Recruitment season, size, and age of young American eels (*Anguilla rostrata*) entering an estuary near Beaufort, North Carolina

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Abstract—Net catches from 1985–86 to 1994–95 at Pivers Island, North Carolina, indicated that glass-eel stage American eels (*Anguilla rostrata*) were recruited to the estuary from November to early May, with peak numbers in January, February, and March. There was no declining trend in recruitment over the years of sampling. Except for one year, there was no clear seasonal decrease in mean length. But shorter glass eels were older than longer glass eels, as judged by age within the glass eel growth zone of the otolith, suggesting that smaller fish took longer to arrive. The mean age of glass eels collected from the lower estuary and a freshwater site 9.5 km upriver differed by 8.4 d (36.2 vs. 44.6, respectively). Outer increments (30–35) of the otolith growth zone of glass eels from North Carolina were significantly wider than corresponding increments of otoliths from New Brunswick. Mean total ages of North Carolina, New Jersey, and New Brunswick elvers were 175.4, 201.2, and 209.3 d, corresponding to mean lengths of 55.9, 60.9, and 58.1 mm TL, respectively. The mean durations of glass-eel growth zones (44.6, 62.3, and 69.8) were in close agreement with those from previous studies, but total ages were not. This suggested that perhaps some finer (leptocephalus stage) increments were not detected by light microscopy, differences occurred in seasonal increment deposition, or absorption of the otolith material may have taken place during metamorphosis, rendering the aging of larvae inaccurate. Judging from the long recruitment period and seasonal uniformity in both mean age and length found in our study, the spawning period of American eels may be somewhat more protracted than previously considered.

The life history of the American eel (*Anguilla rostrata*) is both fascinating and mysterious. It spawns in the Sargasso Sea and the young willow leaf-shaped leptocephalus larva disperses over great distances before it metamorphoses into a transparent glass eel. This stage reaches the estuaries of North America where it typically ascends rivers and streams as an elver, becoming progressively more pigmented as the run progresses. This stage is followed by the juvenile or yellow eel, and finally by the silver or maturing adult (Able and Fahay, 1998). Eel physiology and ecology are still not completely understood, although much has been learned since the early 1900s. Schmidt (1922) discovered the general area of spawning in the Sargasso Sea, and Kleckner et al. (1983) further demarcated breeding to an area defined by thermal front boundaries. Comparini and Rodino (1982) used electrophoretic analysis on American and European eel (*Anguilla anguilla*) leptocephali to confirm that both spawn in the Sargasso Sea.

Based on oceanographic surveys and entrance times into rivers, estimates of migration time to North America of young *A. rostrata* range from 250 days to one year, corresponding with a peak spawning time of February and March (McCleave et al., 1987; Haro and Kreuger, 1988). Many studies have described seasonal sizes of European glass eels and elvers entering estuaries, but similar long-term data sets for the American species are uncommon. Elvers enter estuaries along the coast of North America progressively from south to north, becoming larger with increasing latitude (Haro and Kreuger, 1988), and for many (but not all) areas, sizes have been recorded. We document the recruitment period and variations in its seasonality for the Beaufort, NC, region for the 1985–86 to 1994–95 seasons.

Michaud et al. (1988) documented the sizes but not the ages of American eel elvers entering a Quebec river. Jessop (1998) used large samples from the Nova Scotian elver fishery to show seasonal declines in length and weight and an increase in pigmentation of newly arrived elvers. Wang and Tzeng (1998) used SEM (scanning electron microscopy) and elemental analysis of otoliths to determine ages of elvers taken from Haiti, north to Nova Scotia. They also estimated the length in days of the leptocephalus and glass-eel stages from the same sites. Helfman et al., (1984) described the length range of glass eels entering a Georgia river in February. Although most earlier workers (e.g. Vladykov, 1966; Eldred, 1968, and others) did not have long-term data series, their samples are useful for comparisons with current data.

Long-term records of estuarine recruitment of early life-history stages of eels are particularly relevant at this time, when reduction in juveniles (but not elvers) to the upper St. Lawrence River area in North America has been noted (Castonguay et al., 1994a), and when catches of adults and recruitment of elvers are declining in Europe (Castonguay et al., 1994b). We therefore present subsamples of ages along with our catch per effort (densities) for glass eels. Earlier studies of eel otoliths used SEM to determine ages, but we used light microscopy for comparison with such studies. Castonguay (1986) aged *A. rostrata* leptocephali captured in the Gulf of Maine, and his largest individual of 49 mm TL (which would shrink during metamorphosis) was 130 d. However, only the daily growth increments in the elver growth zone (area after the "transition" or "elver" check) have been validated (Martin, 1995). He validated daily increments in the field over a one-month period. Lecomte-Finiger (1992) aged otoliths of *A. anguilla* elvers from several European locations, as did Antunes and Tesch (1997). The latter suggested that daily increments of *A. anguilla* may be underestimated because of the "diffuse" (their term) nature of the metamorphosis zone. More recently, Cieri and McCleave (2000) suggested that there are a number of inconsistencies when growth zones of leptocephali are compared with the same zone in the otoliths of glass eels and juvenile American eels. Both radii and ages were less in the older fish stages than in the leptocephali. The possibility of resorption of otolith material during metamorphosis (and subsequent obliteration of increments) led them to discourage the use of larval eel otoliths for aging or back-calculating life history events until these discrepancies could be explained. Although the present authors could not validate increments in the leptocephalus stage or metamorphosis stage (these stages metamorphose before reaching North Carolina), we collected samples to temporally validate daily increments in the glass-eel stage. We tested the hypotheses that 1) the increment number for glass eels at an upriver (freshwater) location would be greater than that for glass eels at a lower (estuarine) sampling site by a difference (in days) equal to the distance divided by the sum of the swimming speed and tidal transport, and that 2) increment widths for corresponding glass-eel portions of the otolith for fish from the Bay of Fundy (New Brunswick sample) would be narrower than for fish of warmer water (i.e. North Carolina) because the warmer waters would produce faster growth which, in turn, could produce wider otolith increments. A New Jersey sample was also aged to represent an intermediate geographic position between North Carolina and New Brunswick.

The objectives of this study were 1) to describe the 1985–95 annual recruitment of glass eels to the estuary near Beaufort; 2) to present the variations in seasonal densities of glass eels; 3) to analyze the seasonal length frequency by weekly intervals, and 4) to compare mean ages of glass eels at three locations along the eastern coast of North America (North Carolina, New Jersey, and New Brunswick). We also tested two hypotheses relevant to validating daily deposition of otolith growth increments in the glass-eel stage of *Anguilla rostrata.*

Methods

Collections

Glass eels were collected from two sites in North Carolina: 1) in the lower Newport River at Pivers Island, about 2 km inside Beaufort Inlet; and 2) at Black Creek, a small tributary of the Newport River, at the entrance to a millpond, about 9.5 km upriver from Beaufort, North Carolina. The samples at Pivers Island were collected over the 10-year period 1985–95 with a 1×2 m neuston net fitted with 945-um mesh and flow meter and suspended from a bridge, except during 1985–86, when 60-cm bongo nets were used. Details of the sampling protocol are given in Warlen (1994). Samples were always collected at night during midflood tide, from November to April. Density of fish in the catches was standardized as the mean number per 100 m^3. Additional samples were collected by dip net from Black Creek just below a small dam leading into a millpond (22 February and 20 March 1994). Samples were also obtained from two areas north of North Carolina: 1) Little Egg Inlet, New Jersey, at the site of the Marine Field Station, State University of New Jersey, Rutgers,Tuckerton, NJ (39°30′N, 74°14′W) on 21 February and 9 March 1994 (with a 1-m plankton net); 2) elvers were captured from the Lepreau River, at the village of Lepreau, New Brunswick, Canada, on the Bay of Fundy (45°00′N, 66°20′W) on 6 June 1994. This sample was collected with a 1-mm mesh dip net and was preserved in 70% ethanol. All other samples were preserved in 95% ethanol, and then preserved in fresh 70% ethanol after 24 h.

Aging methods

All eels were measured (TL to the nearest 0.1 mm) with a Vernier caliper and saggital otoliths were removed, washed, dried, and mounted on glass slides with thermal cement, sulcus groove down. The otoliths were ground with a series of wet grit papers (no. 600 to 1200) until the core was visible, then polished with diamond paste, after which they were aged by using an oil-immersion lens from 1200 to 3100×. A subsample of 10 otoliths was also sectioned (transverse) and prepared for reading, and ages were compared with ages from whole otoliths from the same fish. Sectioned otoliths had about 4% more rings in the outer edge. Otolith increments were read from the hatching ring outwards, as suggested by Lecomte-Finiger (1992) and Tzeng (1996). Umezawa and Tsukamoto (1991) found that no rings were formed during the incubation period (5 days) of *A. japonica*. To maintain consistency with other authors, we therefore added five days to our ages. An optical imaging system was used to count increments and to measure increment widths and the distance from the core to the first-feeding (exogenous) ring, etc. The lowest increment width (distance between adjacent dark rings) recorded was 0.326 μ, a distance which was probably close to the resolution minimum of our microscope. Incremental counts were made of the leptocephalus growth zone, the metamorphic zone, the glass-eel growth

zone, and from the "elver" check (transition mark) to the edge of the otolith (see Cieri and McCleave, 2000). Total ages were estimated as the age from the hatching ring to the elver mark. Glass-eel growth zone ages (increments from the outer boundary of metamorphic zone to elver check) were read as in Wang and Tzeng (1998).

Age studies

The mean ages in the glass-eel growth zones of eels taken at Pivers Island in February were compared with mean ages in glass-eel growth zones of eels taken at an upper estuary site, the Black Creek Mill Pond entrance (also in February). The difference in mean age presumably reflected the time required to travel the distance upriver to the collection site.

The total ages and the ages found in the glass-eel growth zone were compared with those for small and larger glass eels arriving during the recruitment season. Glass eels were divided into length groups (from 46.1–48.0 TL to 58.1–60.0) and corresponding age frequencies were assigned to each length group. A linear regression was then fitted to the data to assess whether or not smaller fish were older or younger than the longer members of their recruitment class.
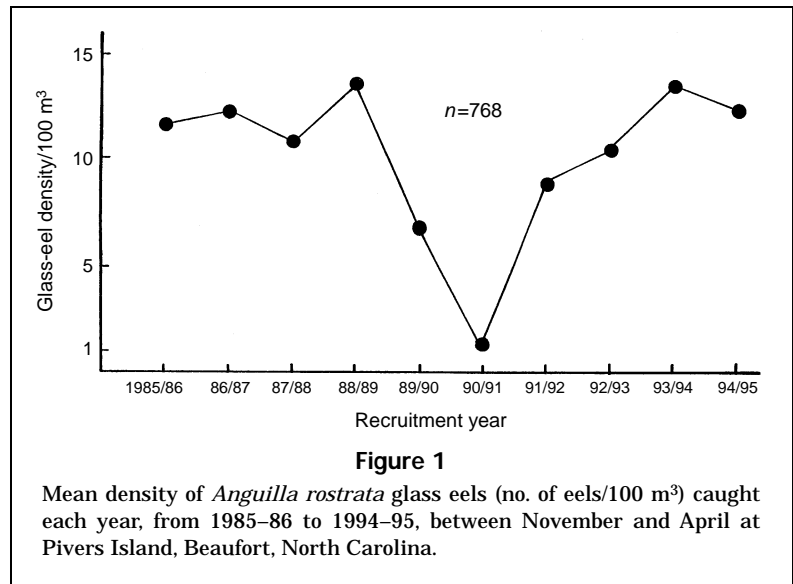
Statistical analysis

Seasonal trends in the weekly length distributions were examined by linear regression (SAS Institute, 1996) for each sampling (recruitment) season, and for the whole 10-year period (1985–86 to 1994–95).

The differences in otolith increment widths in the early (proximal) glass-eel growth zone (increments 10–15) and later (mid-distal) glass-eel growth zone (increments 30–35) from the New Brunswick and North Carolina samples were examined by analysis of variance (ANOVA). Age distributions of glass eels captured by month were compared by using the F-test. Statistical significance was accepted at $P < 0.05$.

Results

Annual recruitment

The total density of glass eels in the Beaufort estuary varied considerably between 1985 and 1995, but there was no significant trend (F_8=1.605, adj r^2=0.123, slope=−0.031, P=0.246) among the 10 consecutive recruitment years in the Beaufort estuary (Fig. 1). Densities were highest in 1988–89 and 1993–94 (13.5–14.0 eels/100 m³) and lowest in 1990–91 (1.5 eels/100 m³), a ninefold difference. Apart from the low of 1990–91, all other years had total densities of more than seven eels/100 m³. After the 1990–91 low, the total annual density of elvers at Beaufort increased

Figure 1

Mean density of *Anguilla rostrata* glass eels (no. of eels/100 m³) caught each year, from 1985–86 to 1994–95, between November and April at Pivers Island, Beaufort, North Carolina.

again (F_3=4.88; slope 2.04, r^2=0.78, P=0.113), approaching the previous mean level.

Seasonal recruitment

Although glass eel recruitment sometimes occurred over a 5 1/2 month period (mid-November to early May), most recruitment of young eels to the estuary occurred from December through April (Fig. 2). Although there was some variation among years within the recruitment period, the largest catches usually occurred in February and March. Peak catches varied from early in the season (1985–86) to late in the season (1987–88). In 1993–94, densities were highest in mid-January and mid-March. In (1990–91), the year with the lowest catches, almost all of the catch occurred in December and January, with virtually none afterwards.

When seasonal changes in length of glass eels among recruitment years were analyzed (Table 1), the slope of the regression for all 10 years (Fig. 3) was positive, but not significant (F_1=19.50, P=0.001). Four seasons had negative regression slopes and slopes for the other years were positive, three of which were significant.

Age studies

The mean age observed in the glass-eel growth zones of eels collected in February from the Pivers Island and Black Creek sites differed significantly, by eight days (F_2= 6.651, P=0.003). The Pivers Island eels averaged 36.2 d (52.9 ±0.9 mm TL) for their as yet uncompleted glass-eel phase, and the Black Creek elvers averaged 44.6 d (55.9 ±0.9 mm TL). The distance between the two sites was about 9.5 km.

In respect to otolith growth, the mean widths of the first 10–15 daily growth increments in the glass-eel growth zone (Table 2) were not significantly different (F_2=1.363, P=0.185) between the northern eels (New Brunswick) and the southern eels (North Carolina). However, both samples of otoliths from North Carolina indicated that mean
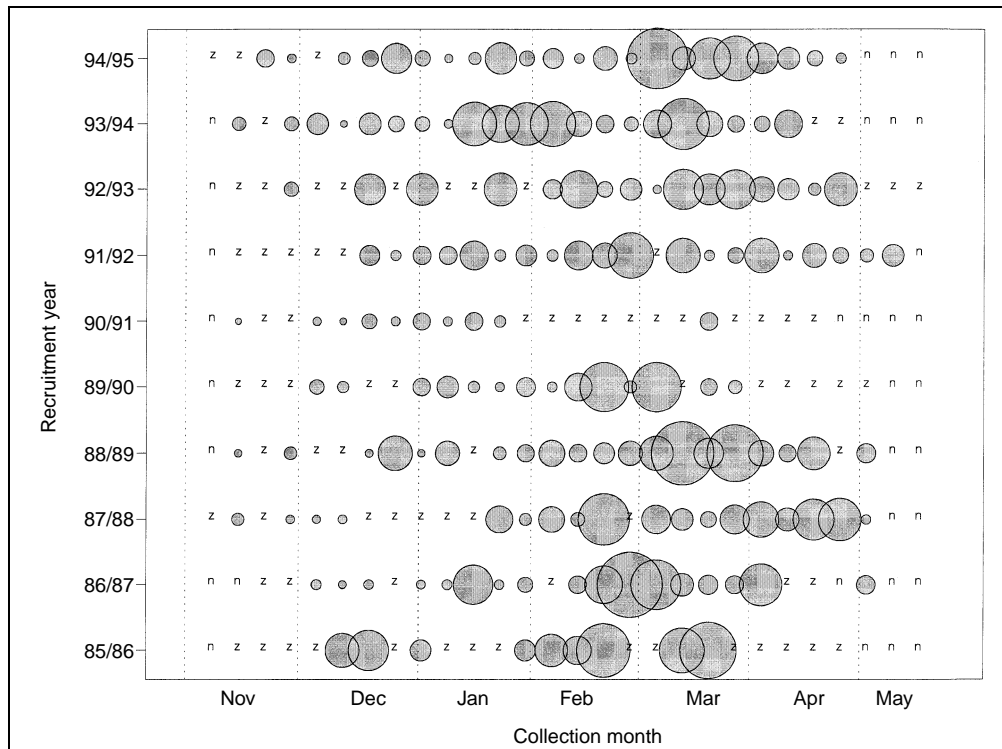
Figure 2

Total densities of *Anguilla rostrata* glass eels (no. of eels/100 m³) by week during recruitment seasons, from 1985–86 to 1994–95. Larval density is proportional to circle area: smallest density (0.034) at week 2 of season 1990–91; largest density (3.690) at week 17 of 1986–87 season. *n* = no sampling and *z* = sampling with zero catch.

Table 1

Linear regression coefficients for total length on collection week for glass-eel stages of American eel taken at Pivers Island, Beaufort, North Carolina, in each of 10 recruitment seasons, with 95% confidence intervals for slopes and intercepts. *P* is the probability of failing to reject the H_0. All years: $Y = 52.15 + 0.088X$ ($r^2 = 0.026$).

Recruitment year	n	Adjusted r^2	Intercept	Slope	F	P
1985–86	34	0.19	48.92 ±3.48	0.24 ±0.15	1.58	0.245
1986–87	61	0.03	50.87 ±2.94	0.15 ±0.14	2.87	0.095
1987–88	73	0.11	50.63 ±2.49	0.19 ±0.12	10.21	0.002
1988–89	81	0.02	52.65 ±2.41	0.09 ±0.07	2.27	0.136
1989–90	48	0.00	54.45 ±2.80	−0.09 ±0.08	1.03	0.315
1990–91	15	0.07	53.18 ±5.24	−0.01±0.39	0.00	0.958
1991–92	60	0.33	48.82 ±1.70	0.27 ±0.10	30.66	0.001
1992–93	60	0.01	54.11 ±4.00	−0.07 ±0.07	1.37	0.247
1993–94	18	0.02	54.94 ±1.48	−0.09 ±0.09	3.70	0.057
1994–95	132	0.01	52.97 ±1.55	0.07 ±0.08	2.40	0.124

incremental widths (1.717 and 1.732) in the later stage of the glass eel (increments 30–35), were wider (F_2=3.93 , P=0.004) than the corresponding mean width (1.314) for New Brunswick otoliths, as hypothesized, suggesting faster growth in the southern waters.

The youngest (mean 168 d) American eel elvers were found at the Pivers Island site (Table 3), whereas elvers at Black Creek (just north of Pivers Island) were not significantly different at age 175 d (F_2=1.125, P=0.376). Neither elvers from New Jersey (201 d) nor those from New

Table 2

Mean increment widths (microns) with 95% confidence limits in the glass-eel growth zone of *Anguilla rostrata* otoliths from three different sampling sites and the number showing the "elver" or "transition" mark. Number in sample (*n*) applies to both increment groups. Means without a letter in common (y and z) were significantly different (*P* ≤0.05).

Sample site	*n*	Width (μ) of 10–15th increment	Width (μ) of 30–35th increment	Presence of elver mark (%)
Pivers Island, North Carolina	77	1.425 ±0.114 z	1.717 ±0.189 z	0
Black Creek, North Carolina	27	1.330 ± 0.169 z	1.732 ±0.180 z	93
Lepreau, New Brunswick	43	1.232 ±0.168 z	1.341 ±0.163 y	98

Table 3

Means (±SD) for total age, glass-eel age, and total length (TL) for young eels, *Anguilla rostrata* collected in our study. Only glass-eel ages were significantly different (*) between locations (*F*-test, *P* ≤0.05). *n* = number of otoliths analyzed.

Location	Date	*n*	Total age (d)	Glass eel age (d)	Length (TL mm)
Pivers Island, North Carolina	Dec–Apr 1985–94	77	167.2 ±16.9	36.2 ±3.2*	52.9 ±2.4
Black Creek, North Carolina	2–23 Feb 1994	25	175.4 ±12.6	44.6 ±1.6*	55.9 ±3.1
Little Egg Inlet, New Jersey	Feb–Mar 1994	22	201.2±16.1	62.3 ±8.8*	60.9 ±3.0
Lepreau, New Brunswick	6 June 1994	43	209.3±18.1	69.8 ±10.5*	58.1 ±3.8

Table 4

Regression of collection week (1–26) against total age in days (with 95% confidence limits) and regression of glass-eel growth zone age (outer metamorphic zone to elver check on otolith) against total length (mm) for glass eels collected at Pivers Island, North Carolina. The sampling period (recruitment season) extended from November to mid-May, 1985–86 to 1994–95. *n* = number of otoliths analyzed.
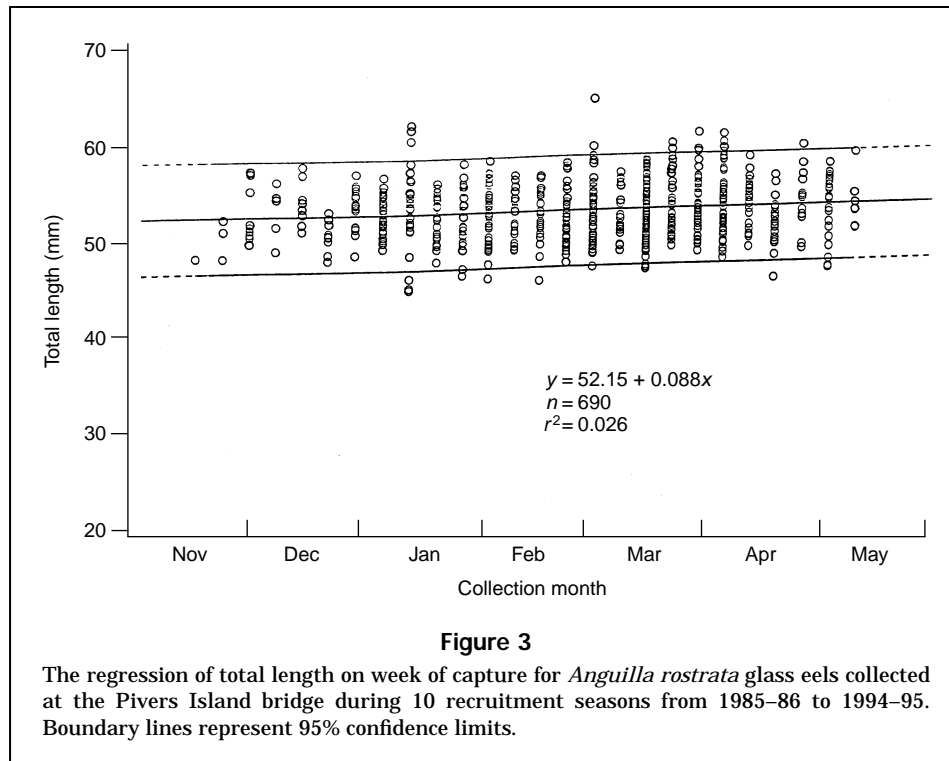
	n	Slope	Adjusted *r*²	Intercept	*P*	Mean age
Collection week against total age	89	0.339	0.053	170.2	0.976	173.1 ±2.7
Glass eel growth zone age against total length	89	– 0.311	0.499	77.5	0.014	60.6 ±1.7

Brunswick (209 d) were significantly older than those from North Carolina (F_2=1.111, *P*=0.407; F_2=1.140, *P*=0.373) with respect to total age. Although New Jersey fish appeared to be longer (60.9 mm TL) than New Brunswick elvers (58.1 mm TL), the difference in mean length was not significant (F_2=1.283, *P*=0.266).

Although total mean age (d) counts were not significantly different between sites (Table 3), glass-eel age (the portion between metamorphosis zone and elver mark of otolith) differed between all three sites (NC vs. NJ, F_2= 7.713, *P*=0.005; NJ vs. NB, F_2=1.622, *P*=0.091). Furthermore, when glass-eel ages were regressed against latitude, the relationship was significant (slope=0.303, adj. *r*²=0.835, *P*=0.028).

In light of Jessop's (1998) finding of a decrease in length over the recruitment season for elvers in the Bay of Fundy waters, we re-examined our age data by month and length. Could it be that even though our lengths showed no significant seasonal decrease, shorter fish were, on average, older than longer fish? The regression of the capture date against total mean age suggested an increase in age over time (Table 4), but the relationship was weak (adj. *r*²=0.053). Furthermore, an *F*-test revealed no difference in incremental total age between any month. But total age is apparently not to be trusted (Cieri and McCleave, 2000). When we regressed mean length against only the glass-eel zone age, it revealed just the opposite relationship: a negative slope (Table 4), with a good relationship (adj. *r*²=0.499). The smaller fish during the recruitment period were indeed older, as suggested by Jessop (1998). The longer fish, on average, had fewer increments in their glass-eel growth zone than the shorter fish, suggesting that the latter had taken longer to reach Beaufort estuary from the Sargasso Sea.

Figure 3

The regression of total length on week of capture for *Anguilla rostrata* glass eels collected at the Pivers Island bridge during 10 recruitment seasons from 1985–86 to 1994–95. Boundary lines represent 95% confidence limits.

Discussion

Glass eels were recruited to the Beaufort estuary over a 7-month period from November to early May during the ten years from 1985–86 to 1994–95. Peak recruitment occurred in February–March of most years. Catch distributions were usually skewed, either positively or negatively, and clumped. Variation in estuarine recruitment time may have been due to differences in oceanic transport rates for larvae, and perhaps to slight differences in times of peak spawning, a well-known phenomenon in many other fish species. Able and Fahay (1998) also found that most glass eels recruited to a New Jersey estuary from January to June (in 1991 to July), with peaks usually in February and March. In Nova Scotia the main fishery for elvers in 1997 extended from late April to mid-August (Jessop, 1998). The recruitment period for the two southernmost localities and Nova Scotia thus overlapped in April and May: as the North Carolina and New Jersey recruitment period ends, the northern Bay of Fundy area typically commences.

Although there was a large variation in the numbers of eels caught among years, there was no indication of an overall reduction in recruitment. Castonguay et al. (1994b), and Marcogliese et al. (1997) have suggested a number of possible reasons for a decline of European eels, but such a decline was not reflected in our catches of elvers at Beaufort. Jessop (1997) also concluded that there had not been a decline in elvers recruited to Atlantic coastal waters of the Canadian maritime provinces over the past decade (last year 1996).

The lengths of elvers captured in the tidal net at Pivers Island fell within the expected latitudinal length range reported by Haro and Kreuger (1988) and were similar to the 49–56 mm TL length range for glass eels from a river in Georgia (Helfman et al., 1984). Mixed elvers and small juveniles (not aged) in the Great Bay area of New Jersey, from 1986 to 1994 averaged 60–90 mm TL (Able and Fahay, 1998). Elvers collected by Jessop (1998) in 1997 in the Bay of Fundy waters ranged from 52.0 to 70.0 mm TL (considerable variation was evident among rivers of New Brunswick and Nova Scotia.). Even farther to the north (Quebec), Michaud et al. (1988) reported lengths of elvers for 1987 from the St. Lawrence River estuary to extend from 50 to 70 mm TL. Comparing our data with that of other studies, and allowing for 2.8% shrinkage in length of our eels (unpubl. data) due to alcohol preservation (our samples), as opposed to 1–2% shrinkage in 6–10% formalin (Jessop, 1998; Stobo, 1972), we found that there was a remarkable consistency in the clinal length ranges from north to south. Some inconsistency was expected because we compared studies in which sampling was done at both river mouths and estuaries, where it is known that ascent up rivers is usually dependent upon temperature or stream level (Martin, 1995; Jessop, 1998).

In a study of the Bay of Fundy waters, Jessop (1998) showed that as the season progressed, lengths of young eels entering most, but not all, rivers declined to a maximum of 7%. The length of recruiting European eel elvers also declined seasonally (Cantrelle, 1981). Yet our combined length-frequency plot of all fish collected over the ten-year period showed a nonsignificant regression. It may be that only elvers to the north of our location show a definitive decrease in lengths over time or that our samples were too small to confirm the phenomenon.

The difference in estimated mean age of 8 days from glass-eel growth zones at two North Carolina locations about 9.5 km apart implies that upriver movement was about 1 km a day, much of which could be tidal. We do not know whether or not this rate of movement is reasonable or typical.

The mean age from our glass-eel growth zones on otoliths of glass eels agreed with the ages determined from other glass eels collected in North Carolina (Wang and Tzeng, 1998).

Finally, the apparent total ages and glass-eel ages from North Carolina, New Jersey, and New Brunswick support the hypothesis that eels are progressively older to the north, and are consistent with their greater distance from the Sargasso Sea.

Total age estimates of glass eels can be compared with those from two other studies of American eel. Our average total age of glass eels from Black Creek (175 d) was 14% older than the 153 d that Budimawan (1996) found for the same location, date, and year. On the other hand, estimated total ages of glass eels were considerably less (20–22%) than the ages obtained by Wang and Tzeng (1998) for eels from the same general areas (but different dates). Because ages from glass-eel growth zones (as opposed to total age) were in very close agreement with those of Wang and Tzeng (1998), one assumption for this inconsistency in total age is a difference in interpreting age in either the leptocephalus or metamorphic zone. It is also possible that increments ≤0.3 μ wide may not have been distinguishable by light microscopy, which could account for our ages being younger than those of Wang and Tzeng (1998), who used SEM. Antunes and Tesch (1997) have also suggested that these two methods of otolith observation may produce different results. It is conceivable that increments in the leptocephalus growth zone may be laid down in fewer numbers in some seasons, but it seems unlikely that low water temperatures would cause a cessation of otolith increment deposition, because the Gulf Stream top 200-m layer (the assumed habitat of leptocephali) maintains an annual temperature above 16°C (Stommel, 1965). Absorption of increments during metamorphosis (Cieri and McCleave, 2000) is possible, but our studies could not shed any light on this proposed phenomenon because all leptocephali had metamorphosed before reaching North Carolina. Obviously, there is consistent agreement among authors in incremental counts of glass-eel growth zones, which are wide and clear, and therefore easy to count.

Regardless of the discrepancy in age estimates of larval eels, evidence from the rate of transport of other species in the Gulf Stream suggests that once they have reached the Gulf Stream, it is possible for leptocephali to reach the continental shelf of North Carolina in about 110 days. A NOAA (National Oceanic and Atmospheric Administration) sea drifter released in 1996 west of the western edge of the Sargasso Sea in 1996 and travelling just inside the western front of the Gulf Stream at 100 m depth reached the North Carolina outer continental shelf in 50 days. Its release site appears to overlap stations where leptocephali of *A. rostrata* were captured (Wippelhauser et al., 1985; Kleckner and McCleave, 1985). Larvae of several fish species from Florida waters are known to reach the area off-

shore North Carolina in 25–30 d (Hare and Ahrenholz).[1] For example, larval Atlantic menhaden (*Brevoortia tyrannus*) that spawned offshore from Beaufort in an area close to the path of the sea drifter reached the estuary near Beaufort, North Carolina, in an average of 60 d (Warlen, 1994). This estimate of across-continental shelf transport, when added to the 50 d of travel for the sea drifter, gives an elapsed time of 110 d. This estimate of transport duration may prove to be useful in the future.

McCleave et al. (1998) surmised that leptocephali of the European eel (virtually identical in physical structure to *A. rostrata*) do not actively swim toward land during their migration to Europe. Granted that the age increments in the larval zone of the otolith of American eels may not accurately depict early life-history duration (Cieri and McCleave, 2000), the consistency of recruited lengths and glass-eel ages over the years from 1985 to 1995 is noteworthy. In addition, the annual recruitment seasons and sizes observed in coastal North Carolina and New Jersey regions (Able and Fahay, 1998) reveal a remarkably consistent sequential latitudinal pattern. It appears that current data on seasonal recruitment of young eels should continue to be used to examine temporal relationships between geographical areas and oceanic transport times from the spawning area (Sargasso Sea) to the estuaries.

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