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Batch Fecundity and Spawning Frequency of Sailfish (*Istiophorus platypterus*) off the Pacific Coast of Mexico[1]

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ABSTRACT: To estimate batch fecundity and spawning frequency of the sailfish, *Istiophorus platypterus* Shaw & Nodder, off the Pacific coast of Mexico, gonads from fish sampled at five tourist ports from 1989 to 1991 were histologically analyzed. Mean batch fecundity, estimated by the gravimetric method, for 21 females was 1,710,000 ± 600,000 eggs per spawning. The relationship between batch fecundity in thousands (F) and total weight of the fish in kilograms (w) was $F = -245 + 61.68$ w. Of 93 mature females, 28% with hydrated oocytes indicated that the average interval between spawnings was 3.6 days.

IN THE EASTERN PACIFIC Ocean, sailfish (*Istiophorus platypterus* Shaw & Nodder) occur from Ecuador to the southern Gulf of California in Mexico. Their migration pattern along the coast has been related to the 28 °C surface isotherm (Ovchinnikov 1966, Kume and Joseph 1969*b*). Along the coast of Mexico, high catch indicates areas of high abundance (Polanco-J. et al. 1988, Squire and Muhlia-Melo 1993). Winter concentrations are found mainly in the Gulf of Tehuantepec. In summer and autumn, the distribution extends into the Gulf of California (Kume and Joseph 1969*a*, Shingu et al. 1974, Miyabe and Bayliff 1987).

Available evidence suggests that sailfish spawn near shore in the eastern North Pacific, with a northward progression of spawning activity during the year. Eldridge and Wares (1974) found that sailfish from the Gulf of California began to mature in late May and reached spawning condition in June and July. Hernández-H. and Ramírez-R. (1998) reported that the sailfish spawning season extended from summer to autumn off the Pacific coast of Mexico when sea surface temperatures ranged between 27 and 30 °C. Kume and Joseph (1969*b*) found ripe females from February to March in coastal waters off Costa Rica.

Beardsley et al. (1975) cited Merrett (1970), who found as many as 19.5 million eggs in sailfish from East African waters and pointed out that fecundity increased sharply with fish size. Jolley (1974, 1977), for the Atlantic sailfish, reported three groups of intraovaric oocytes based on the number of modes in the oocyte diameter distribution. Based on the count of hydrated oocytes, he estimated a batch fecundity of between 750,000 and 1,600,000 eggs per spawning. Eldridge and Wares (1974), counting oocytes with a diameter range between 0.9 and 1.3 mm, estimated fecundity of between 1,800,000 and 5,100,000 eggs for four females, eye-fork length range between 163 and 187 cm, from the Gulf of California. They found no indication of multiple spawning. DeSylva and Breder (1997), based on simultaneous appearance in the ovary of (1) empty follicles left behind by ovulated eggs, (2) ripe ova, (3) ova in which vitellogenesis was still in progress, (4) primary oocytes, and (5) oogonia,

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found Atlantic istiophorids able to spawn more than once during the spawning period.

According to Hunter et al. (1985) and Hunter and Macewicz (1985), to estimate batch fecundity in a multiple spawning fish it is necessary to find females with mature ovaries with hydrated oocytes, but without postovulatory follicles. Spawning frequency may be estimated from the frequency of ovaries containing hydrated oocytes, a stage that probably lasts no more than 12 hr, or of postovulatory follicles of known age.

Spawning frequency has been measured in other scombroid fishes. Schaefer (1987) used the incidence of black skipjack (*Euthynnus lineatus*) females with hydrated oocytes and estimated that the average intervals between spawnings were from 2.1 to 5.7 days in three different zones of the eastern Pacific. Hunter et al. (1986), Dickerson et al. (1992), and Schaefer (1996) used the frequency of females having ovaries containing postovulatory follicles to estimate the mean intervals between spawning of 1.8 days for *Katsuwonus pelamis* from the South Pacific, 12 days for *Scomber japonicus* in the Southern California Bight, and 1.14 days for *Thunnus albacares* near Clipperton Atoll in the eastern Pacific Ocean.

In this paper, our objectives were to estimate the batch fecundity and spawning frequency of sailfish from the Pacific coast.

MATERIALS AND METHODS

From 1989 to 1991, we sampled sailfish caught by sportfishing fleets at the Mexican tourist ports of La Paz, Cabo San Lucas, Mazatlán, Puerto Vallarta, Barra de Navidad, and Manzanillo, mainly from fishing tournaments. As they were landed at the wharf, each fish was weighed (kg) and measured (eye-fork length, cm). The body cavity was opened, the gonads excised and weighed to the nearest gram, and a subsample preserved in 10% neutral buffered Formalin. Eldridge and Wares (1974) showed no evidence of either cross-sectional or longitudinal variation in ova size within ovaries. In the laboratory, ovarian tissue samples were embedded in paraffin, sectioned at about 7 μm, and serial sections stained by Harris' hematoxylin followed by eosin counter stain (Humason 1979). The prepared slides were used for histological analysis to separate those females that fit the Hunter et al. (1985) criteria to determine batch fecundity, a mature ovary with hydrated oocytes but without postovulatory follicles.

For the estimation of batch fecundity, we used the gravimetric method based on counting hydrated oocytes in samples of known weight of ovarian tissue and extrapolating to the total ovary weight (Hunter et al. 1985). To determine the minimum weight of the gonad sample used to count oocytes, we used three mature gonads. From each one, we obtained 60 subsamples, the first three weighing 0.01 g, the next three 0.02 g, and so on until reaching subsamples with a weight of 0.2 g. Hydrated oocytes were counted in every subsample. For each weight group of three subsamples, an average was estimated and used to calculate batch fecundity. Estimations were compared and when there were no differences between batch fecundity values as the weight of the group increased, we took this as the minimum gonad sample weight.

After the minimum sample weight was determined, following McGregor (1957), for each female three gonad samples were obtained, drained for a few minutes on paper towels, and put on a microscope slide with a drop of glycerin covering the sample. Ova were teased out and spread into several rows. A second slide was then placed over as a cover and fastened at the ends with cellophane tape. Each sample was projected at a magnification of 1 mm = 23 μm and the projected oocytes were counted and measured. Batch fecundity for each female and the average value were obtained from the hydrated oocytes. To determine the relation between batch fecundity and the total weight, and the eye-fork length of the female, linear regression analyses were fitted.

To confirm that the sailfish is a multiple spawner, we analyzed the frequency distribution of diameter of the oocytes in some females with gonads with hydrated oocytes and used Bhattacharya's method for separating

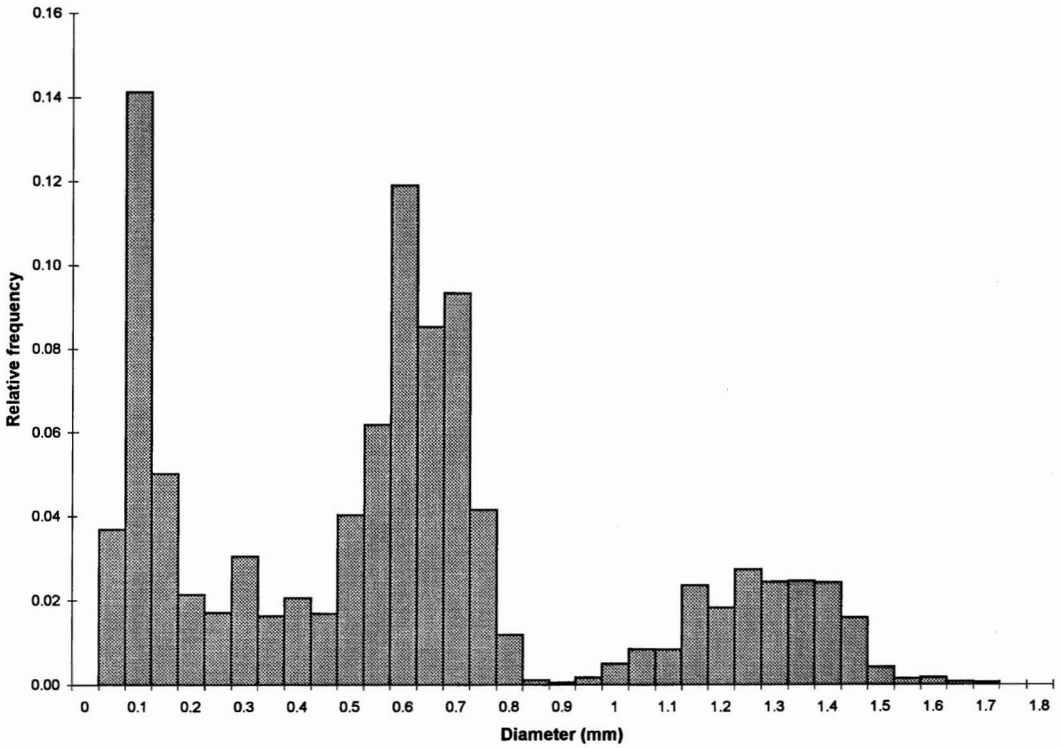

FIGURE 1. Oocyte diameter distribution in a mature gonad with hydrated oocytes.

modal groups using the routine of the FISAT program (Gayanilo et al. 1995). Because the gonads of each fish were not preserved immediately when the fish was caught, as was recommended by Hunter et al. (1986), it was not possible to determine the age of postovulatory follicles to estimate the spawning frequency. Following Schaefer (1987), a preliminary estimate of spawning frequency was derived from the proportion of mature females with ovaries containing hydrated oocytes during summer and autumn of 1991, when the percentage of mature females was high (Hernández-H. and Ramírez-R. 1998).

RESULTS

A total of 867 sailfish was sampled, of which 475 were females with an eye-fork length range of 131 to 203 cm. Only 21 of them fit the criteria for estimating batch fecundity (hydrated oocytes present without postovulatory follicles [Hunter et al. 1985]). These had an average eye-fork length of 174 cm (range 155 to 190 cm), an average total weight of 32 kg (range 23 to 45 kg), and an average gonad weight of 2.7 kg (range 1.2 to 5.0 kg).

The histological analysis showed that the 21 females had, in the same ovary, different generations of ripening ova, as was found by DeSylva and Breder (1997). This was reflected by the presence of three different modal groups determined by Bhattacharya's method. The first group had a mean diameter of 0.116 mm, the second 0.609 mm, and the third, which is clearly separate, 1.251 mm (Figure 1).

The minimum sample weight to estimate batch fecundity was 0.05 g. Average hydrated oocyte diameter was 1.28 mm with a range

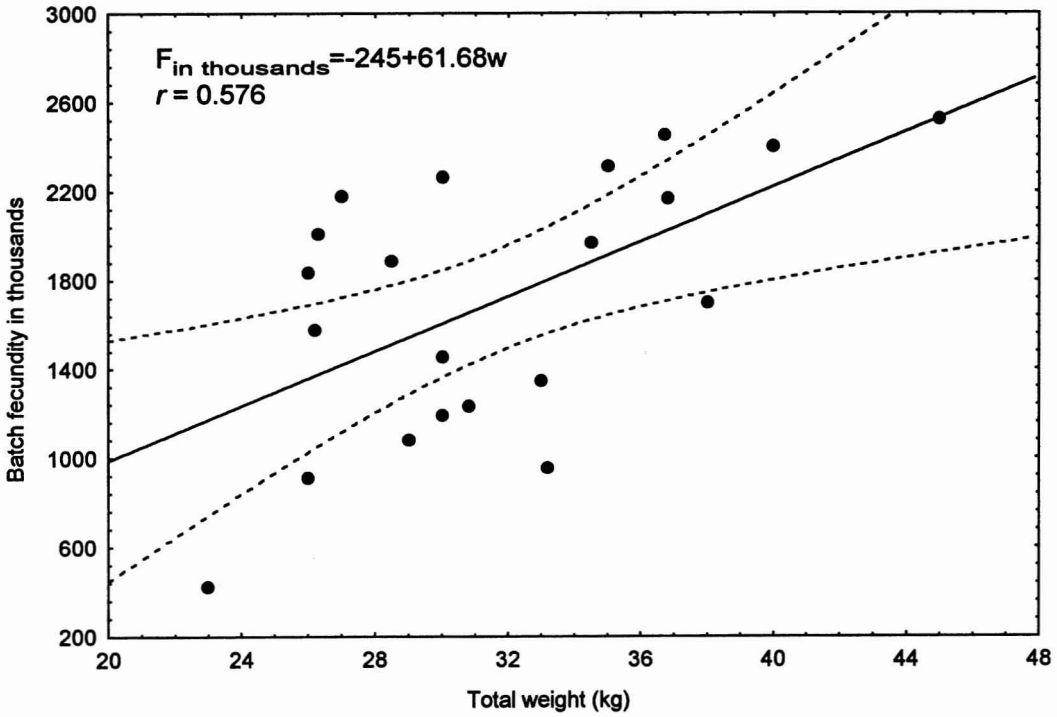

FIGURE 2. Relationship between batch fecundity values and total weight of females with 95% confidence interval (dashed lines).

of 1.11 to 1.41 mm. Results of the count of hydrated oocytes showed batch fecundity values between 420,000 and 2,520,000, with an average of 1,710,000 ± 600,000 eggs per spawning. Batch fecundity in thousands (F) was related to total weight (w) by the equation $F = -245 + 61.68$ w (Figure 2), determined by least squares linear regression ($r = 0.576$, $P < 0.05$). The linear regression analysis between batch fecundity and eye-fork length (cm) was not significant.

During summer and autumn of 1991, of 93 mature females an average of 28% was spawning per day, indicating that the average interval between spawning a new batch of eggs was 3.6 days.

DISCUSSION

The histological analysis showed the presence of different generations of ova in mature ovaries, evidence that sailfish in the study area can spawn more than once during a spawning season. This was not found by Eldridge and Wares (1974).

The length range of mature females sampled (155 to 190 cm eye-fork length) is similar to that reported by Eldridge and Wares (1974) for sailfish from the Gulf of California, but batch fecundity values (420,000–2,520,000 eggs per spawning) are around the minimum fecundity value reported by them (1,800,000 to 5,100,000 eggs per spawning). The difference may be because they did not separate oocyte modes and counted oocytes in different developmental stages. As reported by Jolley for the Atlantic sailfish (1974, 1977), we found three groups of intraovaric oocytes. Our batch fecundity values had a wider range than those of Atlantic sailfish (750,000 and 1,600,000 eggs per spawning) with an average value higher than the maximum observed in Atlantic sailfish.

The difference could be because the Atlantic sailfish studied were smaller (total weight range 17.2 to 33.4 kg) than Pacific sailfish.

Beardsley et al. (1975) cited Merrett (1970), who found that fecundity increased with size for sailfish from East Africa. We found a significant correlation between total weight and batch fecundity, but we did not find a correlation between eye-fork length and batch fecundity, perhaps because of the short range of lengths.

Our estimate of spawning frequency for the population of *Istiophorus platypterus* (3.6 days between spawning) is similar to that reported by Schaefer (1987) for *Euthynnus lineatus* (2.1 to 5.7 days between spawning). As reported by Hunter et al. (1986), we found gonads with postovulatory follicles that also had oocytes in the hydrated stage. If we assume for sailfish a similar length of time for oocyte development as was estimated for skipjack tuna, we can say that fish that had spawned <24 hr before were hydrating eggs that presumably would be spawned in <12 hr. This histological evidence suggests that the time between spawning could be less than 3.6 days.

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