The Link Between Growth and Otolith Size in Young-of-the-Year *Lepomis* Sunfish

~~~~~~~

by

Bruce Stallsmith* *and* William Hagar

*Montserrat College of Art, 23 Essex St.,
Beverly, MA 01915, fundulus@world.std.com

Abstract

Sagittal otolith size in young-of-the-year *Lepomis* sunfish, bluegills and pumpkinseeds (*macrochirus* and *gibbosus*), was compared to 3 variables: age in days, standard length, and dry weight, to determine their utility, together and singly, to predict otolith size. Sagittal otoliths were removed and examined from 265 YOY *Lepomis* sunfish collected in 1992, 1993, and 1996 from Maquan Pond in Hanson, Massachusetts. Examination enables age in days for each YOY to be calculated since the metamorphic event of swim-up from the paternal nest. Multiple regression analysis using age in days, standard length and dry weight as Y-axis variables, and otolith size as the X-axis variable, found a high determination coefficient of r^2=0.87 in this model. Standardized regression coefficients were calculated to determine which of the three variables had the strongest predictive value for otolith length. Dry weight had the largest standardized regression coefficient (0.67) and seems to be the more important of the variables for describing otolith size.

The relationship between weight and length (allometry) is widely regarded as the fundamental parameter of growth and final size in animals. Growth patterns between smaller parts of an animal such as individual bones and overall size or weight are also important descriptors of an animal's life history. This study is a follow-up to earlier work on allometric growth patterns in *Lepomis* sunfish young-of-the-year (YOY) (Stallsmith, Ebersole and Hagar 1996). In particular, the growth of one small but important part of the skeleton, the sagittal otolith, was studied in relation to the age, length and weight of sunfish YOY.

Otoliths are the bony disks in paired chambers in a fish's head that function in hearing and balance. The use of otoliths, particularly the largest pair known as the sagittal otoliths, has become a standard tool of fish recruitment studies that seek to answer a broad range of questions. Otoliths generally grow on some regular pattern, laying down alternate layers of aragonite (calcium carbonate) and a proteinaceous matrix. The proper examination of otoliths, chemically and structurally, can give a wide range of information about both an individual fish and broader population dynamics. This versatility of information contained in otoliths was summarized as follows by Campana (1994):

Recruitment Studies usually are of larval or juvenile stages, to answer questions about mortality or growth.

Stock and hatchery identification Otolith microstructure can be used to differentiate between different population stocks.

Thermal and chemical mass marking of hatchery-reared fish Calcium-binding fluorescent compounds can be used to mark otoliths for later identification of released fish.

Age and growth determination Age in days or years can usually be determined as needed. Otoliths have often proven to be more accurate than scale age estimates.

Size-selective growth and mortality estimates Growth patterns in the otolith are sometimes useful for testing size-specific hypotheses.

Oceanographic influences Isotope properties of different otolith bands can be related to climatic and oceanographic variables, especially temperature.

In this study, the relationships between sagittal otolith growth and standard length, dry weight and age in days are examined. The sagittal otoliths of these two
~~~~~~~

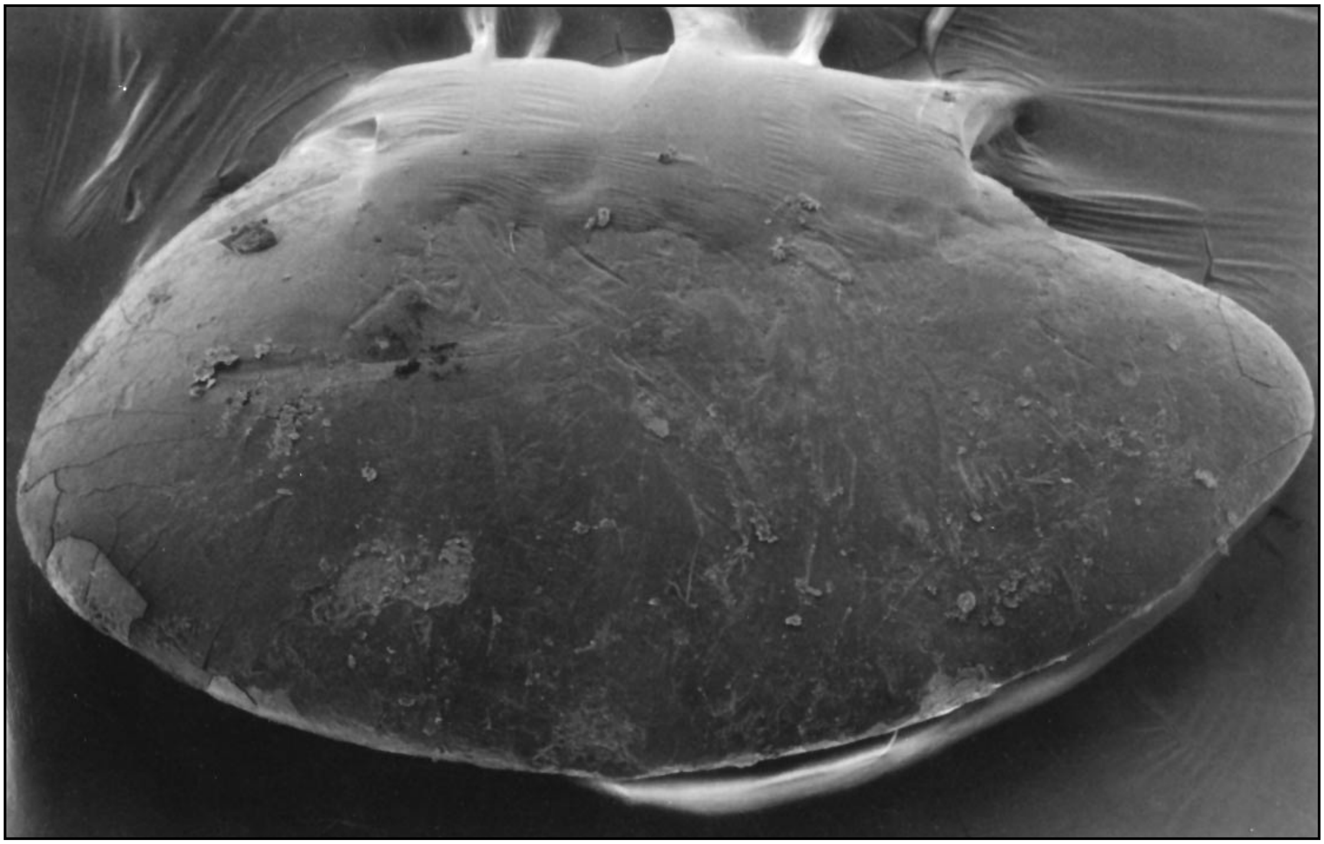

Fig. 1. *Lepomis* YOY sagittal otolith, intact. SEM photograph, 324**X** magnification. Courtesy Aldo Leiva.

Lepomis species are known to grow on a daily 24-hour cycle (Taubert and Coble 1977). This regular growth begins when larval fish metamorphose into gill-breathing juveniles and leave the paternal nest. Figure 1 is a scanning electron micrograph (SEM) of a YOY *Lepomis* otolith. Microscopic examination of prepared YOY otoliths allows the back calculation of the fish's age in days through the counting of regular banding patterns. The SEM in Figure 2 is of a YOY *Lepomis* otolith that has been partially prepared for our standard examination. The daily growth increments are clearly visible as a regular layering pattern.

The increasing use of otoliths in the study of many areas of fish physiology and fisheries biology necessitates the study of otolith growth patterns and relationships to other growth patterns. Otolith size is an important measure in studying the population structure of commercially important fish species, since the size (and weight) of an otolith is related to a fish's age in years in a predictable way. This study is a contribution to the further understanding of otolith and other growth patterns in *Lepomis* sunfish, in general a well-studied group of fish. Given that otoliths grow on a regular 24 hour cycle, how closely linked is this growth to fish age, fish length and fish weight? In particular, aging a YOY *Lepomis* by measuring otolith length would be much less labor intensive than standard methods for counting daily otolith growth increments.

Material and Methods

Location Maquan Pond in Hanson, MA, is a freshwater pond of 17 ha., located 35 km south of Boston, MA.

Fish sampling The two species of *Lepomis* included in this study, *macrochirus* (bluegill) and *gibbosus* (pumpkinseed), are common inhabitants of fresh water in the northeastern United States. In areas where they coexist their YOY are morphologically and behaviorally indistinguishable (Mittelbach 1984), and no effort was made to separate them in this study. Fish were captured with seine nets or hand nets during July and August. Fish were collected in 1992, 1993 and 1996. Sampled fish were frozen

Fig. 2. Partially sanded YOY *Lepomis* otolith. Each ridge pattern is the result of different deposition patterns in a 24-hour cycle. SEM photograph, 1500**X** magnification. Courtesy Jerry Jarrett.

for storage. A total of 265 fish were examined in this study.

Measurements Fish were allowed to defrost overnight in a fume hood. Dry weight was taken in mg. Dry weight is equal to 26% of live weight (Jarrett et al. 1993). Standard length was measured after defrosting. Otoliths were mounted on a slide using clear nail polish as an adhesive, and otolith length was measured using a microscopic ocular at 100X. Length was the maximum measurement along the anterior/posterior plane (the left to right axis in Figure 1). Age in days was calculated through microscopic examination of otoliths at 400X as described in Stallsmith, Ebersole and Hagar (1996).

Statistical treatment Multiple regression analysis was performed using the XLSTAT statistics package which functions as an add-in to the Microsoft Excel 5.0/7.0 spreadsheet program. For this analysis, otolith length was the dependent variable (Y) and independent variables (X) were used to look at the relationship between each one and otolith length. Statistical significance was assigned at the level of α=0.05.

To determine how strongly otolith length increases with each of the three dependent variables, a standardized regression coefficient (b_s) was calculated for each. This coefficient represents the predicted increase in Y (in standard deviation units) that would be expected per standard deviation increase in a given X, in the form $b_s = b \times (s_x/s_y)$ where b is the slope of the regression between Y and X, and s_x and s_y are the standard deviations of X and Y, respectively. Expressing this change in standard deviation units of X controls for differences in the units of measurement for different variables (Rosner 1995).

Results and Discussion

Multiple regression analysis showed a determination coefficient r^2 of 0.87, which means that the three independent variables of fish length, age, and fish weight jointly explain 87% of the variability of the dependent variable, otolith length. The regression equation is given by:

Otolith length, mm = 0.53 + (0.10 x (Fish length, cm))
+ (0.004 x (Age, days)) + (3.78 x (Fish weight, grams))

All three independent variables were significantly correlated with the dependent variable ($p<0.01$).

The standardized regression coefficients for each independent variable were as follows: fish length, 0.16; age, 0.17; fish weight, 0.67. This means that otolith size changes most responsively to changes in fish weight, when the influences of fish length and age are controlled for. Fish length and fish age are also useful predicters of otolith length. For example, one could derive a relationship between age in days and otolith length allowing otolith length to be a predicter of fish age within some margin of error.

These results seem to indicate that the sagittal otolith's growth is more closely linked to body mass rather than to standard length, which is to say to overall skeletal growth. The sagittal otolith is known to grow by laying down alternating layers of aragonite (calcium carbonate) and protein matrix (Taubert and Coble 1977). This cyclicity may be more closely linked to metabolic processes involving weight gain than to other skeletal growth processes. This supports an interpretation that otolith growth in YOY *Lepomis* is strongly linked to the same metabolic/physiological processes and rhythms that control other growth parameters; merely being alive for a period of time may not be enough to ensure otolith growth.

Such a relationship is opposite of what has been observed in other studies of the otolith size/fish size relationship. Secor and Dean (1989), based on their studies of striped bass (*Morone saxatilis*), proposed that otoliths grow in a continuous manner independent of body growth. Beckman et al. (1991) found that otolith growth in sheepshead (*Archosargus probatocephalus*) continues with age, independent of fish growth. This more typical otolith growth pattern may be the case in *Lepomis* species if all age groups, not just YOY, are examined. We hope to be able to do such a research project in the immediate future to resolve this apparent contradiction between *Lepomis* species and most other fishes.

References

Beckman, D. W., A. L. Stanley, J. H. Render and C. A. Wilson. 1991. Age and growth-rate estimation of sheepshead *Archosargus probatocephalus* in Louisiana waters using otoliths. Fish. Bull., U.S. 89:1-8.

Campana, S. E. 1994. Conference Report. Rev. Fish Biol. Fish. 4:124-125.

Jarrett, J. N., M. B. Cutler, W. G. Hagar and J. P. Ebersole. 1993. Seasonal variation in pH and alkalinity and recruitment of sunfish populations. Freshwater Biology 30:409-417.

Mittelbach, G. G. 1984. Predation and resource partitioning in two sunfishes (Centrarchidae). Ecology 65: 499-513.

Rosner, B. A. Fundamentals of Biostatistics, 4th edition. 1995, Duxbury Press.

Secor, D. H. and J. M. Dean. 1989. Somatic growth effects on the otolith-fish size relationship in young pond-reared striped bass, *Morone saxatilis*. Can. J. Fish. Aquat. Sci. 46:113-121.

Stallsmith, B. W., J. P. Ebersole & W. G. Hagar. 1996. The effects of acid episodes on *Lepomis* sunfish recruitment and growth in two ponds in Massachusetts, U.S.A. Freshwater Biology 36:731-744.

Taubert, B. D. & D. W. Coble. 1977. Daily rings in otoliths of three species of *Lepomis* and *Tilapia mossambica*. J. Fish. Res. Bd. Can. 34:332-340.

How to join NANFA's E-mail lists.

If you have a computer and a modem, feel free to join one or all of NANFA's E-mail lists: a list for the discussion of native fish keeping and appreciation, and a Board of Directors (BOD) list for the discussion of Board issues and NANFA management. To join the general NANFA list, send the word "subscribe" in the body (not subject) of an E-mail to:

`nanfa-request@aquaria.net`

To join the digest version of this list, in which each day's E-mails are combined into one (longer) E-mail, send the word "subscribe" in the body (not subject) of an E-mail to:

`nanfa-digest-request@aquaria.net`

To join the BOD list, send the word "subscribe" in the body (not subject) of an E-mail to:

`nanfa-bod-request@aquaria.net`

Likewise, there is a digest version of the BOD list. To subscribe, send the word "subscribe" in the body (not subject) of an E-mail to:

`nanfa-bod-digest-request@aquaria.net`

Instructions on how to use the lists will be issued when you subscribe.