Age and Growth, Food Habits, and Forage Value of the Alewife in Watauga Reservoir, Tennessee

Richard J. Strange, *Department of Forestry, Wildlife, and Fisheries, University of Tennessee, P.O. Box 1071, Knoxville, TN 37901*

Karen Daniel Lee, *Department of Forestry, Wildlife, and Fisheries, University of Tennessee, P.O. Box 1071, Knoxville, TN 37901*

Douglas C. Peterson, *Tennessee Wildlife Resources Agency, 6032 W. Andrew Johnson Hwy., Talbott, TN 37877*

Abstract: In 1976, the alewife (*Alosa pseudoharengus*) was stocked in Watauga Reservoir, Tennessee, by the Tennessee Wildlife Resources Agency (TWRA), in an attempt to strengthen the forage base. To assess ecological impacts of the introduction, both age and growth and food habits of alewives were evaluated along with food habits of adult game fishes. The alewife population was composed of 3 age classes (O+, 1+, and 2+). Average back-calculated lengths were 70 mm at annulus I and 103 mm at annulus II. No significant differences between sexes were found with back-calculated lengths or with the length-weight relationship ($P = 0.05$). Alewives fed primarily on cladocerans, copepods, and crustacean eggs in both littoral and limnetic regions. Only one alewife had fish in its stomach. Alewives contributed to the diets of walleye (*Stizostedion vitreum*), smallmouth bass (*Micropterus dolomieui*), white and black crappie (*Pomoxis* spp.), rainbow trout (*Salmo gairdneri*), and Ohrid trout (*Salmo letnica*). Only in largemouth bass, were no identifiable alewives found, though unidentified clupeids (alewives and/or gizzard shad) occurred.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 39:156–165

Introduction of an exotic prey species is one of the most common forage fish management practices. Planktonic feeding members of Clupeidae, the herring family, have often been used in fisheries management as a forage species, due to their high fecundity and small size. They are presumed to strengthen the food chain between the plankton and piscivorous game fishes. Gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*D. petenense*) are clupeids which have been introduced widely as prey species and have the widest natural distribution throughout the southern United States. Often however, gizzard shad rapidly grow too large to be consumed by most predators. Threadfin shad, on the other hand, do not get as large, but are subject to die-offs when exposed to water below 9° C for prolonged periods (Strawn 1963). The alewife has been introduced in the Southeast as a small, cold tolerant, prey species. Such an introduction was made in Watauga Reservoir, Tennessee, when 1,000 alewives from Lake Hopatcong, New Jersey, were stocked on 1 October 1976. We evaluated this introduction in terms of alewife age and growth, alewife food habits, and forage value of the alewife to game fishes.

We wish to thank Ronald Jenkins, J. N. Markland, and Duane Oyer of the TWRA for their help in field collections. We would also like to thank Melbourne Whiteside for his assistance in the identification and analysis of the zooplankton samples. This study was contracted by TWRA with funds provided by Dingell-Johnson Project F-67 which are administered by the United States Department of the Interior, Fish and Wildlife Service.

Methods

Monthly collections of alewives and game fishes were made from March 1982 to June 1983. Collections of alewives were made at dusk and at night using vertical gill nets (9.5 mm and 12.7 mm mesh) in limnetic regions and horizonal gill nets (9.5 mm and variable mesh) and boat electrofishing in littoral regions. All nets were checked at 2-hour intervals to minimize digestion of stomach contents. Alewives were incised and preserved in 10% formalin. Samples of game fishes were collected by electroshocking, horizontal and vertical gill nets (50.8 mm, 76.2 mm, and variable mesh), and from angler creels. Game fish were weighed, measured, and sexed. The stomach was removed from each fish, wrapped with an identification number and preserved in 10% formalin.

Total scale radius and distance from the baseline to each annulus were measured on alewife scales. Lengths were back-calculated for each year of life using Lea's formula (Bagenal and Tesch 1978). The length-weight relationship of alewives was assumed to be $W = aL^b$. A logarithmic transformation of this equation followed by regression analysis was used to compare length-weight relationships for male and female alewives. The gonosomatic index (GSI) was used to indicate spawning periods. It was calculated as a percentage based on the formula:

$$GSI = \frac{\text{weight of both ovaries or testes}}{\text{total body weight} - \text{ovary or testes weight}} \times 100.$$

Alewife food habits were determined by washing the contents out of the stomach and intestine, diluting to a known volume, and identifying and counting the items in a subsample. Game fish stomach contents were identified and enumerated for numerical analysis (Lagler 1956, Windell and Bowen 1978). Food items were identified to the lowest taxonomic level permitted by digestion. Length of ingested prey species was measured, or estimated when possible.

Results

Sampling of the alewife population from 1982-1983 identified 3 age-classes (O+, 1+, and 2+). Total lengths at annulus I and II were back-calculated (Table 1). No significant difference was found between males and females for back-calculated lengths ($P = 0.05$). Further, no significant differences were found for the y intercept, slope, or regression coefficient of the log transformed linear model of length-weight relationship between males and females. Figure 1 shows the predicted length-weight relationship (not log transformed) for alewives in Watauga Reservoir. Mean gonosomatic indices for alewives indicated spawning occurred during a period beginning in April and terminating by August (Fig. 2).

Principle components of the alewife diet, by relative frequency of occurrence for the period of March 1982 through June 1983, were cladocerans, copepods, and crustacean eggs (Fig. 3). Though dipterans and hymenopterans occurred infrequently, when they did occur they were important due to their relatively large size. Frequency of occurrence by season was examined and found to be fairly constant except that dipterans were absent from stomachs in the winter and most abundant (14%) in the spring. Similarly, there was little difference in the diets of alewives collected in littoral areas and limnetic areas. It appeared that alewives were actively

Table 1. Back-calculated growth at each annulus for alewives from Watauga Reservoir, Tennessee, 1982–83. (Total lengths in mm at each annulus.)

	I				II			
Sex	N	$\bar{X}$	SE	Range	N	$\bar{X}$	SE	Range
Combined	145	70	0.09	44–98	54	103	0.18	88–123
Male	62	70	0.13	44–98	22	103	0.22	88–120
Female	80	70	0.11	46–96	31	103	0.18	88–123

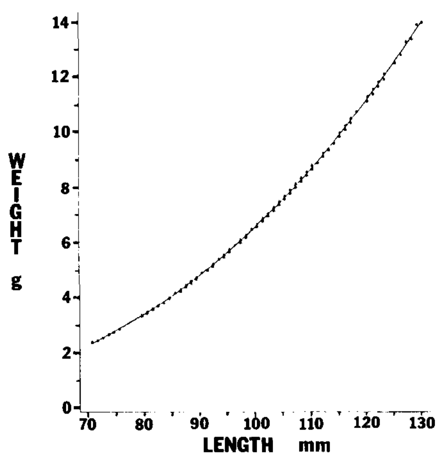

Figure 1. Predicted length-weight relationship for alewives from Watauga Reservoir.

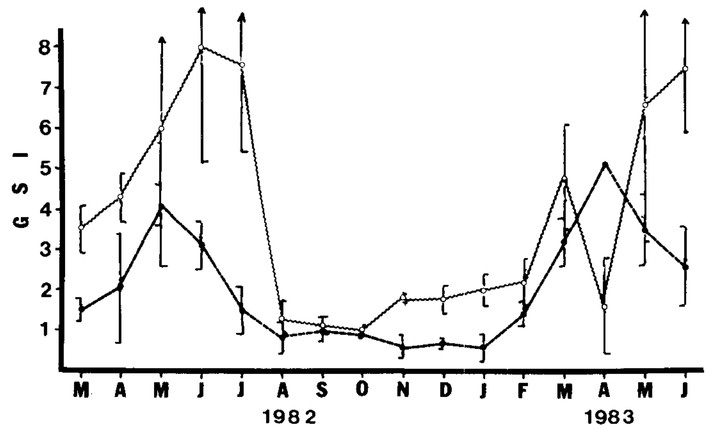

Figure 2. Mean (± standard error) gonosomatic indexes (GSI) for female (open circles) and male (solid circles) alewives by month in Watauga Reservoir.

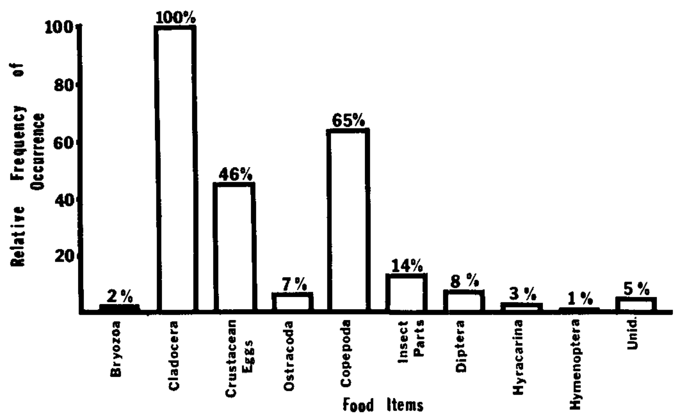

Figure 3. Relative frequency of occurrence of food items in alewives collected from March 1982 to June 1983 in Watauga Reservoir.

feeding in both littoral and limnetic areas as indicated by the presence of littoral food organisms (e.g. *Leydigia* spp., *Alona* spp.) in alewives collected in limnetic reigons, and *Chaoborus* sp., a limnetic food organism found in alewives collected in littoral regions. Alewives fed both in the water column as indicated by the presence of *Daphnia* spp. and cyclopoid copepods, and over the bottom, as indicated by the presence of harpacticoid copepods, ostracods, chironomids, and *Leydigia* spp. Presence of *Graptoleberis testudinaria* and *Alona* spp. indicate the feeding of alewives among weeds. Of 154 alewives analyzed for food habits, only 1 stomach con-

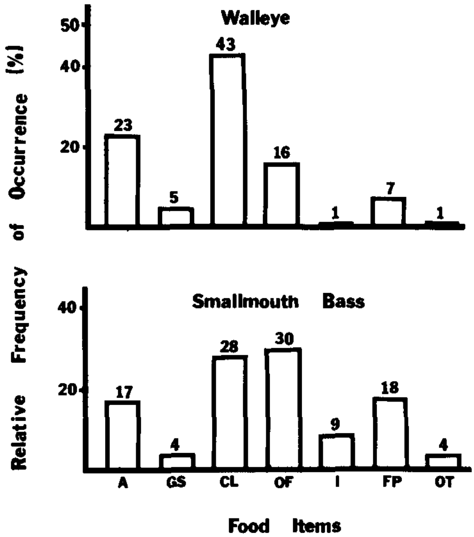

Figure 4. Relative frequency of occurrence (%) of food items for walleye and smallmouth bass from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, FP = fish parts, OT = 'other.'

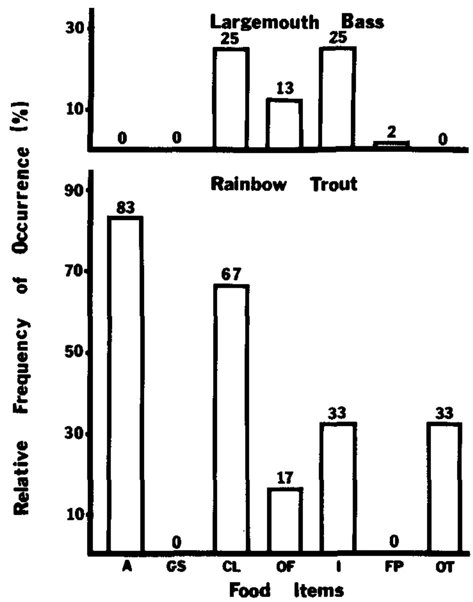

Figure 5. Relative frequency of occurrence (%) of food items for largemouth bass and rainbow trout from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, FP = fish parts, OT = 'other.'

tained fish remains. This individual (130 mm TL) was collected at night in a vertical gill net set under lights which concentrated larval fish.

Relative frequency of occurrence of food items was determined for 272 walleye, 66 smallmouth bass (Fig. 4), 14 largemouth bass, 6 rainbow trout (Fig. 5), 19 crappie, and 6 Ohrid trout (Fig. 6). Alewives were consumed by all species analyzed

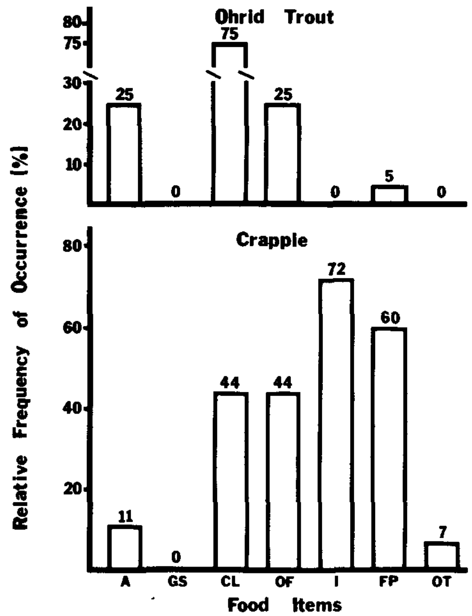

Figure 6. Relative frequency of occurrence (%) of food items for Ohrid trout and crappie from Watauga Reservoir collected from 1982 to June 1983. A = alewife, GS = gizzard shad, CL = clupeid, OF = other fish, I = insects, F = fish parts, OT = 'other.'

(crappie, 11%; smallmouth bass, 17%; walleye, 23%; rainbow trout, 83%; and Ohrid trout, 25%) with the exception of largemouth bass in which no alewives were identified. Gizzard shad were identified in smallmouth bass (4%) and walleye (5%) at a lower relative frequency of occurrence than alewives. All species contained unidentified clupeids (either alewives or gizzard shad). Seventy-two percent of crappie examined contained insects compared to 33% in rainbow trout, 25% in largemouth bass, 9% in smallmouth bass, and 1% in walleye. Included in the "other" category were zooplankton found in crappie and crayfish which occurred in largemouth and smallmouth bass.

Actual total lengths of alewives from stomachs of walleye were 53 to 86 mm and 80 to 97 mm in rainbow trout. Estimated total lengths of alewives ranged from 45 to 134 mm in walleye, 61 to 89 mm in smallmouth bass, and 75 to 132 mm in rainbow trout. Four entire gizzard shad were identified in the stomach analysis of game fishes. Three gizzard shad ranging from 53 to 78 mm were consumed by walleye (381 to 493 mm TL). One gizzard shad (93 mm TL) was consumed by a 310 mm smallmouth bass.

Discussion

Alewives from Watauga Reservoir were smaller for their age than alewives from 8 of 9 inland populations with which they were compared. Average total length of alewives at age I ranged from 68 to 162 mm in the 9 populations compared to 70 mm in the present study, while age II alewives ranged from 91 to 194 mm compared to 103 mm in the present study (Odell 1934, Graham 1956, Gross 1959, Rothschild 1965, Norden 1967, Lackey 1970, Boaze and Lackey 1974, Lewis 1981, Ney et al. 1982). In most of the studies alewives were older and thus larger than age II. The lower growth rate in Watauga is advantageous for predators. Maximum total length of alewives collected in Watauga (1982-83) was 131 mm. Wagner (1972) found that walleye of only 300 to 390-mm TL had consumed 140-mm alewives and that smallmouth bass at 200 to 290-mm TL had consumed alewives of 150 mm TL. Nigro and Ney (1982) calculated that 300 mm largemouth bass could consume 160 mm alewives, based on the predator-prey relationship described by Jenkins and Morais (1978). These reports on lengths of ingestible alewives suggest that the alewife population sampled in Watauga (maximum TL = 131 mm) is morphologically available to the predator population.

Predator length and ingested prey length from stomach analysis were used to examine the predator-prey relationship in Watauga. Walleye (481 to 505 mm) consumed alewives with an estimated total length of as much as 134 mm prior to digestion. Smallmouth bass (271 to 295 mm) consumed alewives estimated to be 89 mm and rainbow trout of 307 to 331 mm consumed alewives estimated at 132 mm. These results support the hypothesis that the alewife population sampled in Watauga (1982-83) is available to piscivorous game fishes in the system.

Survival and reproduction of the original stocking of alewives in 1976 was documented in July 1979, with the collection of alewives (127 to 152 mm TL) assumed to be progeny of the first fish. Whether these progeny were age 1+ or 2+, growth was greater than for age 2+ in 1981-83 (103 mm; range 83 to 123 mm). Reductions in average lengths attained by specific age classes and in number of age classes have resulted from increasing density of alewife populations (Brown 1972, Kohler and Ney 1981).

Sampling of the alewife population from 1982-83 revealed only 3 age classes (0+, 1+, and 2+) with a maximum total length of 131 mm, as compared to 8 age classes in Lake Michigan (Brown 1972). The reduction in maximum size and presence of only 3 age classes in Watauga indicates a high density alewife population, and possibly, a high degree of intraspecific and interspecific competition. Alewife populations fluctuate in year class composition and abundance, and are subjected to massive die-offs (Rothschild 1965, Brown 1972, Warshaw 1972, Kohler and Ney 1981). A massive die-off of the alewife population containing only 3 age classes could alter their abundance, resulting in instability of the forage base available to piscivorous game fishes.

Annuli were formed from the end of March through the first part of June. Scale examination revealed that alewives in Watauga did not spawn until age 2 (83 to 123 mm). This is similar to some northern landlocked populations (Rothschild 1966, Norden 1967), but unlike the Claytor Lake, Virginia, population which matures at age 1 (Nigro and Ney 1982). Spawning of alewives, in Watauga (indicated by maximum female GSI values), began in April and terminated by August. This pattern is similar to the 13-week spawning period of Claytor Lake (early May through July), but longer than the 9-week period in Cayuga Lake and Lake Michigan and the 4-week period in Lake Hopatcong (Nigro and Ney 1982).

In Lake Michigan, Wells (1980) found alewives consumed 4% to 11% (relative frequency of occurrence) fish eggs, all of which were alewife eggs, while Crowder et al. (1981) found no consumption of fish eggs by alewives in Lake Michigan. No identifiable fish eggs were found in alewives examined in Watauga Reservoir. Alewives had been found to consume substantial numbers of larval fish (Smith 1970, Kohler and Ney 1980). However, of 154 alewives examined from Watauga, only 1 contained any fish remains.

Alewives represented a sizeable percentage of the diet in all species analyzed (walleye, rainbow trout, Ohrid trout, smallmouth bass, and crappie) with the exception of largemouth bass in which no identifiable alewives were found. Seasonally, walleye consumed alewives in greater percentage than gizzard shad during winter (38.5% alewives (A) to 4.6% gizzard shad (GS)), spring (16.9% A to 3.1% GS), summer (17.1% A to 2.4% GS), but consumed more gizzard shad in the fall (7.4% A to 11.1% GS). The decrease in alewife consumption in the fall may be attributed to the movement of alewives from littoral areas out into deeper, warmer waters. Increased alewife consumption from fall to winter indicates walleye may follow the alewives with the change of season. Smallmouth bass consumed alewives in the spring (23.1%) and summer (23.8%). Clupeids consumed by largemouth bass could not be identified as either alewives and/or gizzard shad, so the possible contribution of alewives to their diet could not be assessed in this study. Largemouth bass have been found to consume alewives (Lewis 1981), but Kohler and Ney (1981) concluded that alewives were seldom eaten in Claytor Lake by *Micropterus* spp.

Management Summary

Results of this study indicated both positive and negative attributes of Watauga Reservoir alewives as a forage species. Positive attributes were: (1) small size (maximum TL of 131 mm during 1982-1983 collection) which made the population available to piscivorous predators, (2) a virtual absence of piscivority in alewives and (3) a substantial contribution to the diets of game fish. Negative attributes were: (1) alewife consumption of zooplankton species known to be eaten by Y-O-Y gamefish suggesting interspecific competition and (2) the existence of only 3 age classes of alewives (0+, 1+, 2+) with reproduction only by age 2 fish indicating a potentially unstable population.

Literature Cited

Bagenal, T. B. and F. W. Tesch. 1978. Age and Growth. Pages 101–136 *in* T. B. Bagenal, ed. Methods of assessment of fish production in fresh waters, 3rd edition, IBP Handbook No. 3. Blackwell Sci. Publ., Oxford, England.

Boaze, J. L. and R. T. Lackey. 1974. Age, Growth, and Utilization of Landlocked Alewives in Claytor Lake, Virginia. Prog. Fish Cult. 36: 163–164.

Brown, E. H., Jr. 1972. Population biology of alewives, *Alosa pseudoharengus,* in Lake Michigan, 1949-70. Fish. Res. Bd. Can. 29:477–500.

Crowder, L. B., J. J. Magnuson, and S. B. Brandt. 1981. Complementarity in the use of food and thermal habitat by Lake Michigan fishes. Can. J. Fish. and Aquat. Sci. 38: 662–668.

Graham, J. J. 1956. Observations of the alewife, *Pomolobus pseudoharengus* (Wilson), in fresh water. Univ. Toronto Stud., Biol. Ser. 62. Ontario Fish. Res. Lab. Publ. 74:1–43.

Gross, R. W. 1959. A study of the alewife *Alosa pseudoharengus* (Wilson), in some New Jersey lakes, with special reference to Lake Hopatcong. M.S. Thesis, Rutgers State Univ., New Brunswick, N.J.

Jenkins, R. M. and D. I. Morais. 1978. Prey-predator relations in the predator-stocking-evaluation reservoirs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 30:141–157.

Kohler, C. C. and J. J. Ney 1980. Piscivority in a landlocked population of alewife (*Alosa pseudoharengus*). Can. J. Fish. and Aquat. Sci. 37(8):1314–1317.

——— and ———. 1981. Consequences of an alewife dieoff to fish and zooplankton in a reservoir. Trans. Am. Fish. Soc. 110:360–369.

Lackey, R. T. 1970. Observations on newly introduced landlocked alewives in Maine. N.Y. Fish and Game J. 17:110–116.

Lagler, K. F. 1956. Freshwater Fishery Biology, 2nd edition. Wm. C. Brown Co., Publ. Dubuque, Iowa.

Lewis, G. E. 1981. Characteristics of alewives in a small West Virginia impoundment. Prog. Fish Cult. 43:224.

Ney, J. J., C. C. Kohler, and A. A. Nigro. 1982. Landlocked alewife in Claytor Lake, Virginia: Evaluation as a forage species for inland waters. Manage. Publ. 4, Dep. Fish. and Wildl. Sci. Va. Polytechnic Inst. and State Univ., Blacksburg, Va.

Nigro, A. A. and J. J. Ney. 1982. Reproduction and early life accommodations of landlocked alewives *Alosa pseudoharengus* to a southern range extension. Trans. Am. Fish. Soc. 111:559–569.

Norden, C. R. 1967. Age, growth, and fecundity of the alewife, *Alosa pseudoharengus* (Wilson) in Lake Michigan. Trans. Am. Fish. Soc. 96:387–393.

Odell, T. T. 1934. The life history and ecological relationships of the alewife (*Pomolobus pseudoharengus*) (Wilson) in Seneca Lake, New York. Trans. Am. Fish. Soc. 64: 118–126.

Rothschild, B. J. 1965. Aspects of the population dynamics of the alewife, *Alosa pseudoharengus* (Wilson) in Cayuga Lake New York. Am. Midl. Nat. 74:479–496.

———. 1966. Observations on the alewife (*Alosa pseudoharengus*) in Cayuga Lake. N.Y. Fish and Game J. 13:188–195.

Smith, S. H. 1970. Species interactions of the alewife in the Great Lakes. Trans. Am. Fish. Soc. 99:754–765.

Strawn, K. 1963. Resistance of threadfin shad to low temperature. Proc. Annu. Conf. Southeast. Assoc. of Game and Fish Comm. 17:290–292.

Wagner, W. C. 1972. Utilization of alewives by inshore piscivorous fishes in Lake Michigan. Trans. Am. Fish. Soc. 101:55–63.

Warshaw, S. J. 1972. Effects of alewives (*Alosa pseudoharengus*) on zooplankton of Lake Wononskopomuc, Connecticut. Limnol. Oceanogr. 17:816–825.

Wells, L. 1980. Food of alewives, yellow perch, spottail shiners, trout perch, and slimy and fourhorn sculpins in southeastern Lake Michigan. U.S. Dep. Int., Fish and Wildl. Serv. Tech. Pap. 98.12 pp.
Windell, J. T. and S. H. Bowen. 1978. Methods for study of fish diets based on analysis of stomach contents. Pages 219–266 *in* T. Bagenal, ed. Methods for assessment of fish production in fresh waters, third edition. Blackwell Sci. Publ., London.