Fisheries Session

Density-dependent Fishing Mortality of American Shad in the Altamaha River, Georgia

Ronald A. Michaels,[1] *Georgia Department of Natural Resources, Fisheries Management Section, P.O. Box 2089, 108 Darling Ave., Waycross, GA 31502-2089*

Abstract: Catchability of American shad (*Alosa sapidissima*) from the Altamaha River, Georgia, was compared with population size of female adult spawners to determine if density-dependent fishing mortality was occurring in that fishery. Mark-recapture techniques and effort and harvest data were utilized to examine this relationship. An inverse power function described the relationship between fishing mortality per unit effort and female population size from 1982 to 1991. The relationship became slightly stronger by holding the flow variable constant. Therefore, shad populations in the Altamaha River are most vulnerable when weak spawning runs are subjected to commercial fishing pressure, and to a lesser extent, when low flows occur.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:470–475

American shad (*Alosa sapidissima*) is a valuable commercial fish in Georgia's larger coastal streams and historically has comprised one of the largest finfish landings in the state. Since the early 1900s, commercial landings of this species have declined in almost all of the Atlantic coast states. Following this trend, Georgia's landings peaked in 1908 at 590,000 kg, dropping to a low of 34,020 kg in 1939, rising to only to 85,680 kg by 1980.

The Altamaha River's commercial shad fishery was once the largest in Georgia. Walburg and Nichols (1967) reported that shad landings from this river made up 67% of the state's total harvest in 1960. Godwin and McBay (1967) showed that in 1967 the Altamaha River fishery contributed 69% to Georgia's shad harvest. However, it comprised only 37% of the state's total harvest in 1979 (Hardisky and Smith 1980) and 38% in 1980 (Music 1981).

Management of Georgia's shad fishery to protect the resource and benefit the fishermen has been inadequate for many years. Regulations, including season length, open and closed days, and allowable stream width, have been changed in

[1]Present Address: Georgia Department of Natural Resources, Coastal Resources Division, One Conservation Way, Brunswick, GA 31523-8600.

an attempt to stabilize the fishery, but they were instituted without sufficient biological basis. Landings data have underestimated total harvest and cannot show relative changes in stock size because they are independent of shifts in fishing effort. Also, fishermen underreport their catch for tax purposes and differentially cull male shad owing to their low market value (Leggett 1976).

Very little information is available about population dynamics of shad in Georgia. Studies on catch and effort have been conducted by Sykes (1956), Godwin and McBay (1967), Godwin (1968), and Hardisky and Smith (1980). Since these were short-term studies, estimates of catch rates are of limited value and cannot be compared with current stock levels or success rates (Ulrich et al. 1979). More importantly, the abundance of adult shad and the relationship between spawning stock size and exploitation have not been examined since Godwin's (1968) study of the Altamaha River.

Since an understanding of shad population dynamics is necessary in order to regulate and restore this important anadromous fishery, Georgia Game and Fish Division began a study of American shad in 1982. The Altamaha River was chosen for the study because it has the largest shad runs in the state and because some baseline information for this particular fishery existed (Godwin and McBay 1967, Godwin 1968). Initially, data from 1982 to 1986 on harvest, effort, success, population size, age class composition, and exploitation rates were collected and analyzed. In 1986, the study was extended an additional 5 years to strengthen an exploitation prediction model, to build a model which demonstrated density-dependent fishing mortality of female spawners, and to broaden the data base necessary for development of stock-recruit relationships. For purposes of this paper we concentrated on the interaction between instantaneous fishing mortality rate, standardized effort, and population size of female American shad in the Altamaha River, Georgia. The study was supported by state funds allocated to the Fisheries Section's Southcentral Region, Project G-3. I gratefully acknowledge personnel of the Waycross Fisheries Office, Georgia Department of Natural Resources, for assistance with tagging shad and for their editorial comments on an earlier draft of this paper. I would also like to thank 2 commercial fishermen, David Gale and Darwin Gale, for their tireless efforts for 10 consecutive years in providing fish for tagging.

Methods

Attempts were made to capture, sex, tag, and release at least 500 adult American shad during each commercial fishing season, 1 January–31 March 1982–1991. The same 2 commercial fishermen were employed each year to catch shad with drift gill nets on Saturdays and Sundays in the lower Altamaha River which was otherwise closed to fishing on those days of the week. The fishermen were paid \$3.25 to \$4.00 for every fish that was live, healthy, tagged, and returned to the water. Randomized variable rewards between \$4.00 and \$100.00 were offered to all commercial fishermen for tags returned to the Game and Fish Division.

The number of marked fish (M) and subsequent recaptures (R) were used to estimate exploitation (u = R/M) of female shad. Instantaneous fishing mortality rates were directly attainable by the equation: $F = -\log_e (1-u)$ (Ricker 1975). Two separate roving creel surveys with non-uniform probability sampling were conducted in the lower and upper Altamaha River during the same time period to provide information on shad fishermen's effort (f) and harvest (C). Since the efficiency of different gear types (drift or set nets) and of similar gear types fished in different areas (upper or lower river) varied considerably, standardization of effort was necessary for comparisons among years. A standard fishing unit (SFU) day (Fredin 1954) was defined as 1 drift gill net, 91.4-m long, fished for 4 hours in the lower Altamaha River (Michaels 1984, 1990) throughout the 10-year study period to calculate the catchability coefficient (q = F/f) (Crecco and Savoy 1985). Population size during each season was calculated by the Petersen method (N = MC/R) using tag return data in conjunction with harvest estimates from the creel surveys. This method gives a consistent estimate of N and is accurate with large samples (Ricker 1975). Finally, the relationship between q and N was examined to determine if density-dependent fishing mortality of female shad was occurring in the Altamaha shad fishery.

Abiotic factors such as river flow, however, can mask the relationship between fishing mortality and stock size (Crecco et al. 1986). To separate those effects, the model was altered by holding the flow variable constant from 1982 to 1991. This required 6 steps: 1) a regression of q vs. flow was run to determine if river discharge had any effect on the catchability of female shad, 2) if it did, new q values were predicted from this regression, 3) these predicted q values were subtracted from each year's observed q to calculate residuals, 4) the mean q for 1982 to 1991 was calculated, 5) this mean q was added to each year's residual to generate an adjusted q, and 6) the adjusted q values were regressed against female population size to produce a new function. How much the fit improved was an indication of flow's influence on shad catchability in addition to stock size.

Results and Discussion

From 1982 to 1991, exploitation of female American shad in the Altamaha River was high, ranging from 0.642 to 0.417 and averaging 0.502 (Table 1). No apparent trend was observed in exploitation during the 10-year study period; however, a significant inverse relationship between catchability and female shad population size existed (Fig. 1). This relationship can best be described by the power function $q = aN^B$, where q = catchability coefficient, a = intercept, N = population size, and B = slope (Paloheimo and Dickie 1964). Disregarding flow, the regression showed a rise in q as N declined (B = −0.746, $r^2 = 0.536$, t-test of slope significantly less than zero at $P = 0.100$). To hold the flow variable constant, q was regressed against flow, giving a fair fit (B = -1.509×10^{-5}, $r^2 = 0.248$, P = 0.150). The adjusted q vs. N regression showed a slight (10%) improvement in the coefficient of determination and, again, a significant (P = 0.100) slope. Based on similar findings from other studies (MacCall 1976, Peterman and Steer 1981, Crecco and Savoy 1985),

Table 1. Data used to develop the relationship between catchability and population size of female American shad in the Altamaha River, Georgia.

Year	Harvest (C)	Exploitation (u)	Fishing mortality rate (F)	Effort (f in SFU days)
1982	40,810	0.642	1.027	4,509
1983	55,091	0.472	0.639	5,089
1984	54,350	0.496	0.685	4,708
1985	82,686	0.484	0.662	3,503
1986	31,847	0.552	0.803	1,859
1987	50,398	0.483	0.660	3,400
1988	39,799	0.448	0.594	2,089
1989	38,098	0.566	0.835	3,289
1990	25,481	0.465	0.625	2,029
1991	27,079	0.417	0.540	2,167

these data demonstrated density-dependent fishing mortality of female shad in the Altamaha River. Flow, while having some effect on catchability, played a minor role in the relationship.

Why does this phenomenon exist and what are its implications on the American shad fishery in the Altamaha River? Neither shad nor shad fishermen behave in a random manner. Spawning stocks move upstream in schools, creating a spatial

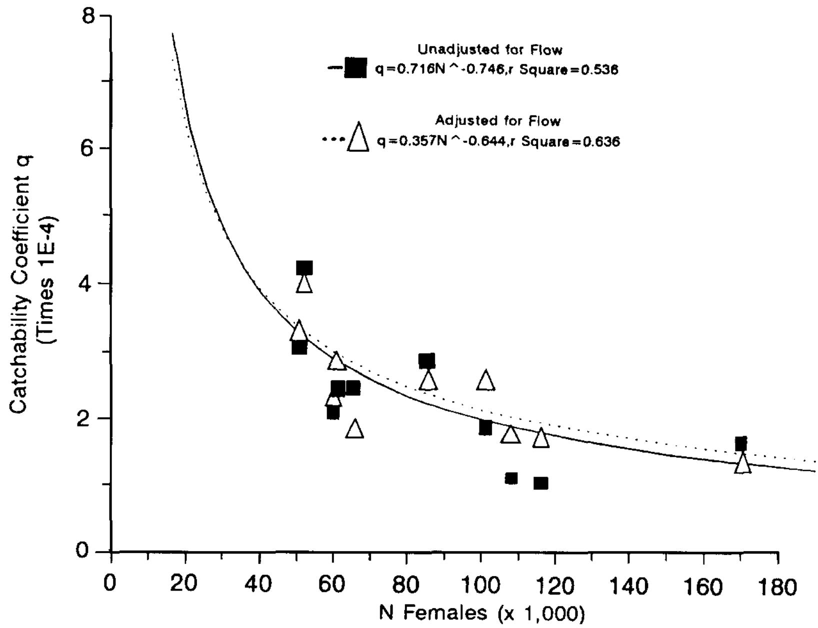

Figure 1. Relationship between catchability coefficients of female American shad and population size in the Altamaha River, Georgia, 1982–1991.

patchiness of the fish population (Paloheimo and Dickie 1964). Fishermen tend to differentially locate and exploit these patches. In years of strong runs, more fish are harvested but a smaller percentage of the population is removed. Conversely, in years of weak runs, harvest decreases but a higher percentage of the available population is removed. Furthermore, when B drops below –0.5, as was the case in our study, q and F increase steadily on a depleted stock, not only reducing the number of adult females to very low levels, but also the resiliency with which the fish population stabilizes under unfavorable environmental conditions (Peterman 1977).

The negative feedback between shad abundance and catchability shows that density-dependent fishing mortality is occurring, and it is likely that a considerable rise in commercial fishing effort would lead to a significant increase in the fishing mortality rate (Clark 1974, Peterman 1977, Crecco and Savoy 1985). Eventually, there would be recruitment failure unless fishing effort was reduced at the first signs of stock collapse (Fox 1974). Shad populations in the Altamaha River showed the expected rise in catchability as female numbers declined. Of greater concern is that half the data points were located along the left one-third of the graph at the steepest limb of the curve where population size dropped below 80,000 shad. This influence goes unnoticed for 4–6 years when a particularly weak year class finally returns to spawn.

Based on 1982–1991 data, the Altamaha River shad fishery has probably been over-exploited. The study has been extended another 3 years (1992–1994) to continue monitoring trends in fishing mortality and population size. Stock-recruit relationships will estimate maximum sustainable yield and the allowable fishing mortality rate at which this yield occurs.

Literature Cited

Clark, C. W. 1974. Possible effects of schooling on the dynamics of exploited fish populations. Jour. de Conseil Intern. Expl. Mer 36:7–14.

Crecco, V. A. and T. F. Savoy. 1985. Density-dependent catchability and its potential causes and effects on Connecticut River American shad, *Alosa sapidissima.* Can J. Aquat. Sci. 42:1649–1657.

———, ———, and W. R. Whitworth. 1986. Effect of density-dependent and climatic factors on American shad, *Alosa sapidissima,* recruitment: a predictive approach. Can. J. Fish. Aquat. Sci. 43(2):457–463.

Fox, W. W. 1974. An overview of prediction modelling. Proc. of the ICCAT workshop on tuna population dynamics. Pages 142–156.

Fredin, R. A. 1954. Causes of fluctuations in abundance of Connecticut River shad. U.S. Fish Wildl. Serv. Bul. 54:247–259.

Godwin, W. F. 1968. The shad fishery of the Altamaha River, Georgia. Ga. Game and Fish Comm., Mar. Fish. Div., Contrib. Ser. No. 8, 39pp.

——— and L. G. McBay. 1967. Preliminary studies of the shad fishery of the Altamaha River, Georgia. Ga. Game and Fish Comm., Mar. Fish. Div., Ser. No. 2, 23pp.

Leggett, W. C. 1976. The American shad, *Alosa sapidissima,* with special reference to its migrations and population dynamics in the Connecticut River. Am. Fish. Soc. Monogr. I. 252pp.

Hardisky, M. A. and K. H. Smith. 1980. 1970 Georgia shad catch-effort study. Ga. Dep. Nat. Resour., Coastal Res. Div., Proj. No. AFC-11, 41pp.

MacCall, A. D. 1976. Density dependence of catchability coefficient in the California Pacific sardine, *Sardinops sagax cearula*, purse seine fishery. Calif. Coop. Oceanic Fish. Invest. Rep. 18:136–148.

Michaels, R. A. 1984. Population dynamics of American shad in the Altamaha River. Ga. Dep. Nat. Resour., Game and Fish Div., Interim Rep. for 1982–1984, State Proj. G-3, 39pp.

———. 1990. Population dynamics of American shad in the Altamaha River. Ga. Dep. Nat. Resour., Game and Fish Div., Interim Rep. for 1982–1987, State Proj. G-3, 41pp.

Music, J. F., Jr. 1981. Assessment of Georgia's 1980 commercial shad season. Ga. Dep. Nat. Resour., Coastal Res. Div., Proj. No. AFC-11-1, 40pp.

Paloheimo, J. E. and L. M. Dickie. 1964. Abundance and fishing success. Rapp. P. V. Reunion, Cons. Int. Expl. Mer 155:152–163.

Peterman, R. M. 1977. A simple mechanism that causes collapsing stability regions in exploited salmonid populations. J. Fish. Res. Board Can. 34:1130–1142.

——— and G. J. Steer. 1981. Relation between sport fishing catchability coefficients and salmon abundance. Trans. Am. Fish. Soc. 110:585–593.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bul. Fish. Res. Board Can. 191, 382pp.

Sykes, J. E. 1956. Shad fishery of the Ogeechee River, Georgia, in 1954. U.S. Fish and Wildl. Serv., Spec. Sci. Rep., Fish. 191, 11pp.

Ulrich, G., N. Chipley, J. W. McCord, D. Cupka, J. F. Music, Jr., and R. K. Mahood. 1979. Development of fishery management plans for selected anadromous fishes in South Carolina and Georgia. S.C. Wildl. Mar. Res. Dep., Contrib. Ser. No. 14, Ga. Dep. Nat. Resour., Coastal Res. Div., Contrib. Ser. No. 31, 135pp.

Walburg, C. H. and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U.S. Fish and Wildl. Serv. Spec. Sci. Rep., Fish. No. 550, 135pp.