GROWTH OF LARVAL SARDINES OFF PERU

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ABSTRACT

The growth rate of sardine larvae from Peru was determined from daily increments in the otoliths. Scanning electron microscopy was used to confirm the size of increments. The growth rate of sardine larvae is discussed in relationship to other clupeoid fishes, in particular the anchoveta and northern anchovy.

RESUMEN

Se determinó la tasa de crecimiento de las larvas de la sardina peruana sobre la base del incremento diario de los otolitos. Se utilizó microscopía electrónica de barrido para confirmar la magnitud de los incrementos. La tasa de crecimiento de las larvas de sardina es analizada en relación con otros clupéidos, en particular la anchoveta y la anchoveta del norte.

INTRODUCTION

Since El Niño of 1972 the population of Pacific sardine, *Sardinops sagax sagax*, in the Peruvian Current has increased greatly while the anchoveta, *Engraulis ringens*, has declined. The biomass of sardines was estimated at 3 million metric tons in 1978. The Pacific sardine is now the basis for the most important fishery off Peru, having replaced the formerly abundant anchoveta. The resurgence of the sardine population following the decline of the anchoveta raises many questions about the interactions between the two species.

Sardines and anchovies share many similarities in addition to their differences (Murphy 1966, 1967; Smith 1972). The sardine, anchoveta, and northern anchovy all spawn between sunset and midnight (Ahlstrom 1943; Hunter and Macewicz 1980; Ahlheit et al. 1984). The eggs of sardines and anchovies are quite different. The eggs of both the northern anchovy (*Engraulis mordax*) and the anchoveta (*Engraulis ringens*) are oblate spheroids about 1.34 mm long and 0.66 mm wide, with a narrow perivitelline space (Ahlstrom 1956; Fischer 1958; Einarsson and Rojas de Mendiola 1963). However, the sardine (*Sardinops sagax caeruleus*) egg is spherical with an average diameter of 1.70 mm (range 1.35-2.05 mm) (Ahlstrom 1943).

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In spite of the differences in egg morphology, incubation times and larval morphology are quite similar. Sardine hatch in 2.8 days at 15°C (Lasker 1964); northern anchovy hatch in 2.9 days at 15°C (Zweifel and Lasker 1976); and anchoveta hatch in 2-2.5 days at 14-16°C (Ware et al 1981). The elongate larvae of sardines and anchovies are morphologically quite similar (Ahlstrom 1943, 1956; Smith 1972). Yolk-sac larvae begin feeding one to two days after hatching (Zwiefel and Lasker 1976). Feeding behavior of both sardines and anchovies is characterized by S-shaped feeding strikes.

Off California from 1951-60 anchovy larvae were taken at 71.3% of all stations where sardines occurred (Ahlstrom 1966). Sardine and anchovy larvae may interact through interspecific competition for food or through differential mortality. Copepod nauplii and copepodites are the dominant food items of sardine and northern anchovy larvae off California (Arthur 1976) and of anchoveta larvae off Peru (Rojas de Mendiola 1974; Ware et al. 1981). Interspecific competition for food implies that the abundance of one species affects the availability of food for the other species. However, even at the station where anchovy were most abundant, anchovy larvae constituted no more than 0.02% by volume of all organisms collected by .333-mm mesh plankton netting; many of these organisms consume the same food as the anchovy larvae (Bob Owen, pers. comm.). Thus intraspecific competition among anchovy larvae or interspecific competition for food between anchovy and sardine larvae seems unlikely. Differences in growth between species of larvae could lead to differential survival, since the smallest (youngest) stages are the most vulnerable to predation (Hunter 1984). High growth rates of sardine larvae during periods of warm water may be one mechanism whereby environmental variations may lead to large changes in abundance.

At present, however, little is known about the growth rates of sardine larvae in the sea, because the techniques for investigating such growth rates have only recently been developed (Brothers et al. 1976), and adequate samples were difficult to obtain when the populations were low. We investigated sardine growth as part of the continuing research at the Institu-

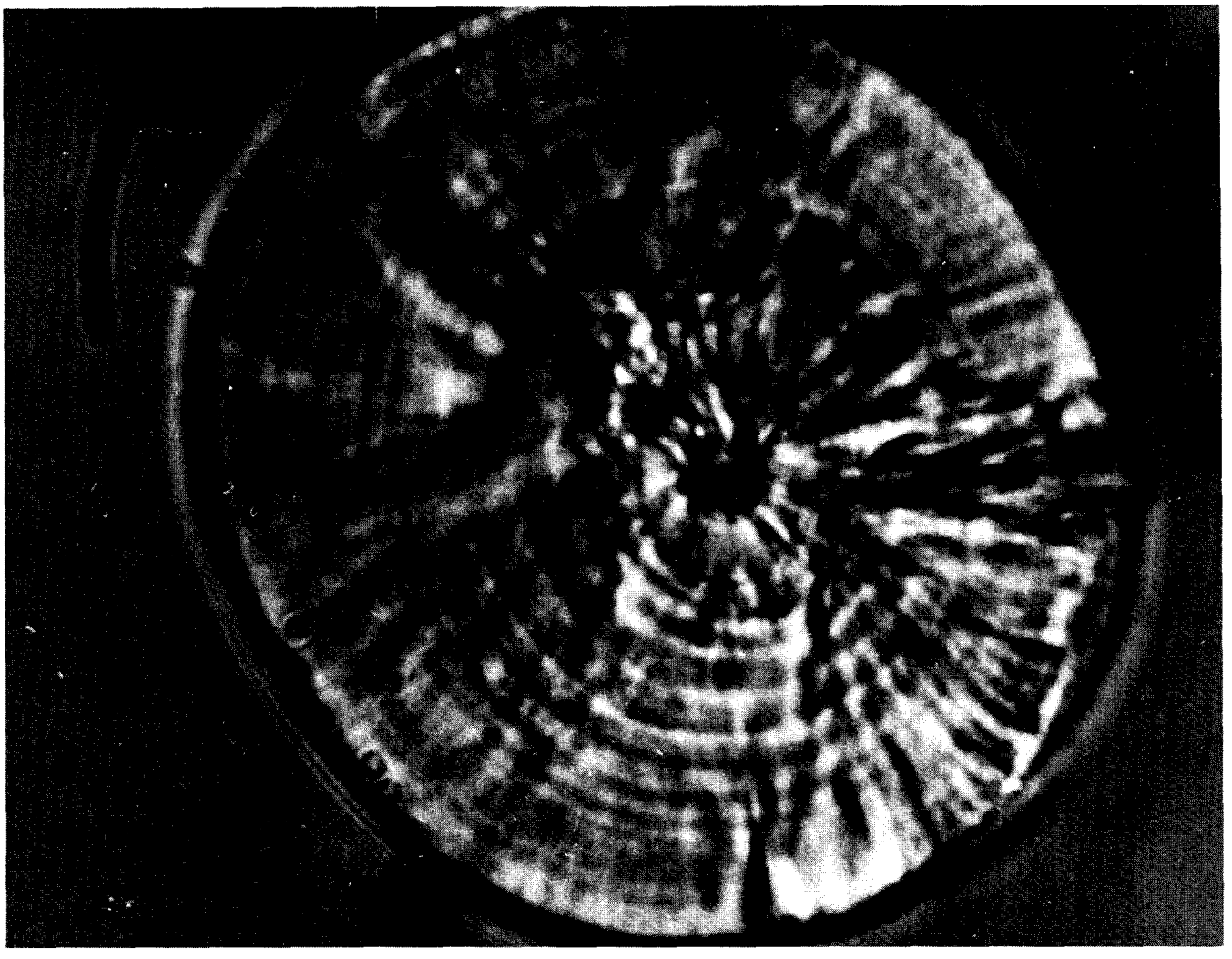

Figure 1. Photomicrograph of the otolith from a 13.8-mm sardine larvae (3400×). The increments are difficult to interpret in this specimen.

to del Mar del Peru on the pelagic resources of Peru and as a basis for estimating larval sardine mortality rates in the sea.

MATERIALS AND METHODS

Pacific sardine larvae (*Sardinops sagax sagax*) were collected with a 1-m ring net on August 27, 1983, at 09°39.8'S, 78°24.7'W off Chimbote, Peru. The sea-surface temperature at the time of capture was 18.6°C. Plankton samples were fixed in 80% ethanol at the time of collection and refixed with 80% alcohol one day after collection. Larvae were sorted from the preserved samples and stored in 80% ethanol.

Adult Pacific sardine (*Sardinops sagax caeruleus*) were spawned in the laboratory at the Southwest Fisheries Center on December 18, 1984. The eggs hatched two days later at 18.5°C. Ten to fifteen larvae were preserved in 80% ethanol. We used the laboratory-reared specimens to determine the length of the larvae and the size of the otolith at hatching. Daily increments in the otoliths (sagittae) were examined with light microscopy and electron microscopy. We dissected otoliths from larvae in water on a microscope slide, cleaned them of adhering tissue, and allowed them to dry before covering them with clear nylon nail hardener (Sally Hansen Hard as Nails with nylon) for examination under a compound microscope at 400 and 1000 magnification.

Otoliths examined with scanning electron microscopy (SEM) were transferred to a drop of nylon nail hardener on an aluminum SEM stub. We polished the otoliths with .3-micron lapping compound and etched them for one minute with 5% ethylenediaminetetraacetic acid (EDTA) buffered to pH 7.5. We then coated the specimens with gold before viewing them at 1790 × with scanning electron microscopy.

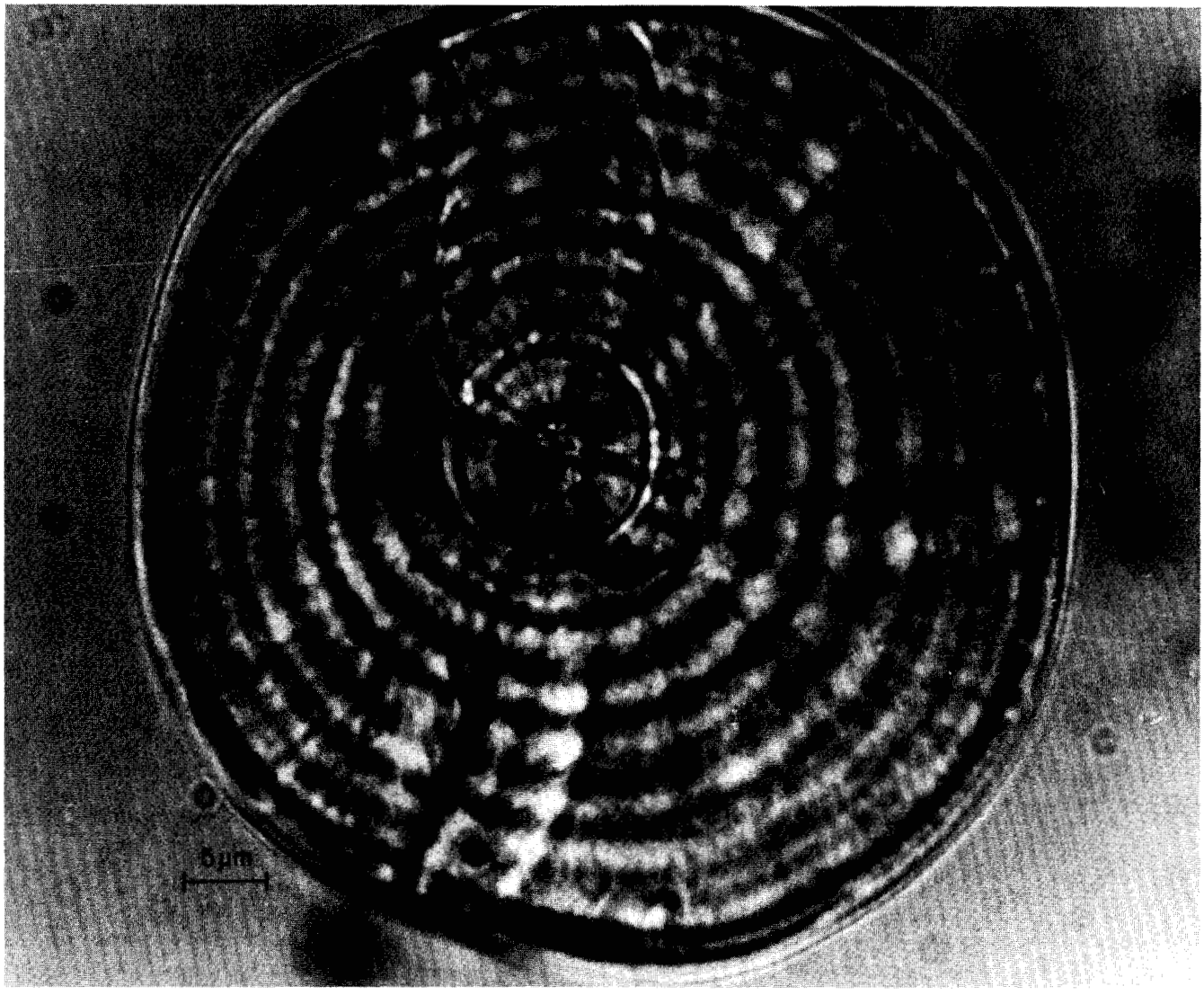

Figure 2. Photomicrograph of the otolith from a 14.5-mm sardine larva (3300×). The large dark lines correspond in size to the increments seen in scanning electron micrographs.

RESULTS

We examined the otoliths of sardine larvae hatched in the laboratory with light microscopy and with scanning electron microscopy. No increments were found in the otoliths from larvae sampled on the day of hatching (day 0) or the following day (day 1). Rearing conditions of the larvae were apparently suboptimal, because all larvae died within a few days. Otoliths from these larvae were ambiguous. Brothers et al. (1976) found that northern anchovy formed the first increment on day 5. Because of similarities in larval development (see Introduction), we assume that sardine larvae also form the first increment on the fifth day after spawning. This assumption is subject to verification.

The use of light microscopy (Figures 1 and 2) alone can lead to ambiguous interpretation of the number of increments in an otolith because small increments may not be resolved or because subdaily increments within large increments may be interpreted as daily increments. Thus we examined sardine otoliths using scanning electron microscopy. This technique confirmed the size of the increments (Figure 3) and a fast growth rate of sardine larvae (Figure 4). The laboratory-reared specimens indicated that sardine larvae do not form daily increments until about three days after hatching. Therefore the age of field-collected specimens was calculated by adding five days to the number of increments in the otolith (Figure 4). The length-at-age data were fitted to a Laird-Gompertz equation

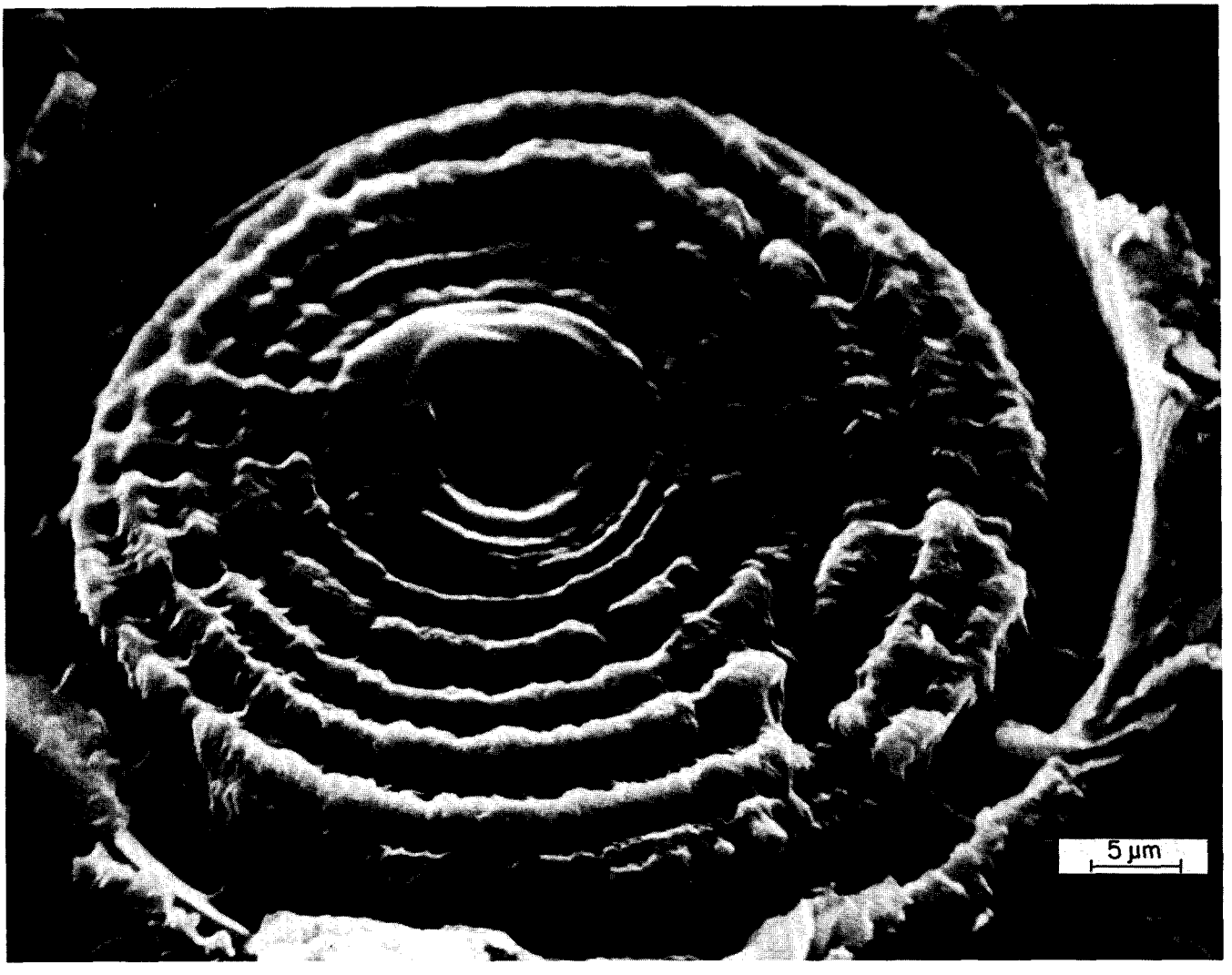

Figure 3. Scanning electron micrograph of a polished and etched otolith from a 14.8-mm sardine larva (3500×). The large pit in the center is the focus.

(Zwiefel and Lasker 1976) and to a logistic equation. The logistic equation gave a slightly better fit with more degrees of freedom, but neither curve adequately described the data.

DISCUSSION

According to the parameters from the logistic equation, sardine larvae grow at a rate of 0.8 mm per day at a size of 12.7 mm. This growth rate compares well with the average growth rate of 0.7 mm per day reported by Kimura and Sakagawa (1972) for laboratory-reared *Sardinops sagax caeruleus*, and the embryonic growth rate of 0.8 mm per day for *Sardinops sagax musica* at 18° (Garretón and Balbontín 1982). The growth rate of sardine larvae is among the highest reported for any clupeoid larva and greater than that of laboratory-reared anchovy larvae at the same temperature (Blaxter and Hunter 1982). It is also about twice the growth rate of the northern anchovy in the sea (Methot and Kramer 1979).

If early sardine larvae truly have a faster intrinsic growth than anchovy, then this may be a key to identifying a fundamental ecological difference between these superficially similar species. For example, faster growth probably implies higher ration and hence, at a given food density, larger search volumes and greater swimming speeds. Ahlstrom (1966) found that sardine larvae were most abundant where anchovy and sardine co-occurred. Faster growth may also imply lower predation risk to size-specific predators. Faster growth may also be a necessary feature of a seasonally later spawner. Sinclair and Tremblay (1984) have proposed that the timing of spawning of Atlantic herring populations is not coupled to spring phytoplankton blooms. Rather, it is associated with growth rates in larval retention areas that allow metamorphosis within a sea-

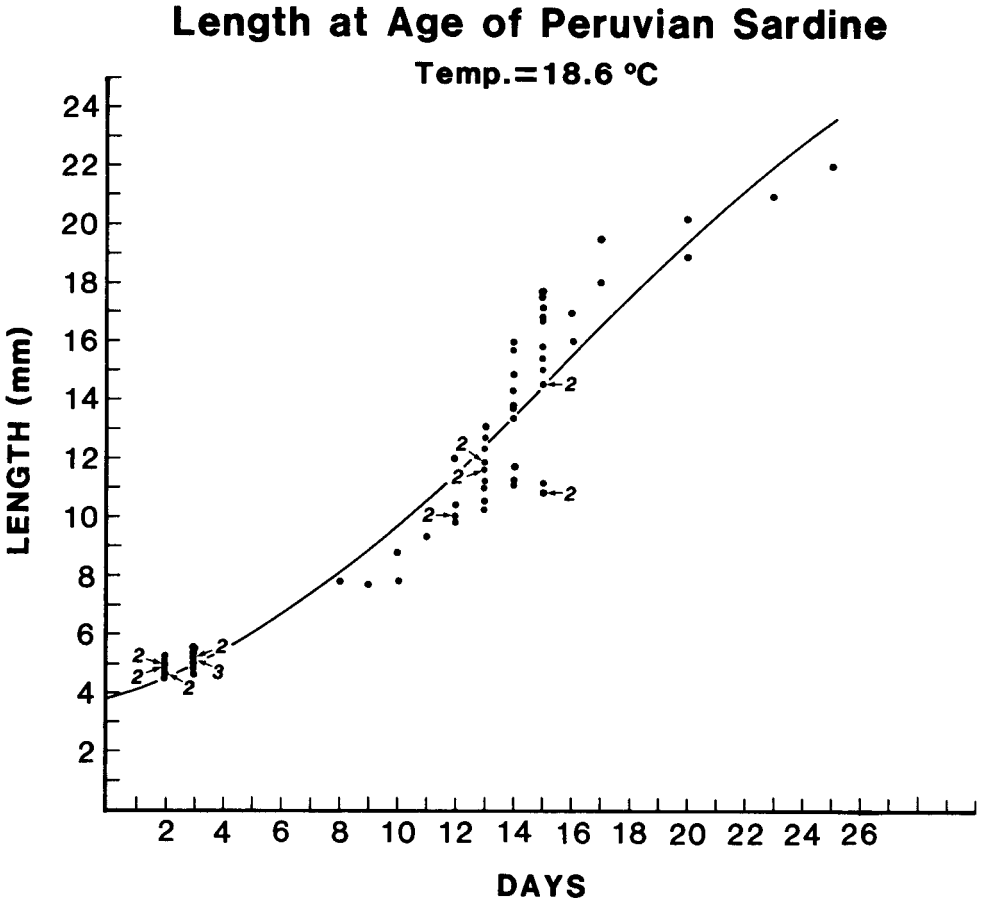

Figure 4. Length at age of Peruvian sardine larvae. The solid line is a logistic growth curve fit to the data points. Data points at 2 and 3 days are from laboratory-reared California sardines.

sonal window. Different stocks of herring exhibit different larval growth rates, but all reach metamorphosis at about the same time. It may be necessary for sardine larvae to grow faster than anchovy larvae in order to metamorphose and reach an optimal juvenile size before winter.

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