Bull. Fac. Bioresources, Mie Univ.
No. 6: 47–55
March 28. 1991

# Daily Egg Production of the Brazilian Anchovy, *Engraulis anchoita*

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**Abstract**

The daily egg production of the Brazilian anchovy was estimated. Anchovy eggs were collected by CalVET net in January, 1988. Eggs were classified into each developmental stage and their ages were calculated on the basis of sea water temperatures. The surface temperatures where anchovy eggs were found were relatively high, ranging 25–29°C, and the hatching occurs within 24 hours. The spawning did not occur during any specified hours but almost all day long. The relation between the mean elapsed time from spawning and the frequency of eggs was analyzed by the non-linear regression method and a exponential function was fitted. The daily egg production of the Brazilian anchovy was $8.87 \times 10^{11}$.

**Key words:** daily egg production, anchovy, EPM, spawning time, southern Brazilian coast

## Introduction

The stock of the Brazilian anchovy, *Engraulis anchoita,* is one of potential fishery resources along the southern Brazilian coast. Estimation of population biomass is important not only for rational exploitation of the stock, but also for diagnosis of the stock and forecast of the recruitment variation. In this study, we estimate the daily egg production (DEP) of the Brazilian anchovy which is one of the most important parameters to obtain informations about their abundance.

## Materials and Methods

Anchovy eggs were collected during two cruises of the R/V "Atlantico Sul" of FURG (Fundação Universidade de Rio Grande), which aimed to apply the EPM (Egg Production Method) for Brazilian sardine, *Sardinella brasiliensis,* and were carried out in January 10–19 (from Cabo Frio to Santos) and January 22–31 (from Santos to C. S. M. Grande), 1988 (Fig. 1). A total of 80 tows of Bongo nets, 392 tows of CalVET net, 302 measurements of BT, 80 castings of NANSEN bottles and fishing were made during the cruises. Anchovy eggs used in this study were derived only from CalVET net samples. The mouth area of the CalVET net was 0.038 $m^2$ with mouth diameter of 22 cm and the mesh size of 0.300 mm. The net was towed vertically from a depth of 70 m or from 5 m above the bottom to surface in shallow water with towing speed of 1 m/s. Distance

Accepted November 27, 1990

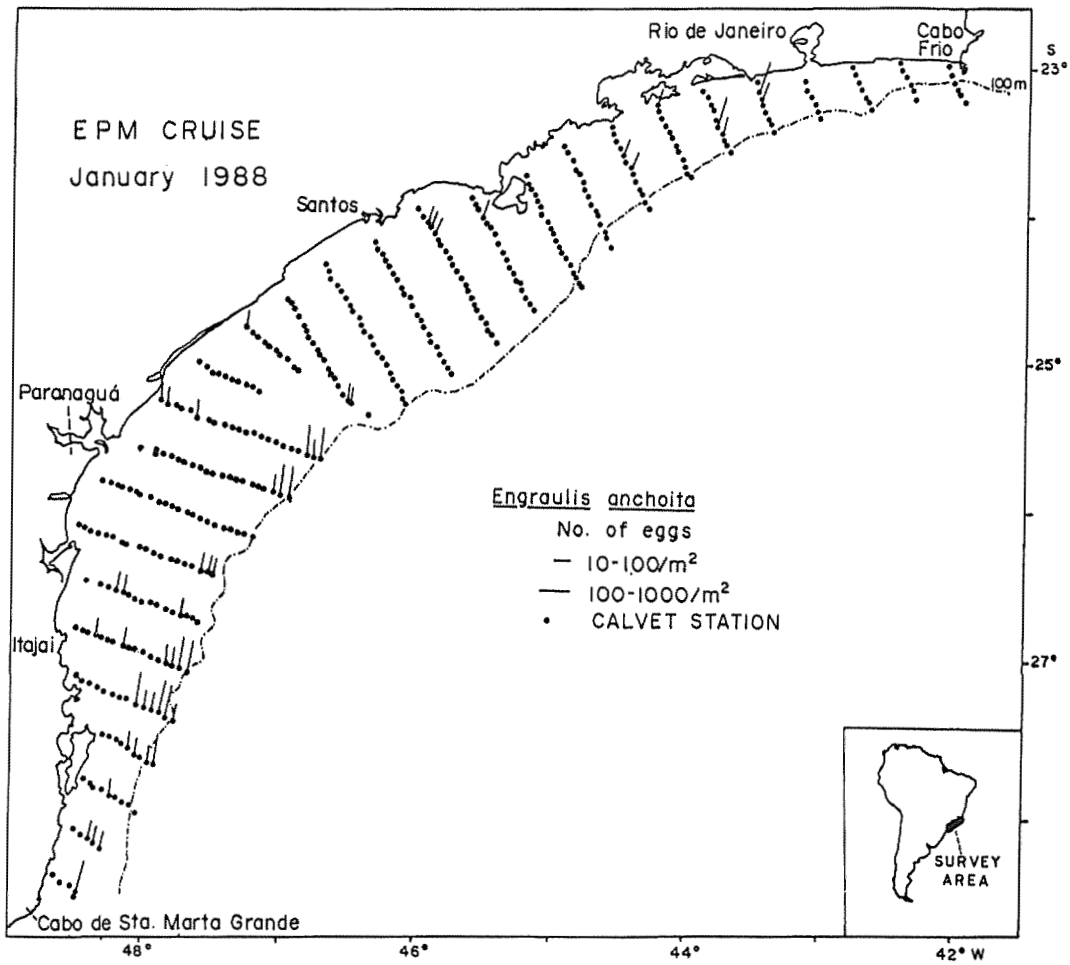


Fig. 1. Geographic distribution of sampling stations and positive stations for anchovy eggs.

between observation lines perpendicular to coast was 20 nm and interval between CalVET stations was 3 nm.

To estimate the daily egg production per unit area, we used the equation (1) of PICQUELLE and STAUFFER (1985)[1]. A FISHPARM program[2] was used in the non-linear regression analysis.

## Results

### 1. Sorting of the anchovy eggs

Fish eggs and larvae were sorted from CalVET net samples and anchovy eggs and larvae were identified at the Ichthyoplankton laboratory of the IOUSP. Out of 392 CalVET net samples, anchovy eggs were found in 56 stations. The number of anchovy eggs in a positive station ranged from one to 25 per tow.

### 2. Developmental stages of the eggs

A sample contained various developmental stages which ranged from recently spawned egg to one just before hatching. We adopted a criterion of staging established for the northern anchovy[3], because we could not

**Table 1.** Staging of the Brazilian Anchovy Eggs

| STATION NO. | SAMPL. TIME | EGG STAGES | | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | |
| 27 | 4.92 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 5 |
| 28 | 5.42 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 37 | 14.98 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 38 | 15.6 | 0 | 11 | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 20 |
| 39 | 15.97 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 48 | 2.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 64 | 13.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 66 | 14.48 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 106 | 22.17 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 143 | 19.83 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 145 | 23.42 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| 146 | 23.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 147 | 0.27 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 204 | 6.83 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 205 | 7.75 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 215 | 15.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 4 |
| 226 | 3.83 | 0 | 0 | 0 | 0 | 6 | 3 | 0 | 3 | 4 | 4 | 4 | 24 |
| 227 | 4.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 228 | 5.02 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 5 |
| 242 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 246 | 13.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 247 | 14.25 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| 266 | 3.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 267 | 4.05 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 0 | 0 | 0 | 2 | 11 |
| 268 | 5 | 0 | 0 | 0 | 0 | 4 | 14 | 3 | 1 | 1 | 2 | 0 | 25 |
| 269 | 7.63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 293 | 22.25 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 307 | 6.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 308 | 6.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 |
| 309 | 7.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| 313 | 11.43 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 321 | 15.87 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| 322 | 16.27 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 330 | 21.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 334 | 23.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 340 | 3.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 341 | 3.83 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| 342 | 4.5 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 1 | 0 | 6 |
| 343 | 5.03 | 1 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 2 | 1 | 0 | 13 |
| 344 | 7.25 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 345 | 7.83 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 6 |
| 346 | 8.52 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| 347 | 8.97 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 1. Continued

| STATION NO. | SAMPL. TIME | EGG STAGES | | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | |
| 348 | 9.5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 349 | 10.08 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 350 | 10.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 351 | 11.17 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 358 | 3.67 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 364 | 23.5 | 0 | 0 | 0 | 0 | 0 | 9 | 3 | 0 | 0 | 0 | 0 | 12 |
| 365 | 0.38 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 367 | 3.25 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 371 | 5.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 381 | 16.42 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 |
| 382 | 18.53 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 383 | 18.98 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 384 | 19.55 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | TOTAL | 14 | 33 | 13 | 3 | 17 | 45 | 19 | 12 | 22 | 15 | 11 | 204 |

carry out rearing experiments of the Brazilian anchovy eggs. The result of staging is shown in Table 1.

### 3. Aging of the eggs—the elapsed time from spawning in reference to the sea temperatures

In the next step, staged eggs must be converted into age categories. The age of an egg means the elapsed time from its deposition into the sea until the moment of sampling. The time that an egg spends from spawning to hatching has close relation with sea temperature and it varies with species[4]. So, in order to estimate correct age of an egg of target species, it is necessary to obtain knowledge on the time needed from the spawning to each developmental stage for a different sea temperatures. Generally these values are derived from incubation experiments of eggs. In the case of Brazilian anchovy, there is no information about such values, so we had to adopt a model which were developed by Nancy Lo (1985) for the temperature-dependent northern anchovy egg development[5]. Putting $y_{i,t}$ as the mean elapsed time from spawning, the equation is

$$y_{i,t}=16.07e^{-(0.1145t+0.0098i)}i^{1.74} \quad \cdots\cdots(1)$$

However, we found an error parameter in the equation and made a correction as the following form;

$$y_{i,t}=16.07e^{-(0.1145t+0.098i)}i^{1.74} \quad \cdots\cdots(2)$$

where $i$ is the developmental stage of anchovy eggs and $t$ is the water temperature (°C). Following this equation, the time needed to reach individual developmental stages from spawning was calculated and is shown in Table 2. For example, an egg requires 33.56 hours at 20°C to reach the X stage. The value of t at 10 m depth obtained with Bathythermograph were used. The result of calculation showed that the most youngest egg was 0.7 hour old (stage I, 26–27°C) and the oldest one was 22 hours old (stage IX, 22.8°C). The exact time of spawning for each egg can be back-calculated using values of the age and their collection time (Table 3).

**Table 2.** Function Relationship of Average Age of Eggs (hours) for the i-th Stage

| TEMP. (°C) | EGG STAGES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
| 30 | 0.47 | 1.42 | 2.61 | 3.9 | 5.22 | 6.499 | 7.705 | 8.813 | 9.807 | 10.68 | 11.43 |
| 29 | 0.53 | 1.59 | 2.93 | 4.38 | 5.85 | 7.287 | 8.639 | 9.882 | 11 | 11.98 | 12.82 |
| 28 | 0.59 | 1.79 | 3.28 | 4.91 | 6.56 | 8.171 | 9.688 | 11.08 | 12.33 | 13.43 | 14.37 |
| 27 | 0.66 | 2 | 3.68 | 5.5 | 7.36 | 9.162 | 10.86 | 12.42 | 13.83 | 15.06 | 16.12 |
| 26 | 0.74 | 2.25 | 4.13 | 6.17 | 8.25 | 10.27 | 12.18 | 13.93 | 15.5 | 16.89 | 18.07 |
| 25 | 0.83 | 2.52 | 4.63 | 6.92 | 9.25 | 11.52 | 13.66 | 15.62 | 17.39 | 18.93 | 20.26 |
| 24 | 0.93 | 2.83 | 5.19 | 7.76 | 10.4 | 12.92 | 15.32 | 17.52 | 19.49 | 21.23 | 22.72 |
| 23 | 1.05 | 3.17 | 5.82 | 8.7 | 11.6 | 14.49 | 17.17 | 19.64 | 21.86 | 23.81 | 25.48 |
| 22 | 1.17 | 3.55 | 6.52 | 9.76 | 13 | 16.24 | 19.26 | 22.03 | 24.51 | 26.69 | 28.57 |
| 21 | 1.32 | 3.98 | 7.32 | 10.9 | 14.6 | 18.21 | 21.59 | 24.7 | 27.48 | 29.93 | 32.03 |
| 20 | 1.48 | 4.47 | 8.2 | 12.3 | 16.4 | 20.42 | 24.21 | 27.69 | 30.82 | 33.56 | 35.92 |
| 19 | 1.65 | 5.01 | 9.2 | 13.8 | 18.4 | 22.9 | 27.15 | 31.05 | 34.56 | 37.64 | 40.28 |
| 18 | 1.86 | 5.62 | 10.3 | 15.4 | 20.6 | 25.68 | 30.44 | 34.82 | 38.75 | 42.2 | 45.16 |
| 17 | 2.08 | 6.3 | 11.6 | 17.3 | 23.1 | 28.79 | 34.14 | 39.04 | 43.45 | 47.32 | 50.64 |
| 16 | 2.33 | 7.06 | 13 | 19.4 | 25.9 | 32.29 | 38.28 | 43.78 | 48.72 | 53.06 | 56.79 |
| 15 | 2.62 | 7.92 | 14.5 | 21.7 | 29.1 | 36.2 | 42.92 | 49.09 | 54.63 | 59.5 | 63.67 |
| 14 | 2.93 | 8.88 | 16.3 | 24.4 | 32.6 | 40.59 | 48.13 | 55.05 | 61.26 | 66.72 | 71.40 |
| 13 | 3.29 | 9.96 | 18.3 | 27.3 | 36.6 | 45.52 | 53.97 | 61.72 | 68.69 | 74.81 | 80.06 |
| 12 | 3.69 | 11.2 | 20.5 | 30.7 | 41 | 51.04 | 60.51 | 69.21 | 77.02 | 83.89 | 89.77 |
| 11 | 4.13 | 12.5 | 23 | 34.4 | 46 | 57.23 | 67.85 | 77.61 | 86.37 | 94.06 | 100.66 |
| 10 | 4.64 | 14 | 25.8 | 38.6 | 51.5 | 64.18 | 76.08 | 87.02 | 96.85 | 105.5 | 112.88 |
| 9 | 5.2 | 15.7 | 28.9 | 43.2 | 57.8 | 71.96 | 85.31 | 97.58 | 108.6 | 118.3 | 126.57 |

$$Y(i,\ t)=16.07e^{-(0.1145t+0.098i)}t^{1.74}$$

**Table 3.** Estimation of Average Age of Eggs for Each Developmental Stage Age: hours

| SAMPL. TIME | EGG STAGES | | | | | | | | | | | ST. NO. | SURFACE TEMP. (°C) | 10 m TEMP. (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | | | |
| 4.92 | 1.0 | 3.0 | 5.5 | 8.2 | 11 | 14 | 16 | 19 | 21 | 22 | 24 | 27 | 25.9 | 23.5 |
| 5.42 | 0.9 | 2.7 | 4.9 | 7.3 | 9.8 | 12 | 14 | 17 | 18 | 20 | 21 | 28 | 26 | 24.5 |
| 14.98 | 0.9 | 2.8 | 5.2 | 7.8 | 10 | 13 | 15 | 18 | 19 | 21 | 23 | 37 | 25.4 | 24 |
| 15.60 | 0.8 | 2.4 | 4.4 | 6.5 | 8.7 | 11 | 13 | 15 | 16 | 18 | 19 | 38 | 26.2 | 25.5 |
| 15.97 | 1.1 | 3.4 | 6.2 | 9.2 | 12 | 15 | 18 | 21 | 23 | 25 | 27 | 39 | 26.5 | 22.5 |
| 2.05 | 1.1 | 3.2 | 6 | 8.9 | 12 | 15 | 18 | 20 | 22 | 24 | 26 | 48 | 26.2 | 22.8 |
| 13.50 | 0.7 | 2.2 | 4.1 | 6.2 | 8.3 | 10 | 12 | 14 | 16 | 17 | 18 | 64 | 27 | 26 |
| 14.48 | 0.8 | 2.5 | 4.6 | 6.9 | 9.3 | 12 | 14 | 16 | 17 | 19 | 20 | 66 | 27 | 25 |
| 22.17 | 0.9 | 2.7 | 4.9 | 7.3 | 9.8 | 12 | 14 | 17 | 18 | 20 | 21 | 106 | 27.9 | 24.5 |
| 19.83 | 0.7 | 2.2 | 4 | 6 | 8.1 | 10 | 12 | 14 | 15 | 17 | 18 | 143 | 29.1 | 26.2 |
| 23.42 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 145 | 27.5 | 26.8 |
| 23.80 | 0.7 | 2.1 | 3.9 | 5.8 | 7.8 | 9.7 | 12 | 13 | 15 | 16 | 17 | 146 | 27.5 | 26.5 |
| 0.27 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 147 | 27.7 | 27 |
| 6.83 | 0.7 | 2.1 | 3.9 | 5.9 | 7.9 | 9.8 | 12 | 13 | 15 | 16 | 17 | 204 | 26.5 | 26.4 |

Table 3. Continued

| SAMPL. TIME | EGG STAGES | | | | | | | | | | | ST. NO. | SURFACE TEMP. (°C) | 10 m TEMP. (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | | | |
| 7.75 | 0.8 | 2.4 | 4.4 | 6.5 | 8.7 | 11 | 13 | 15 | 16 | 18 | 19 | 205 | 26.8 | 25.5 |
| 15.08 | 0.7 | 2.1 | 3.8 | 5.7 | 7.6 | 9.5 | 11 | 13 | 14 | 16 | 17 | 215 | 28 | 26.7 |
| 3.83 | 0.7 | 2.1 | 3.9 | 5.8 | 7.7 | 9.6 | 11 | 13 | 14 | 16 | 17 | 226 | 26.6 | 26.6 |
| 4.60 | 0.7 | 2 | 3.7 | 5.6 | 7.4 | 9.3 | 11 | 13 | 14 | 15 | 16 | 227 | 26.9 | 26.9 |
| 5.02 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 228 | 26.9 | 26.8 |
| 12.00 | 0.6 | 1.7 | 3.2 | 4.8 | 6.4 | 8 | 9.5 | 11 | 12 | 13 | 14 | 242 | 28.8 | 28.2 |
| 13.65 | 0.6 | 1.7 | 3.2 | 4.7 | 6.3 | 7.9 | 9.4 | 11 | 12 | 13 | 14 | 246 | 29 | 28.3 |
| 14.25 | 0.6 | 1.7 | 3.1 | 4.6 | 6.1 | 7.6 | 9 | 10 | 12 | 13 | 13 | 247 | 29 | 28.6 |
| 3.62 | 0.6 | 1.8 | 3.3 | 4.9 | 6.6 | 8.2 | 9.7 | 11 | 12 | 13 | 14 | 266 | 28 | 28 |
| 4.05 | 0.6 | 1.8 | 3.3 | 5 | 6.6 | 8.3 | 9.8 | 11 | 12 | 14 | 15 | 267 | 27.9 | 27.9 |
| 5.00 | 0.7 | 2.2 | 4.1 | 6.2 | 8.3 | 10 | 12 | 14 | 16 | 17 | 18 | 268 | 27.7 | 26 |
| 7.63 | 0.8 | 2.3 | 4.3 | 6.4 | 8.5 | 11 | 13 | 14 | 16 | 17 | 19 | 269 | 26.7 | 25.7 |
| 22.25 | 0.6 | 1.8 | 3.4 | 5 | 6.7 | 8.4 | 9.9 | 11 | 13 | 14 | 15 | 293 | 28 | 27.8 |
| 6.02 | 0.6 | 1.8 | 3.3 | 5 | 6.6 | 8.3 | 9.8 | 11 | 12 | 14 | 15 | 307 | 27.9 | 27.9 |
| 6.67 | 0.6 | 1.8 | 3.3 | 5 | 6.6 | 8.3 | 9.8 | 11 | 12 | 14 | 15 | 308 | 27.9 | 27.9 |
| 7.37 | 0.7 | 2.1 | 3.8 | 5.7 | 7.6 | 9.5 | 11 | 13 | 14 | 16 | 17 | 309 | 27.8 | 26.7 |
| 11.43 | 0.6 | 1.9 | 3.6 | 5.3 | 7.1 | 8.9 | 10 | 12 | 13 | 15 | 16 | 313 | 27.5 | 27.3 |
| 15.87 | 0.6 | 1.9 | 3.6 | 5.3 | 7.1 | 8.9 | 10 | 12 | 13 | 15 | 16 | 321 | 27.8 | 27.3 |
| 16.27 | 0.6 | 1.8 | 3.3 | 4.9 | 6.6 | 8.2 | 9.7 | 11 | 12 | 13 | 14 | 322 | 28.5 | 28 |
| 21.50 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 330 | 27.5 | 26.8 |
| 23.67 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 334 | 27.4 | 26.8 |
| 3.25 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 340 | 27 | 27 |
| 3.83 | 0.7 | 2.2 | 4.1 | 6.2 | 8.3 | 10 | 12 | 14 | 16 | 17 | 18 | 341 | 27 | 26 |
| 4.50 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 342 | 27 | 26.8 |
| 5.03 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 343 | 27 | 27 |
| 7.25 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 344 | 27 | 27 |
| 7.83 | 0.7 | 2.1 | 3.9 | 5.8 | 7.8 | 9.7 | 12 | 13 | 15 | 16 | 17 | 345 | 27.2 | 26.5 |
| 8.52 | 0.7 | 2 | 3.7 | 5.6 | 7.4 | 9.3 | 11 | 13 | 14 | 15 | 16 | 346 | 26.9 | 26.9 |
| 8.97 | 0.7 | 2.1 | 3.8 | 5.7 | 7.6 | 9.5 | 11 | 13 | 14 | 16 | 17 | 347 | 26.8 | 26.7 |
| 9.50 | 0.7 | 2.2 | 4 | 6 | 8 | 9.9 | 12 | 13 | 15 | 16 | 17 | 348 | 26.5 | 26.3 |
| 10.08 | 0.7 | 2.1 | 3.9 | 5.9 | 7.9 | 9.8 | 12 | 13 | 15 | 16 | 17 | 349 | 26.5 | 26.4 |
| 10.60 | 0.7 | 2.1 | 3.9 | 5.9 | 7.9 | 9.8 | 12 | 13 | 15 | 16 | 17 | 350 | 26.4 | 26.4 |
| 11.17 | 1.9 | 5.7 | 10 | 16 | 21 | 26 | 31 | 35 | 39 | 43 | 46 | 351 | 26.5 | 17.9 |
| 3.67 | 0.8 | 2.3 | 4.2 | 6.3 | 8.4 | 11 | 12 | 14 | 16 | 17 | 18 | 358 | 27.1 | 25.8 |
| 23.50 | 0.7 | 2.1 | 3.9 | 5.8 | 7.8 | 9.7 | 12 | 13 | 15 | 16 | 17 | 364 | 27 | 26.5 |
| 0.38 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 365 | 27 | 26.8 |
| 3.25 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 367 | 27 | 27 |
| 5.50 | 0.7 | 2.2 | 4.1 | 6.1 | 8.2 | 10 | 12 | 14 | 15 | 17 | 18 | 371 | 26.2 | 26.1 |
| 16.42 | 0.7 | 2.2 | 4 | 6 | 8.1 | 10 | 12 | 14 | 15 | 17 | 18 | 381 | 26.9 | 26.2 |
| 18.53 | 0.7 | 2.1 | 3.8 | 5.6 | 7.5 | 9.4 | 11 | 13 | 14 | 15 | 16 | 382 | 27 | 26.8 |
| 18.98 | 0.7 | 2 | 3.7 | 5.6 | 7.4 | 9.3 | 11 | 13 | 14 | 15 | 16 | 383 | 27 | 26.9 |
| 19.55 | 0.7 | 2 | 3.7 | 5.5 | 7.4 | 9.2 | 11 | 12 | 14 | 15 | 16 | 384 | 27 | 27 |

## 4. Measurement of the total area of spawning ground

Egg densities calculated from each sample must be enlarged into the whole spawning area and the total daily egg production must be estimated. The information about the spawning area is indispensable to this estimation. To determine the representative area of each positive station, graphically a mid-distance line was put between two neighboring stations. Then an area was formed by four lines surrounding a positive station. We supposed the characteristics of a positive station was homogeneously held in this area.

The total area of positive stations was measured from a chart using a Polar Planimeter. In order to minimize the latitudinal scaling error, the sampling area was divided into two parts in north-sourth direction and were measured separately. Also the area coefficient were calculated respectively. The area coeff. of north region was 10.753 $km^2$ and the south was 10.233 $km^2$.

The total spawning area represented by positive stations ($A_P$) was:

$$A_P = U_N \times AC_N + U_S \times AC_S = 275 \times 10.753 + 1094.5 \times 10.233 = 1456.86 \text{ km}^2$$

where $U_N$=the measured value of the northern part.
$AC_N$=the area coefficient for the northern part.
$U_S$=the measured value of the southern part.
$AC_S$=the area coefficient for the southern part.

## 5. Estimation of the total daily egg production by EPM

In the case of the northern anchovy, spawning occurs within the fixed hours around 10:00 pm and this is incorporated in the fixed hours spawing model. In contrast, we found the Brazilian anchovy spawns all day long and there was no fixed spawning hour (Fig. 2 and Table 3). It is difficult to apply the northern anchovy model

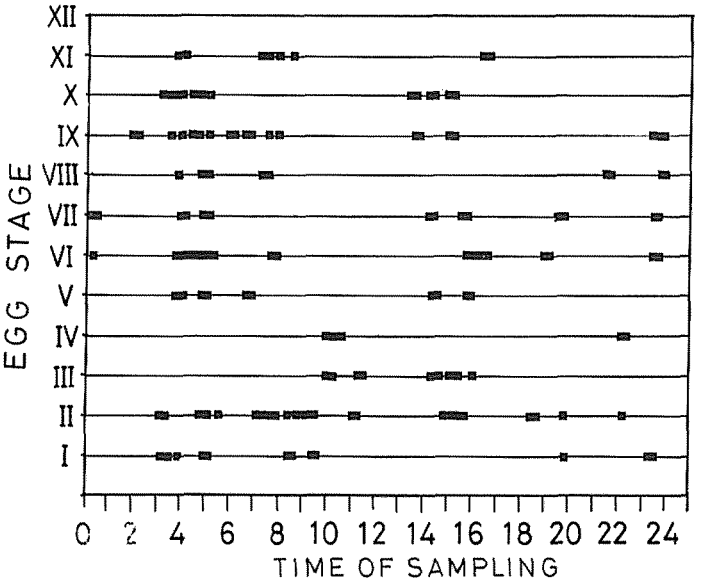


**Fig. 2.** Distribution of developmental stages of anchovy eggs in relation to the sampling time (hours).

itself for the estimation of the daily egg production per unit area of the Brazilian anchovy.

In order to estimate the DEP of the Brazilian anchovy, we used a non-linear regression analysis; putting ages of eggs at the abscissa and their frequencies to the ordinate for each sample. Assuming a constant mortality rate of eggs, a exponential function were fitted; $Y(T)=2.381e^{(-0.3486T)}$, where $Y(T)$=number of eggs and $T$=age (hours). The number of eggs at time 0, means the one at the instance of spawning. The reduction rate of this curve is considered as mortality rate during the embroynic period (Fig. 3). The DEP per unit area (=0.038 $m^2$) was estimated as 2.381 eggs. And the total daily mortality rate (=$Z$) was 0.3486 (Fig. 3).

The total DEP was estimated by following calculations:

Total spawning area ($A_P$): 14156.86 $km^2$
Daily egg production per unit area (0.038 $m^2$): 2.381 egg/0.038 $m^2$
Daily egg production per $km^2$ ($P_1$): 62657890 eggs/$km^2$
Daily egg production (whole area) ($P_A=P_1\times A_P$): $8.87\times10^{11}$
Daily mortality rate (=$Z$=$M$): 0.3486

Therefore, the average daily egg production of the Brazilian anchovy which was estimated by the EPM was $8.87\times10^{11}$.

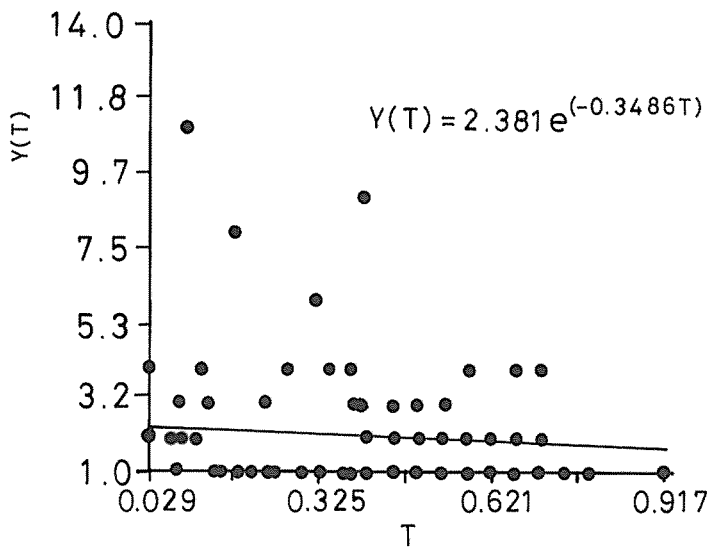


Fig. 3. Abundance of different ages of the Brazilian anchovy eggs. T: age (day), Y(T): number of eggs per unit area (0.038 $m^2$).

## Discussion

The estimated values of the DEP for the Brazilian anchovy were $8.87\times10^{11}$ egg/day by the EPM. We can point out many sources of possible error factors, e.g., unsuitable assumptions, the majority of parameter values from other anchovy stock and so on.

In the case of the northern anchovy, the DEP had the range of $12.98-26.36\times10^{12}$ egg/d (1980–1984)[1].

Though the spawning area of the northern anchovy at the California coast is wider than that of the Brazilian coast, we could consider our results to be fairly reasonable.

For the future estimation of stock abundance, it is indispensable to obtain biological parameters of adults, i.e., the batch fecundity, spawning frequency, proportion of female and etc.

## Acknowledgments

The EPM cruise was financed by the CIRM (Comissão Interministerial para Recursos do Mar) and was conducted under coordination of Dr. Carmen L. B. R. Wongtschowski. The senior author previewed a research fellowship of the CNPq to analyze the data of the EPM cruise. Also thanks are extended to the staff of the Ichthyoplankton laboratory, Oceanographic Institute of the University of São Paulo.

## References

1) PICQUELLE, S. and G. STAUFFER. Parameter estimation for an egg production method of northern anchovy biomass assessment. in An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish : Application to the Northern Anchovy, *Engraulis mordax* (ed. by R. LASKER, U. S. Dept. Commer., NOAA Tech. Rep. NMSF 36) p 7–15 (1985).
2) PRAGER. M. H., S. B. SAILA and C. W. RECKSIEK. FISHPARM: A Microcomputer Program for Parameter Estimation of Nonlinear Models in Fishery Science, Technical Report 87–10, Old Dominion University Research Foundation, Norfolk, p 1–37 (1987).
3) MOSER, H. G. and E. H. AHLSTROM. Staging anchovy eggs. in An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish : Application to the Northern Anchovy, *Engraulis mordax* (ed. by R. LASKER, U. S. Dept. Commer., NOAA Tech. Rep. NMSF 36) p 7–15 (1985).
4) AHLSTROM, E. H. Influences of the temperature on the rate of development of pilchard eggs in nature. Spec. Sci. Rep. U. S. Fish. Wildl. Serv., 15: 132–67 (1943).
5) LO, N. C. H. A model for temperature-dependent northern anchovy egg development and an automated procedure for the assignment of age to staged eggs. in An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, *Engraulis mordax* (ed. by R. LASKER, U. S. Dept. Commer., NOAA Tech. Rep. NMSF 36) p 43–50 (1985).

# ブラジル・カタクチイワシの日間産卵量

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ブラジル南部沿岸産カタクチイワシの日間産卵量を推定した。カタクチイワシ卵標本は1988年1月に Cal VET ネットを用いて採集した。卵の発生段階を調べ，採集場所の水温に基づき，産卵からそれぞれの発生段階に至るまでの時間を計算した。カタクチイワシ卵が採集された海域の表面水温は 25–29°C と高く，孵化は産卵後24時間以内に起こる。産卵は特定の時間帯にではなく，ほぼ終日にわたって行われている。横軸に卵の年齢（産卵からの経過時間）を，横軸に採集卵の年齢別頻度をとり，非線形回帰分析により指数関数をあてはめた。日間産卵量は $8.87\times10^{11}$ と推定された。