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OVARIAN CYCLING IN LONGJAW GOBIES, *GILLICHTHYS MIRABILIS*, FROM THE SALTON SEA[1]

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The ovarian condition of the longjaw goby *Gillichthys mirabilis*, changes with the seasons in the Salton Sea. The protracted spawning period extends from December or January to June. Each female spawns more than once, and the population does not spawn synchronously. Regression of the ovaries starts by late June, and recrudescence begins in September or October. The timing of ovarian development at different localities in the lake varies slightly. Ovarian cycling appears to be correlated with temperature changes.

INTRODUCTION

Reproduction is one of the most important considerations in understanding the ecology of animals. The survival of any species in a seasonally unstable environment depends on the development of mechanisms that permit it to adjust physiological functions to changes in that environment. Reproduction would therefore be expected to occur during the season that assures maximum survival of young. Information on reproductive cycling (e.g., the schedule and duration of the breeding season) and the relation of this cycling to the environment is essential for understanding the biology of a species, and hence for intelligent management of a fishery.

Although teleosts form the largest group of vertebrates, knowledge of the breeding seasons and reproductive adaptations of these fishes is relatively limited. Due to this lack, meaningful comparisons of seasonal changes in the reproductive system of fishes are not possible, either within or between families. The majority of the species for which we have information on sexual cycles are freshwater fishes of the north temperate latitudes. Furthermore, data concerning adaptation of breeding schedules in widely distributed fish species are not presently available.

The family Gobiidae (Order Perciformes) has more than 700 species and is the largest family of fishes that is primarily marine (Herald, 1961; Böhlke and Chaplin, 1968). Gobies are widely distributed fishes that are mainly tropical. Most are small, carnivorous, lurking fishes dwelling on the bottom.

Although Breder and Rosen (1966) summarized reports on the time of spawning in several gobies, seasonal patterns of gametogenesis in

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this family are poorly known. Seasonal histological changes in the testes of *Gobius paganellus* were described by Stanley et al. (1965). Weisel (1949) briefly described seasonal spermatogenic changes in the longjaw goby from 47 males collected in seven different months near San Diego, California (32° 46′N). De Vlaming (1972) went on to follow seasonal changes in gonadal histology over a 4-year period in both sexes of the longjaw goby from a population in the Alviso salt ponds in California (37° 27′N); he also reported on reproductive changes in a population of this species occurring in Scammons Lagoon, Baja California (24° 47′N).

The longjaw goby occurs from central California south to Magdalena Bay, Baja California, and in the Gulf of California south to Mulege on the west coast, and south to Agiabampo Bay on the east coast (Barlow, 1963). The typical habitat of this species is the intertidal region of coastal sloughs. Commonly this is a muddy canal region exposed to air at low tide, but often it is an isolated marine-water pool. Barlow (1961, 1963) treated the systematics and some aspects of the ecology of the longjaw goby. It is an important bait fish because it can be transported out of water in moist algae, it tolerates fresh water and withstands being hooked, and it cannot reproduce in fresh water.

The intent of the present investigation was to describe seasonal ovarian changes in longjaw gobies collected from various locations in the Salton Sea (33° 18′N). These findings are compared with data obtained from populations at other latitudes.

MATERIALS AND METHODS

The Salton Sea is a large saline lake lying 235 ft below sea level in the Colorado Desert of southern California. It was formed in 1905–1907 by escaped irrigation water from the Colorado River, which flooded the dry Salton Sink (Sykes, 1937; Hubbs and Miller, 1948). The Salton Sea population of longjaw gobies presumably stems from 500 fish planted in 1930 by the California Department of Fish and Game; these fish were secured in San Diego Bay (Walker et al., 1961).

Monthly samples were obtained from September 1954 to June 1955. The fish were taken at three localities. Most were trapped within the boat landing at Fish Springs on the northwest side of the Salton Sea. Water there was uniformly about 2 m deep; the bottom was soft mud and the banks were broken concrete pavement. Large numbers of fish were seined at Salton Sea Beach on the west shore of the lake; this habitat, consisting of shore pools, has been described in detail (Barlow, 1958). Some fish were also collected at Bombay Beach on the eastern side of the lake. The hydrobiology of the Salton Sea has been carefully described by Carpelan (1958).

Body weight, standard length, and the volume of the right ovary were recorded for each female. Ovary volume was obtained by displacement in water. Fish used in these studies varied between 60 and 125 mm (standard length). To standardize ovarian weights, the following formula was used:

$$\frac{(\text{Ovary volume in ml})\ (1000)}{\text{Standard length in mm}}$$

This method was justified because a coefficient of + 0.627 ($p < .001$) was obtained in a correlation of ovarian volume and standard length from a group of 27 fish collected in January.

Ova diameters were also measured using an ocular micrometer. Ovarian condition was then classified according to the criteria described in Table 1.

TABLE 1—Criteria Used for Staging Ovaries of Longjaw Gobies

Stage	Characteristics
I	Regressing or regressed ovary. Ova being reabsorbed.
II	Early phase of ovarian development. Ova <0.5 mm in diameter.
III	Intermediate phase of ovarian development. Ova diameter measure 0.5–0.8 mm.
IV	"Ripe" or pre-spawning condition. Ova >0.8 mm in diameter.
V	"Spent" or post-spawning conditions.

RESULTS

Ovarian volume was low in September (Figure 1), and no yolky oocytes were present (Figure 2). Gonadal recrudescence was initiated in October and the ovaries were characterized by oocytes in Stages II and III. Ovarian development apparently started earlier at Bombay

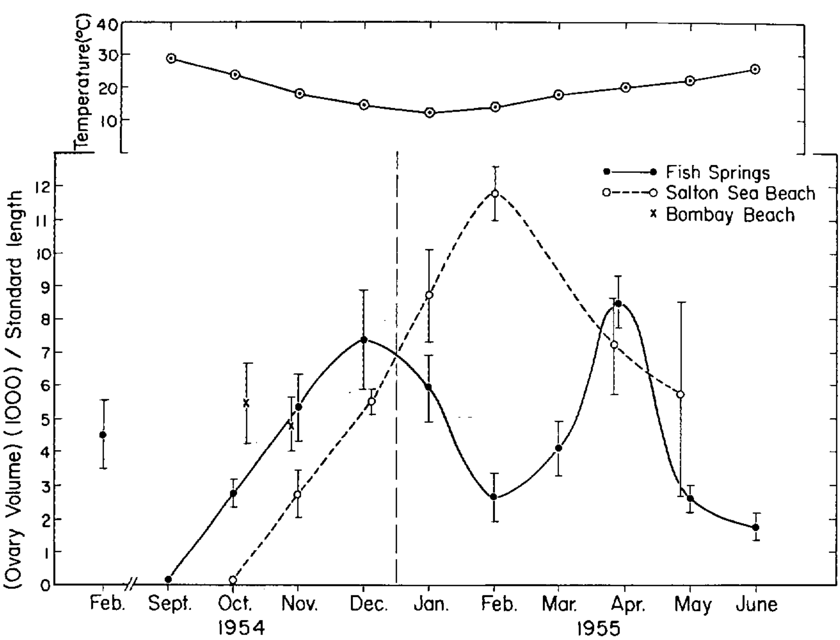

FIGURE 1—Seasonal variation in ovarian volume in *G. mirabilis* from the Salton Sea. Mean value (see text) is bracketed by ± one standard error of the mean. Temperature data presented in upper graph are modified from Carpelan (1958).

Beach than at Fish Springs; mean ovarian volume for Bombay Beach was greater than for Fish Springs (Figure 1), and more fish from Bombay Beach were in Stage III of oocyte development (Figure 2). Recrudescence had not been initiated in the Salton Sea Beach population in October.

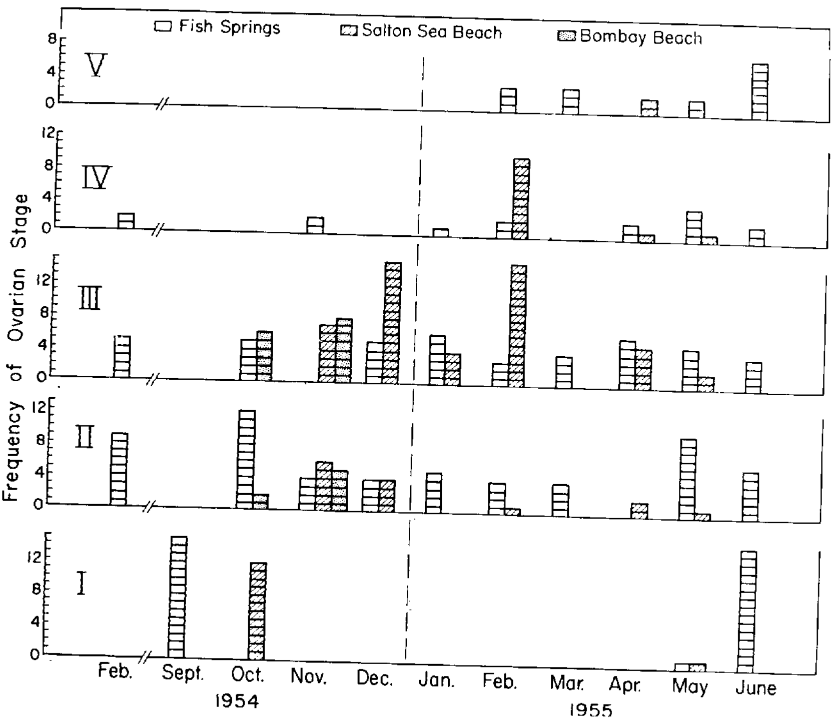

FIGURE 2—Seasonal variation in ovarian condition (see Table 1). Each cell represents one fish. Open cells = Fish Springs; cross-hatched cells = Salton Sea Beach; stippled cells = Bombay Beach.

By November some fish at Fish Springs were ripe (Stage IV). But ovarian development was not synchronous since other fish were in Stage II during that month. Recrudescence had been initiated in the Salton Sea Beach population, and oocytes were in Stages II or III.

Ovarian volume continued to increase in both the Fish Springs and Salton Sea Beach populations during December. Spawning at Fish Springs probably began in January and February; mean ovarian volume decreased sharply in February and "spent" females were found. That this population did not spawn as a unit is evident since females in various stages of ovarian development were collected during February. Spawning probably did not begin until late February; ovarian volumes were high in mid-February, and there was no evidence of "spent" individuals.

At Fish Springs ovarian volumes began to increase again in March, indicating that a large portion of the population was undergoing recrudescence following the first spawning. Some spawning, however, occurred during this month because "spent" individuals were collected (Figure 2).

By April, mean ovarian volume in the Fish Springs populations was again high (Figure 1) and some individuals were "ripe" (Figure 2). The second wave of spawning apparently began in March and April since individuals in the "spent" condition and various stages of development were caught in April.

The decrease in ovarian volume by mid-May (Figure 1) suggests that a large portion of the Fish Springs population spawned in late April and early May. Many of the fish at this time were "spent" and many were in early stages of ovarian recrudescence (Figure 2). In the Salton Sea Beach population, fish in various stages of ovarian development were obtained.

Spawning apparently continued through May and June in the Fish Springs population for many "spent" individuals were collected in mid-June. Fish in various stages of ovarian development were also taken, but gonadal regression had been initiated in several fish, and the reabsorption of yolky oocytes was in progress.

DISCUSSION

The spawning seasons of several gobies were summarized by Breder and Rosen (1966). A preponderance of species in this large family have short breeding periods. Some of the Pacific Ocean forms, however, have protracted spawning seasons comparable to that of the longjaw goby. Reproduction evidently extends from January to May in *Chaenogobius urotaenia* (Dôtu, 1955) and in *Chasmichthys dolichognathus* (Nakamura, 1936); *Pterogobius elapoides* spawns from December to March in Japan (Nakamura, 1936).

Longjaw gobies in the Salton Sea apparently spawn between December and June. Since fish in the pre- and post-spawning condition and in various stages of ovarian development can be collected during this period, spawning is not synchronous. Species in which ovarian development is asynchronous, as in the longjaw goby, normally spawn more than once per season and have an extended breeding season (Yamazaki, 1965). In longjaw gobies in the Salton Sea, reabsorption of yolky oocytes begins in June and is complete by September (and probably sooner).

There is usually a relatively simple relation between latitudes and breeding seasons of vertebrates in the temperate zones, the nearer the poles, the later the beginning of the reproductive season. Barlow (1963), however, suggested that spawning commences in January throughout the range of the longjaw goby. Weisel (1949) presented some evidence indicating that the breeding period extends from January to July in Mission Bay, near San Diego, California (32° 46′N). Longjaw gobies occurring in the Alviso salt ponds (37° 27′N), just south of San Francisco, California, spawn from December through June (de Vlaming, 1972). In the Scammons Lagoon population (27° 48′N) of longjaw gobies, however, gonadal regression occurs in May and June; furthermore, spawning begins in late September or early October (de Vlaming, 1972). Thus a January to June spawning period for the longjaw goby seems typical in the northern half of its distribution. But more southerly populations, especially in the Gulf of California, should be investigated before reaching a general conclusion relating time of spawning to latitude.

Most fishes occurring in the north temperate latitudes produce mature gametes during a relatively brief period of the year; a preponderance of these species attain their maximum gonadal weight in spring (Nikolsky, 1963). This is not the case in the longjaw goby. Prolonged spawning periods are mainly characteristic of tropical and subtropical species of fish (Nikolsky, 1963). The longjaw goby apparently reflects its gobiid ancestry in this respect, being presumably tropical in origin.

The nontypical protracted spawning period in this species of the north temperate latitudes might be facilitated by the environments in which it occurs. The typical habitat of longjaw gobies is the coastal slough with pools, canals, and flats (Barlow, 1963). These habitats are shallow and thus are warmer during spring and summer than the adjacent ocean at that latitude. Further, productivity in these estuarine habitats is probably high. High productivity over a large portion of the year could facilitate prolonged breeding. In similar estuarine habitats in Florida, *Fundulus confluentus* (Harrington, 1959) and *Hippocampus zosterae* (Strawn, 1958) show a breeding period similar to that of the longjaw goby.

This species possibly utilizes the nonreproductive season for growth and fattening (i.e., energy is channeled into growth or fattening rather than reproduction). For example, Walker et al. (1961) reported that growth of longjaw gobies is most rapid in the hot summer months. De Vlaming (1971), furthermore, presented evidence that longjaw gobies fatten in the nonspawning season and become more lean in the spawning season. Moreover, the interrupted breeding period of the longjaw goby may be due to adaptations which were necessary to occupy habitats in the north temperate latitudes where there is greater variability in availability of food.

Photoperiod and temperature are the most important (i.e., the most studied) environmental factors regulating teleost reproductive cycles (de Vlaming, 1972*b*). Correlations between phenological data and environmental changes provide some insight into this problem of the regulating factors.

Ovarian involution in longjaw gobies from the Salton Sea occurred as temperatures reached their annual maxima (Figure 1). Gonadal recrudescence took place as temperatures decreased in autumn. And spawning happened when temperatures were still relatively low. These data suggest that temperature plays an important role in regulating reproduction in the longjaw goby. Indeed, de Vlaming (1972*c, d*) presented evidence that temperature is the primary environmental factor controlling sexual cycling in this species.

Differences in temperature, in fact, may have been responsible for the variation in reproductive condition in the various local populations of the longjaw goby from the Salton Sea. Ovarian recrudescence began in October in the Salton Sea Beach population, but in September in the Fish Springs population. Fish from Bombay Beach were collected in the open lake, compared to the protected boat landing where fish were taken at Fish Springs. The relatively high ovary volume in the

October sample (Figure 1) from the Bombay Beach population could be due to an earlier onset of recrudescence which, according to de Vlaming (1972*c, d*) is a function of low temperatures. The fish from Salton Sea Beach were collected from shallow pools around the edge of the lake. Temperatures in these pools fluctuated more than in the adjacent lake, reaching much greater maxima and minima (Barlow, 1958). This might account for the differences in the curves for the samples from Salton Sea Beach and Fish Springs.

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