of-the-year; data summarized in Grabe 1978). *Gammarus* spp. were important throughout this period, especially on 4 December (Table 4). *Crangon septemspinosa* was important only during November and copepods were important during January and February. Since gonad production was generally greatest November through December and coefficient of maturity peaks during November for males and January for females (Orange and Rockland Utilities, Inc.[5]), the observed shift in prey selection corresponded well with gonad maturation. Causation has yet to be determined and small sample sizes may not depict the situation accurately.

Tomcod are occasionally piscivorous (Alexander 1971; Scott and Crossman 1973; Nittel see footnote 1). Five fish species, including eggs, larvae, and juvenile tomcod were identified as prey and were most important during the fall (Table 2). Cannibalism occurred at low levels during winter and spring. Cannibalism has been reported in other fishes, e.g., *Alosa pseudoharengus* (Rhodes et al. 1974) and *Stizostedion v. vitreum* (Chevalier 1973) and may be a factor affecting recruitment.

TABLE 3.—Index of fullness[1] (for subsamples) and percentage of empty stomachs of age 1 and 2 Atlantic tomcod from Haverstraw Bay, Hudson River, 1973-76.

Season	Sample size	Index of fullness		Percent empty[2]
		Mean	95% confidence limits	
Winter	70	6.21	4.19- 8.23	12.5
Spring	68	10.24	7.94-12.53	4.2
Summer	5	0.32	0.09- 0.55	10.0
Fall	52	20.62	12.08-29.12	3.3

[1]Dry weight of stomach contents × 10^4 as a percentage of wet weight of fish.
[2]Based on total number of fish analyzed; see Table 1.

Acknowledgments

Appreciation is extended to Orange and Rockland Utilities, Inc. for permission to analyze the fish, to Lawler, Matusky & Skelly Engineers for laboratory facilities, and to R. E. Schmidt for reviewing an earlier draft of the manuscript.

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[5]Orange and Rockland Utilities, Inc. 1977. Bowline Point Generating Station: Near-field effects of once-through cooling system operation on Hudson River biota.

TABLE 4.—Changes in the importance of *Crangon septemspinosa* (CS), copepods (Cop), and *Gammarus* spp. (Gamm) in the diet of Atlantic tomcod from Haverstraw Bay, Hudson River during the period November 1974 through February 1975.

Date	Sample size	Percent occurrence[1]			Percent composition[2]			Importance[3]			Mean number/stomach		
		CS	Cop	Gamm	CS	Cop	Gamm	CS	Cop	Gamm	CS	Cop	Gamm
5 Nov.	14	57.1	0.0	85.7	14.8	0.0	77.4	29.1	0.0	81.4	1.2	0.0	6.4
13 Nov.	13	69.2	0.0	46.2	41.2	0.0	23.5	53.4	0.0	33.0	2.2	0.0	1.2
4 Dec.	28	0.0	7.1	100.0	0.0	0.2	95.4	0.0	1.2	97.7	0.0	0.1	48.9
25 Jan.	15	6.7	73.3	66.7	0.1	68.1	18.7	0.9	70.7	35.3	0.1	39.1	10.7
19 Feb.	4	0.0	75.0	75.0	0.0	26.3	61.1	0.0	44.4	6.7	0.0	11.5	26.8

[1]Number of occurrences/total number of fish.
[2]Number of prey item "a"/total number of prey.
[3]Geometric mean of (percent occurrence × percent composition).

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STEPHEN A. GRABE

Normandeau Associates, Inc.
15 Pickering Avenue
Portsmouth, NH 03801