

Reproductive Migrations of American Eels in Georgia

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Abstract: Information on silver American eels was obtained over a three-year period from seasonal sampling of 4 Georgia rivers, commercial fishermen, and from systematic sampling of eels migrating from a pond. All silver eels were captured from October through March. Of 80 animals examined, 73 were male and averaged 329 mm, 69 g, and 5.5 years. Seven females averaged 584 mm, 448 g, and 8.6 years. These findings suggest that silver eels leave Georgia waters later in the year and at younger ages and smaller sizes than eels at more northerly latitudes.

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Information on silver European eels, *Anguilla anguilla*, is extensive (Bertin 1956, Sinha and Jones 1975, Tesch 1977, Moriarty 1978). However, comparable information on the reproductively migrating stage of the American eel, *A. rostrata*, is surprisingly limited. Several studies have provided initial data on sizes, ages, and times of migrations from northern portions of North America (Smith and Saunders 1955, Eales 1968, Hurley 1972, Winn et al. 1975, Facey and LaBar 1981). Our objectives in this study were to gather data on times, locales, and characteristics of migrating eels in Georgia for comparison with more northerly populations and with the better known European species. This study represents the first investigation directed specifically at silver American eels in the southeastern United States.

American eels, like European eels, spend most of their lives in freshwaters and estuaries. At some point they metamorphose from the relatively sedentary yellow eel stage to the migratory silver, or bronze, eel stage and return to the sea to spawn. American eels in southern fresh waters seem to grow faster than northern eels, but do not grow as large or get as old (Helfman et al. 1984). The absence of large, old eels in the south may indicate maturation, and hence migration, at a younger age and smaller size than among eels in northern regions. If the North American eel population is panmictic (Williams et al. 1973, Koehn and Williams 1978, Williams and Koehn 1984), southern eels may migrate later in the year than their northern

counterparts so that all arrive at the presumed spawning grounds in the southern Sargasso Sea (Kleckner et al. 1983) at about the same time (Wenner 1973).

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Methods

Periodic canvassing of commercial fishermen and frequent collections in coastal rivers (see Helfman et al. 1984) enabled us to gather information on the migration of silver eels from Georgia waters. We also systematically sampled eels at the outlet of McKinney's Pond (32°47'28" N, 82°13'12" W), a 21-ha spring-fed pond on the Georgia coastal plain that flows into the Ogeechee River about 300 river km from the ocean. A wire trap (1.2-cm x 1.2-cm mesh) and a fyke net (2.0-cm stretch mesh, 65-cm diameter net with 60-cm high leads) were set on 21 nights and 10 days from 11 November 1982 to 23 April 1983.

Eels with enlarged eyes, silvery bellies, prominent lateral line pores, and dark backs and pectoral fin margins were classified as silver eels (Winn et al. 1975, Todd 1981*a*). Total length and live wet weight were measured, as was horizontal diameter of the left orbit. Sagittal otoliths and a section of gonadal tissue were removed for age and sex determination.

Gonads were embedded in glycol methacrylate and 4 μ m sections were cut on a rotary microtome. Sections were stained with Lee's methylene blue (Bennett et al. 1976). Otolith examination and age interpretation was done by E. B. Brothers, Cornell University. Some otoliths were difficult to interpret. Deelder (1981) reported that periods of interrupted summer growth can lead to supernumerary zones in otoliths. Obvious supernumerary zones (narrow opaque zones between 2 annuli) were not counted in order to guard against overestimation of age. However, Deelder's concerns warrant consideration when interpreting otolith data.

Results

Silver eels were found in Georgia waters from October to March (Table 1). Two female silver eels were caught in baited eel pots in the Brunswick River, Brunswick, Georgia, in late October 1980, (E. L. Bozeman, University of Georgia, pers. commun.). Commercial shrimpers caught several silver eels about 3.2 km offshore of the Altamaha River in about 15 m of water during December 1982 and January 1983 (G. Wallace, Darien, Georgia, pers. commun.). These eels were large (>500 mm) and we therefore suspect that they were females. About a dozen silver eels were captured in baited eel pots in fresh tidewater of the Darien River in March 1982 (E. Brown, Darien, Georgia, pers. commun.). These were <450 mm in length and may therefore have included males.

Table 1. Silver American eels reported in Georgia by month, 1980–1983.

Date	Location	Sex	N	Mean length (mm) (range)	Mean weight (g) (range)	Mean age (years) (range)
8 Oct 1983	Satilla River	M	4	327 (309–352)	62 (49–85)	5.5 (4–8)
20–26 Oct 1980	Brunswick River	F	2	660 (637–682)		4.5 (4–5)
26 Oct 1983	Savannah River	F	3	521 (413–628)	366 (160–522)	10.0 (6–13)
Oct 1983	Savannah River estuary	F	4	631 (615–646)	509 (476–560)	7.5 (5–11)
		M	53	330 (283–375)	71 (42–119)	5.3 (3–7)
12 Nov 1982	McKinney's Pond	M	2	352 (347–357)	83 (71–95)	3.0 (2–4)
24 Nov 1982	Savannah River estuary	M	7	312 (282–337)	57 (36–80)	5.7 (5–7)
7 Dec 1982	McKinney's Pond	M	1	361	79	8
8 Dec 1982	McKinney's Pond	M	1	328	64	5
Dec 1982– Jan 1983	off mouth of Altamaha River		several	>500		
4 Feb 1982	McKinney's Pond	M	4	334 (307–351)	58 (43–71)	4.5 (2–6)
4 Mar 1982	McKinney's Pond	M	1	328	58	6
Mar 1982	Darien River		~12	<450		

Fifty-seven silver eels were caught in baited pots by a commercial fisherman in the estuary of the Savannah River in October of 1983. Orbit diameter averaged 2.0% of body length for the males and 1.5% for the females. Because the otoliths of these silver eels were easy to interpret (Helfman et al. 1984), it is likely that the eels had been residents in the estuary rather than migrants from freshwater areas further upstream. Four male silver eels were among 57 eels caught in the Satilla River estuary on 8 October 1983. Their orbit diameters averaged 1.9% of body length as compared to 1.5% for male yellow eels and 1.3% for female yellow eels in the same collection. On 26 October 1983, 3 female silver eels were among 41 eels captured by electrofishing in the Savannah River at river km 272. Seven male silver eels were among more than 200 eels taken in baited pots in the Savannah River estuary on 24 November 1983.

Between 11 November 1982 and 23 April 1983, 9 silver eels were caught during 21 nights of trapping at McKinney's Pond. None were caught during 10 days of trapping. All were males, ranging in length from 307 to 361 mm (\bar{x} = 339), and in weight from 43 to 95 g (\bar{x} = 66). Otoliths indicated that these eels were 4 to 10 years old (\bar{x} = 6.4). Fifteen yellow eels caught simultaneously with the silver eels were 287 to 607 mm long (\bar{x} = 452), weighed 48 to 453 g (\bar{x} = 225), and were 3 to 11 years (\bar{x} = 8.0). All but 1 of the yellow eels were female. Silver eels were caught in November, December, February, and March, whereas yellow eels were caught December through March (an additional 7 female yellow and no silver eels were cap-

tured in unbaited traps during 1 night's sampling in mid-April 1985). Orbit diameter was significantly greater in silver eels than in yellow eels (t -test, $P < .001$), averaging 2.24% of total body length for silver eels and only 1.17% for yellow eels. However, all silver eels were males and all but 1 of the yellow eels were females.

Discussion

Reports from northern temperate regions of North America indicate that many eels move downstream during late summer and fall (Eales 1968; Table 2). In 1979, large numbers of eels were caught moving downstream in the Richelieu River, Quebec, Canada, during June, July, and August, but the number declined in September (R. Thout, St. Jean, Quebec, pers. commun.). During August and September, 92 female silver eels were caught migrating from a Newfoundland pond (Gray and Andrews 1970). Thirty six eels tagged in Lake Ontario were captured by commercial fishermen in the lower St. Lawrence River from mid-September through late October (Hurley 1972). Two American eels tagged in Vermont waters of Lake Champlain were also caught in the St. Lawrence River, Quebec, during October (G. W. LaBar, University of Vermont, pers. commun.). Large runs of eels, including some that were noticeably silver, occurred from lakes in the Maritime provinces

Table 2. Months of capture, lengths, and ages of silver eels caught in North America.

Location	Months of capture	Sex	<i>N</i>	Mean length (mm) (range)	Mean age (years) (range)	Reference
Newfoundland	Aug-Sep	F	92	694 (535-931)	12.3 (9-18)	Gray and Andrews 1970, 1971
Lower St. Lawrence River	mid Sep-late Oct		36	(832-918)	(~13-14) ^a	Hurley 1972
Rhode Island	Sep-Nov	F	54	~537 (410-800)		Winn et al. 1975
		M	87	~334 (280-400)		
Southeast of Cape Cod	early Nov	F	1	642		Wenner 1973
		M	1	373		
East of Assateague Island	late Dec	F	6	636 (609-658)		Wenner 1973
Cape Charles	Nov	F	46	633 (418-845)		Wenner & Musick 1974
		M	52	372 (339-438)		
Southeast of Chesapeake Bay	early Dec	F	3	551 (512-579)		Wenner 1973
Georgia	Oct-Mar	F	7	584 (413-682)	8.6 (4-13)	present study
		M	73	329 (282-375)	5.5 (3-10)	

^a Ages estimated by Hurley (1972) based on length of specimens.

of Canada in April and May, and again in late August through November (Smith and Saunders 1955). Silver eels were prominent in many Nova Scotia rivers during late summer and early autumn (Medcof 1969). Silver eels were captured leaving Rhode Island waters during September through December (Winn et al. 1975). During late November silver eels were obtained at Cape Charles, Virginia (Wenner and Musick 1974). Reproductively maturing American eels have also been caught southeast of Cape Cod on 5 November 1969, southeast of the mouth of Chesapeake Bay on 5 November 1967, and east of Assateague Island (off the Maryland-Virginia coast) on 22 December 1971 (Wenner 1973). In the Cooper River, South Carolina, 6 male silver eels were captured, mainly in August, although criteria for this designation and other months of capture were not mentioned (Harrell and Loyacano 1980).

Of more than 80 silver eels reported in the present study, 66 were caught in October and the rest were seen from November to March. Eel collections from 4 Georgia rivers during all seasons, which yielded more than 2,300 yellow eels (e.g. Helfman et al. 1984), are included in these data. Because commercial fishermen and eel buyers knew of our interest in silver eels, we believe that we had a reasonable probability of learning of the occurrence of silver eels during other months.

The literature on silver eels indicates a degeneration of the digestive tract and cessation of feeding (Deelder 1970). Some silver eels were caught in baited traps, suggestive of attraction to bait. However, yellow eels are frequently captured in unbaited traps (pers. obs.), and silver eels are captured in unbaited "shelter" traps (Tesch 1977). We saw no obvious signs of gut degeneration in the silver eels we captured, although histological examination was not performed. Six of the silver eels captured in unbaited traps at McKinney's Pond were dissected for stomach contents analysis; 2 contained food items and 4 were empty. For comparison, 6 of 15 yellow eels captured at McKinney's Pond had food in their guts. We hesitate to draw conclusions concerning cessation of feeding in silver American eels. If gut degeneration occurs, it may not take place at the very early stage of migration during which our animals were captured. Enlarged eyes are also reportedly characteristic of anguillid eels in the migratory stage (Wenner and Musick 1974, Winn et al. 1975, Tesch 1977, Todd 1981*a*) and are presumed to increase photosensitivity (see Tesch 1977). Among the eels caught at McKinney's Pond and in the Satilla River, silver eels had larger eyes than did yellow eels.

Only 1 of the 15 yellow eels caught at McKinney's Pond was a male. This ratio is consistent with other freshwater samples of American eels in the southeastern United States (Harrell and Loyacano 1980, <2% males; Helfman et al. 1984, 5%–7% males). Despite the low percentage of males observed among yellow eels at McKinney's Pond, all silver eels captured were males. Why no female silver eels were found in an area where the great majority of the yellow eels are female is intriguing. Perhaps eels in the southeastern United States have different migration times, with the females leaving before or after the males. Males congregated at the outlet area of 2 New Zealand lakes before the females in both *A. australis* and *A. dieffenbachii*, although this sequence was not observed in a New Zealand stream

(Todd 1981b). Among European eels, the percentage of larger migrating eels increases as the migratory period (late summer through fall) progresses. Tesch (1977) attributed this to a shorter migration distance for the smaller, and therefore presumably male eels, rather than an indication of earlier migration by males.

Silver male European eels average between 350 and 410 mm and have spent 6 to 9 years in continental waters, whereas females generally average from 540 to 610 mm and about 8 to 12 years in fresh water (see Tesch 1977). Male anguillid eels typically migrate at a younger age and smaller size than females (Tesch 1977, Todd 1980). The reported age and size at migration of silver American eels varies. Studies at northern latitudes have found silver female American eels ranging from 9 to 18 years old and 410 to >900 mm and males from 280 to 400 mm (Table 2). Female silver eels in the present study averaged 584 mm and 8.6 years of age, whereas males averaged 329 mm and 5.5 years. Two female silver eels caught in the Brunswick River, Georgia, were 4 and 5 years old (637 and 682 mm long; Helfman et al. 1984), which is much younger than other reports of migrating female American eels. The present study suggests that silver American eels in Georgia migrate later in the year and at younger ages and smaller sizes than northern eels (Table 2). These data concur with the suggestion of Helfman et al. (1984) that American eels in the southeastern United States grow faster and mature earlier than eels in northern waters.

American eels are believed to spawn in late winter and spring, with a peak in spawning activity in February (see Kleckner et al. 1983). Eels leaving Georgia in February and March would certainly miss this peak of spawning activity, but might arrive in the Sargasso Sea before the spawning season has ended. At present not enough is known of eel migration rates, routes, or the length of the spawning season to draw any conclusions about these eels.

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