

# A comparison of larval and postlarval gulf menhaden, *Brevoortia patronus*, growth rates between an offshore spawning ground and an estuarine nursery

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The fishery for gulf menhaden, *Brevoortia patronus*, was the largest by weight in the United States from 1963 through 1988 and has had a significant impact on the economy of the northern Gulf of Mexico coast. The species is also an ecologically important prey item for a number of commercially and recreationally important species (Lassuy, 1983).

Gulf menhaden early life history has been reviewed by a number of authors (Lassuy, 1983; Deegan, 1985; Powell and Phonlor, 1986; Shaw et al., 1988; Christmas and Waller<sup>1</sup>). Adults spawn in offshore and coastal waters in depths ranging from 11 to 128 m; peak spawning occurs between the 10- and 60-m isobaths (Shaw et al., 1988). Most spawning generally occurs between October and March; peak spawning occurs in December (Fore, 1970; Shaw et al., 1985; Christmas and Waller<sup>1</sup>). Once spawned, gulf menhaden eggs are pelagic and hatch within about two days. The offshore larval drift period may last from 4 to 10 weeks (Deegan and Thompson, 1987; Shaw et al., 1988). Peak immigration through tidal passes into estuarine nurseries generally occurs

between December and March (Suttkus, 1956; Lassuy, 1983).

In the estuary, larval gulf menhaden move into bayous and other low salinity areas at the onset of transformation into juveniles (Fore and Baxter, 1972; Simoneaux, 1979; Deegan, 1990; Raynie and Shaw, in press). Estuarine residence is typical during summer months. As juveniles grow larger, they tend to move downstream to higher salinity waters and from late summer to winter many emigrate to open coastal waters (Deegan, 1990).

Daily otolith increment formation has been validated and is estimated to begin at the onset of exogenous feeding, which occurs about three days after hatching (Warlen, 1988). Growth rate estimates based on larval gulf menhaden otolith analyses have been made from larvae collected off the Mississippi River Delta, Florida and Texas (Warlen, 1988) and from young of the year collected within estuarine waters of Louisiana (Deegan and Thompson, 1987). A comparison between growth rates of gulf menhaden captured from continental shelf and adjacent estuarine waters during the same

time period has not been done. The purpose of this paper is to examine growth rates of larval and postlarval gulf menhaden from offshore and estuarine habitats and relate the results to metamorphosis.

## Materials and methods

### Sampling procedure

Gulf menhaden larvae and postlarvae were collected at two stations in the northern Gulf of Mexico (6 and 32 km from shore) on 23 January 1990 and from three locations (Lower Bay, Mosquito Island, and Big Carencro Bayou) within the adjacent estuary, Fourleague Bay, Louisiana, on 24–25 January 1990 (see Raynie and Shaw, in press). Larvae were collected offshore with a 60-cm bongo frame equipped with a 505- $\mu$ m mesh net fitted with a flow meter (General Oceanics Model no. 2030). Within Fourleague Bay, collections were made with a bow-mounted plankton push net of the same diameter and mesh size as that used offshore. One three-minute collection was taken at each station offshore and at each station each day within Fourleague Bay. Plankton push nets have been shown to be effective at collecting larval fish (Miller, 1973; Raynie and Shaw, in press) and juvenile fish (Herke, 1969; Kriete and Loesch, 1980). The use of this gear in this highly turbid and shallow estuarine system (mean depth=1.5 m; Teague et al., 1988) minimizes net avoidance.

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<sup>1</sup> Christmas, J. Y., and R. S. Waller. 1975. Location and time of menhaden spawning in the Gulf of Mexico. CCRL/NMFS Contract Rep. 03-4-042-24.

Samples were initially preserved with 95% ethanol, stored in ice, and later preserved with a 70% ethanol solution in the lab. Temperature and salinity were measured with a Beckman Portable Electronic Salinometer (Model No. RS5-3).

## Laboratory analysis

Notochord lengths (preflexion, NL) or standard lengths (SL) were measured to the nearest 0.1 mm with an ocular micrometer under a dissecting microscope. Sagittal otoliths were then removed from a random subsample ( $n=111$ ) of larvae under a dissecting microscope with polarized light. Otoliths were air-dried and mounted on a glass microscope slide with S/P Accu-mount 60. Otoliths were sufficiently thin and rings sufficiently spaced to allow for optical sectioning (focusing to the plane of maximum clarity) under a compound microscope (400 $\times$  or 1,000 $\times$ ) to make total increment counts and otolith diameter measurements. Increments were independently counted by each author and averaged.

Spawning dates were back-calculated for each larva by subtracting the estimated age from date of capture (i.e. capture date - [ring count + 5 days for egg incubation and yolk-sac absorption]) (Warlen, 1988). It was assumed that there were no differences in the age at first increment deposition (5 days) among larvae.

## Statistical analysis

Age and growth data from each environment (offshore and estuarine) and the combined data were fit to the Laird version of the Gompertz growth equation (Laird et al., 1965) by means of nonlinear least squares regression techniques (SAS Institute, Inc., 1985):

$$L_t = L_0 e^{K(1 - e^{-at})},$$

where  $L_t$  = standard length of larvae at day  $t$ ;  $L_0$  = initial length;  $K = A_0/a$ ;  $A_0$  = age-specific growth rate at  $L_0$ ; and  $a$  = the exponential decline in the age-specific growth rate. Because five days were added to otolith counts to attain age estimates (2 days incubation + 3

days between hatching and exogenous feeding and first increment formation), two days were subtracted from the age estimates, so that the Y-intercept would approximate the hatching length. The length at hatching has been observed from laboratory data (2.6–3.0 mm NL; Hettler, 1984) and estimated from field data (2.4 mm NL; Warlen, 1988). With these data, we fixed the hatching length at 3.0 mm NL in our models.

Average daily growth rate was estimated by

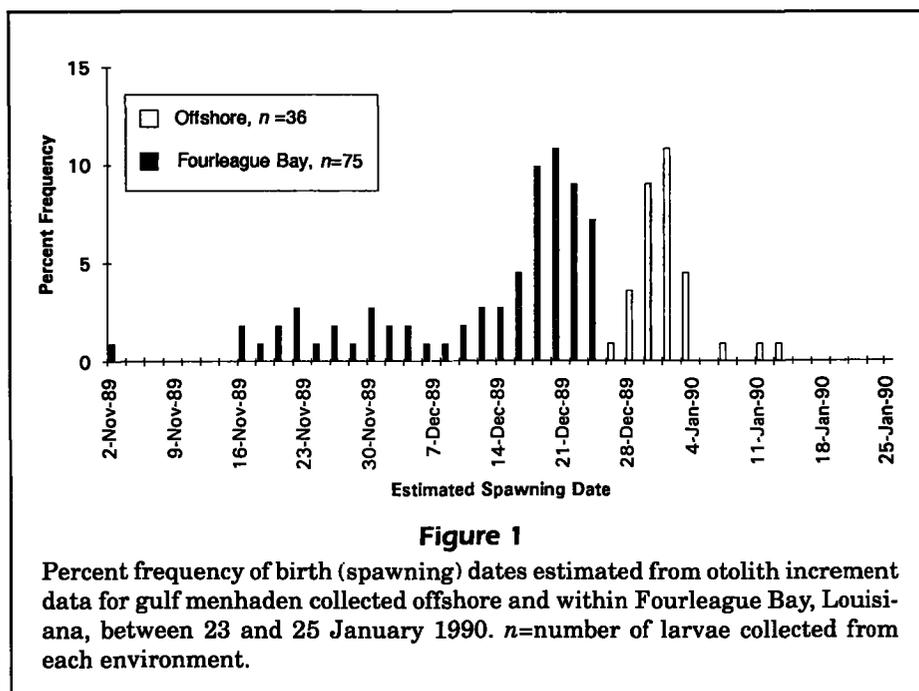
$$\text{Average daily growth} = \frac{(\text{standard length} - 3.0 \text{ mm})}{\text{days posthatch}}$$

(after Deegan and Thompson, 1987).

## Results and discussion

The mean surface water temperature offshore at the time of capture was 17.8°C (range 17.5–18.0°C) and the mean salinity was 31.0 ppt (range 29.0–33.0 ppt). Within Fourleague Bay, the mean temperature was 19.0°C (range 17.5–20.1°C) and salinities ranged from 2.7 to 7.3 ppt, with the exception of our 24 January 1990 Lower Bay collection when the salinity was 23.9 ppt.

According to age estimates, most of the larvae collected offshore were spawned within one week between 27 December 1989 and 3 January 1990. Virtually all larvae collected within Fourleague Bay were spawned between mid-November and 24 December 1989, with a peak between 17 and 24 December 1989 (Fig. 1). One 85-day-old larva was col-



lected from Mosquito Island and was estimated to have been spawned on 1 November 1989.

Growth of larval fish (and other vertebrates) typically proceeds through a series of consecutive intervals (thresholds) which characterize ontogeny. Periods of rapid growth are generally followed by periods of slower development during which complex structures prepare for the next series of changes (Balon, 1984). The Laird-Gompertz equation has been used to describe larval fish growth when the length-age plots are nonlinear and upper asymptotes are apparent (Zweifel and Lasker, 1976; Methot and Kramer, 1979; Laroche et al., 1982; Warlen and Chester, 1985; Warlen, 1988). This model was used to estimate the age-specific growth rate and the exponential decline in the age-specific growth rate as larval gulf menhaden approach metamorphosis to juveniles.

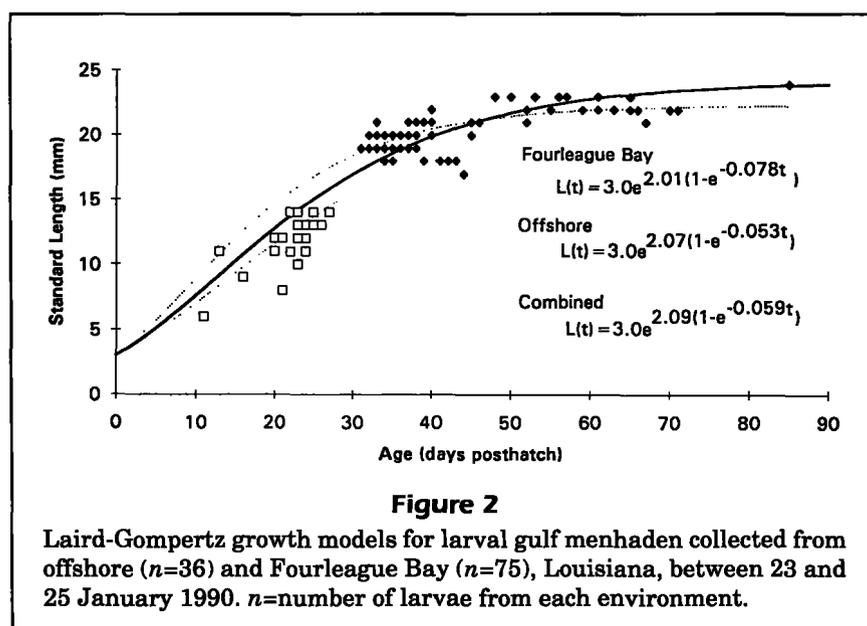
Growth rates were estimated from larvae between 5.8 and 16 mm SL collected offshore and larvae between 17 and 24 mm SL collected within Fourleague Bay. The average daily growth of larvae collected offshore (0.44 mm/day) was greater than within Fourleague Bay (0.12 mm/day). The average daily growth rate of larval gulf menhaden from the combined data was 0.25 mm/day.

Postlarval gulf menhaden are estimated to be 15–25 mm SL (Shaw et al., 1988) upon entering the estuary and begin transformation to the juvenile stage around 20 mm SL. Transformation is complete at about 30 mm (Suttkus, 1956; Hettler, 1984). Between 20 and 30 mm SL, however, growth characteristics change (Fig. 2): mouth parts and gill rakers are modified and the body begins to thicken and take on the

deep-bodied characteristics of juveniles and adults (Suttkus, 1956). During this threshold, postlarval (prejuvenile) gulf menhaden growth in weight is disproportionately greater than growth in length (Deegan and Thompson, 1987).

The period of slowed growth in length just before and during juvenile transformation is followed by a dramatic increase in growth rate (Springer and Woodburn, 1960; Deegan and Thompson, 1987). Average daily growth of gulf menhaden between 18 and 82 mm SL reportedly ranges from 0.20 to 0.48 mm/day within Fourleague Bay (Deegan and Thompson, 1987). Our estimate of average daily growth rate for postlarvae (17–24 mm SL) within Fourleague Bay was expectedly lower (0.12 mm/day), since our larvae were approaching or were in the process of transformation.

Our estimate of average daily growth from offshore is similar to Warlen's (1988) growth estimates for larval gulf menhaden collected off Southwest Pass, Louisiana (0.28–0.42 mm/day). Some marine larvae have been shown to grow faster at higher temperatures (Laurence et al., 1981); however, this has not been demonstrated for gulf menhaden (Warlen, 1988). During the winter, surface water temperatures are generally warmer offshore than within Fourleague Bay; however, this difference is generally minimal (Raynie and Shaw, in press). Our temperature data are insufficient (and may be atypical of the average conditions) to evaluate the relationship between growth and temperature. The difference in growth rates between environments, however, is most likely the result of ontogeny. A 71% decrease in growth rate between larval and juvenile



stages based on developmental history alone has been shown for Atlantic herring, *Clupea harengus*, and a 96% decrease in growth rate has been shown for bay anchovy, *Anchoa mitchilli* (Houde, 1987). These two clupeiform species have high larval growth rates and relatively long metamorphosis intervals (Houde, 1987) as does gulf menhaden. Lewis et al. (1972) also related varying growth in length to growth in weight through larval, prejuvenile, and juvenile stages of Atlantic menhaden, *Brevoortia tyrannus*. Therefore, physiological and morphological changes occurring between larval and juvenile stages may be more important in the regulation of the shape of growth curves (both length and weight) than variability in exogenous factors.

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