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Early life history and recruitment of the tropical eel
Anguilla bicolor pacifica, as revealed by otolith microstructure and microchemistry

Abstract  Otolith microstructure and microchemistry of the tropical eel Anguilla bicolor pacifica Schmidt were examined in glass eels collected at the mouth of the Dumoga River, North Sulawesi Island, Indonesia. Ages of the glass eels examined (age at recruitment) ranged from 124 to 202 d (167 ± 19.3 d; mean ± SD), hatching being estimated as having occurred between November 1995 and March 1996. Otolith increment widths markedly increased from age 101 to 172 d (135 ± 18.2 d; mean ± SD), coincident with a drastic decrease in otolith Sr:Ca ratios, suggesting that metamorphosis began during that period. The duration of metamorphosis was estimated as 20 to 40 d, on the basis of otolith microstructural characteristics. The fluctuation patterns in otolith increment widths and Sr:Ca ratios were similar to those of the temperate Japanese eel A. japonica.

Introduction  Recent progress in otolith techniques has revealed many important aspects of the early life histories of temperate Anguilla species, including A. japonica and A. anguilla. Numerous reports have demonstrated relationships between otolith characteristics, such as growth patterns (Tabeta et al. 1987; Tsukamoto 1990; Tsukamoto and Umezawa 1990; Tzeng 1990; Umezawa and Tsukamoto 1990; Lecomte-Finiger 1992; Tzeng and Tsai 1992; Cheng and Tzeng 1996) and Sr:Ca ratios (Otake et al. 1994; Tzeng 1994, 1996; Tzeng and Tsai 1994), and metamorphosis in these Anguilla species. Arai et al. (1997) proposed that a marked increase in otolith increment width, coincident with a drop in Sr:Ca ratios, heralded the onset of metamorphosis, the latter apparently being completed before the occurrence of maximum otolith increment width.

Compared with temperate Anguilla species, little is known about the early life history of tropical species, including aspects such as spawning area and season, larval growth and metamorphosis, and migration and recruitment. Twelve of eighteen Anguilla species are known to be distributed in tropical waters, seven occurring in the western Pacific around Indonesia (Ege 1939; Matsui 1972; Castle and Williamson 1974), where freshwater eels are thought to have originated (Aoyama and Tsukamoto 1997). According to Tsukamoto (1994), long-term larval migration in the sea might be the reason for the world-wide distribution and consequent speciation of Anguilla species. The early life history, including migration and metamorphosis, of tropical eels, i.e. old-type eels, may provide a key for understanding how Anguilla species achieved their world-wide distribution.

The final goals of our study are an understanding of the evolution and distribution of Anguilla species from examination of their early life histories, including larval migration and metamorphosis. In the present study otolith microstructure and microchemistry of a tropical species, A. bicolor pacifica, from North Sulawesi Island, Indonesia, were examined, and the timing and duration of metamorphosis, in addition to age at recruitment (age at estuarine arrival) and hatching date, determined.

Materials and methods

Specimens, and otolith preparation

Anguilla bicolor pacifica Schmidt glass eels were collected by night (20:00 to 23:00 hrs) with a dip net at the mouth of the Dumoga River, North Sulawesi Island, Indonesia, on 5 June and 22 July 1996 (Fig. 1). The glass eels sampled were preserved in 99% ethanol.
immediately after collection. Total lengths were measured to the nearest 0.1 mm, and pigmentation stages determined according to Bertin (1956). Sagittal otoliths were extracted from each fish, embedded in epoxy resin (Struers, Epofix) and mounted on glass slides. A total of 25 otoliths (15 specimens from the 5 June sample, 10 from the 22 July sample) was used for the present study (Table 1). Those otoliths were ground to expose the core in the sagittal plane, using a grinding machine equipped with a diamond cup-wheel (Struers, Discoplan-TS), and further polished with 6 μm and 1 μm diamond paste on an automated polishing wheel (Struers, Planopol-V). They were then cleaned in an ultrasonic bath and rinsed with deionized water pending subsequent examinations.

Otolith X-ray microprobe analysis

For electron microprobe analyses, ten otoliths from glass eels (5 June sample) ranging from 46.2 to 51.1 mm in total length (mean ± SD: 49.1 ± 1.6 mm) were carbon coated by a high vacuum evaporator. Otolith Sr and Ca concentrations were measured along the longest axis using a wavelength-dispersive X-ray electron microprobe (JEOL JXA-733), with calcite (CaCO₃) and strontianite (SrCO₃) as standards. Accelerating voltage and beam current were 15 kV and 7 nA, respectively. The electron beam was focused on a point about 1 μm in diameter, measurements being spaced at 1 μm intervals. Each datum represents the average of three measurements (each counting time: 4.0 s). Microprobe measurement points, which were seen as burn depressions (Fig. 2), were assigned to otolith growth increments which were examined as described below. The averages of successive data of Sr and Ca concentrations pooled for every ten successive growth increments were used for the life-history transect analysis.

Otolith increment analysis

Following the electron microprobe analysis, the otoliths were re-polished to remove the coating, etched with 0.05 M HCl and vacuum coated with Pt-Pd in an ion-sputter for scanning electron microscope (SEM, Hitachi S-4500) observations. Otoliths of 15 glass eels (5 from the 5 June sample, 10 from the 22 July sample), which had not been used for electron microprobe analysis, were also etched and coated by the same procedure for SEM observation. SEM photographs at various magnifications (180x, 1000x, 1500x, 2000x) were used for measuring otolith radii, counting the number of growth increments and measuring their widths. The longest axis of the ground otolith surface was regarded as the otolith radius along which increment widths were measured. The averages of every ten succeeding ring widths between the hatch check and the edge were used for otolith growth analysis. Following the suggestions of Lecomte-Finiger and Yahyaoui (1989), Tsukamoto (1989) and Umezawa et al. (1989), the increment number in Anguilla bicolor pacifica was taken to represent the age in days, although the daily deposition was not validated in this species.

Results

Size and stage at recruitment

The total lengths of the glass eels collected on 5 June and 22 July 1996 were 48.9 ± 1.4 mm and 48.9 ± 1.7 mm (mean ± SD), respectively (Table 1); there was no significant difference between the two sample groups (Mann–Whitney U-test, p > 0.05).

Pigmentation in all of the glass eels conformed to Stage VA, i.e. pigmentation advanced only in the caudal fin region, with no pigmentation on any other portion of the body.

Otolith microstructure

The otoliths of Anguilla bicolor pacifica glass eels were oval (Fig. 2), such shape was similar to those observed