Observations on the Spawning of Mullet, *Crenimugil crenilabis* (Forskål), at Enewetak, Marshall Islands

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Abstract—The spawning of mullet, *Crenimugil crenilabis*, was observed in close proximity to the R/V ALPHA HELIX in Enewetak lagoon on the night of 25–26 June 1971. Prespawning behavior consisted of a dense school of 500 to 1500 individuals swimming rapidly in a counter-clockwise pattern near the surface in shallow water. This pattern persisted with occasional breaking of the school into two segments between 2030 and 0005 hr, at which time the mullet formed a single school and made a rapid explosive jump; it appeared as though the entire school broke the surface of the water after which dense clouds of released gametes were observed. The spawning behavior was repeated several times. Seventeen females (mean fork length 425.8 mm) and twenty-four males (mean fork length 389.5 mm) were sampled from the spawning school; all specimens were running ripe. The sex ratio did not differ significantly from the expected 1:1. Ovaries examined microscopically contained only fully developed ova, with estimated fecundity ranging from 195,000 to 897,000 ova per female.

Although mullet form the basis for important fisheries and are widely cultured for food, very little is known of their spawning habits. Oren (1971) has emphasized the importance of completing our understanding of the life cycle of mullet, so that this knowledge may be applied to their mass-propagation under artificial conditions. In the past, mullet culturists have been hampered by their dependence on an uncertain and variable supply of wild juveniles. Intensive research on induced spawning and controlled breeding of mullet has been conducted in Israel (Yashouv, 1969), Taiwan (Liao *et al.*, 1971) and Hawaii (Shehadeh and Ellis, 1970; Kuo *et al.*, 1973; Shehadeh *et al.*, 1973a, 1973b; *inter alios*). Thomson (1963, 1966) has summarized the published data on the biology of the Mugilidae. Most of the literature deals with the cosmopolitan *Mugil cephalus* Linnaeus, the only species for which well authenticated and detailed accounts of spawning have been published (Dekhnik, 1953; Arnold and Thompson, 1958). On the night of 25–26 June 1971, the authors observed mullet spawning near the R/V ALPHA HELIX which was moored to the end of the pier at Japtan Islet* in Enewetak

* Muti Islet on U. S. Dept. of the Interior Geological Survey, Professional Paper 260, chart 5.

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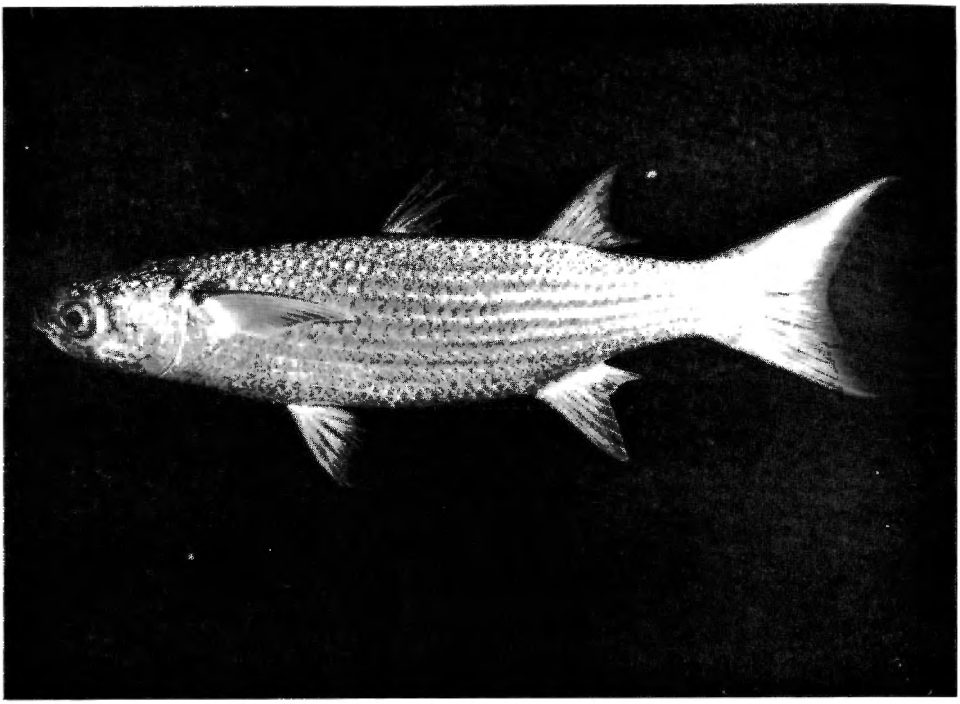

Fig. 1. *Crenimugil crenilabis* (Forskål) (Bernice P. Bishop Museum catalog no. 10887), male, 337 mm standard length, from Japtan Islet spawning aggregation.

lagoon. Specimens collected were subsequently identified by Dr. John E. Randall of the Bernice P. Bishop Museum as *Crenimugil crenilabis* (Forskål) (Fig. 1). Although this species is widely distributed in the tropical Indo-Pacific region, little is known of its biology. This report comprises the first record of spawning for *C. crenilabis*.

Shortly before noon on 25 June 1971, while skindiving in 4 to 6 m of water near the lagoon beach adjacent to the Japtan Islet pier, Allen observed a large school of adult mullet milling about over the sandy bottom. The fish were swimming well above the bottom and were not feeding. At approximately 2030 hr mullet were being caught with a hand scoop net from the side of the R/V ALPHA HELIX. A very dense school of mullet was observed to be swimming rapidly in a counterclockwise pattern just beneath the surface in an area between the stern of the vessel and the sandy beach approximately 50 m away. The vessel was tied with its starboard side to the end of the pier, with the aft portion and adjacent waters well illuminated by a number of large lights; the waters adjacent to the forward two-thirds of the ship were in shadow close to the vessel, but were well lit on each side of the ship 3 or 4 m out from the hull. The water adjacent to the vessel was about 5 m in depth with a gently sloping sand bottom. The water temperature was 28°C, the sea state calm, and typical of this area, the water was very clear. The

tide was ebbing, with high of 4.4 ft at 1718 and low of 1.0 ft at 2306 hr. A very light breeze was blowing and the sky was intermittently clear with occasional light passing showers of 3 to 5 min duration. The lunar cycle was in its first quarter, with the new moon having been on 22 June.

The mullet school maintained its position in the area of the starboard stern from 2030 to 2230 hr, occasionally drifting either toward shore or around the stern of the vessel. It was difficult to obtain an accurate estimate of the number of fish in the tight rapidly swimming school; various scientists aboard independently gave figures ranging from 500 to 1500 individuals. The school varied from 5 to 12 m in diameter. Observations were made from beneath the surface of the water with the aid of a face mask; the school was observed during the cyclonic swimming pattern to extend about 3 m below the surface, the bottom of the school never coming within 2 m of the sandy substrate. During this cyclonic swimming, the movement of individual fish was almost exclusively horizontal with no marked vertical motion. The swimming speed throughout the evening was estimated to be in excess of 3 knots. Roughley (1916) reported alleged spawning behavior of *M. cephalus* in Australia in which the fish swam near the surface "very close together and in a circle", and Kesteven (1942) recorded similar observations of mullet activity termed "ringing" by Australian fishermen.

During the initial period of observation several blacktip sharks, *Carcharhinus melanopterus*, were seen swimming rapidly through the school. Individual attacks did not persist for more than a few minutes, and each time the sharks passed through and scattered the fish, the school rapidly reformed and resumed the cyclonic swimming pattern. One severely wounded mullet was observed swimming slowly just beneath the surface following an attack on the school by several sharks.

The fish were estimated to be less than 5 cm apart in the school, and were so intent on their activity that they could easily be scooped from the water with a large dip net. Forty-one individuals were netted during the evening between 2030 and 2300 hr, and each fish was examined and measured within 5 min following its capture. It was obvious that the fish were in a running ripe condition; they all began to expel a stream of gametes soon after being brought on deck. The sex ratio of 17 females to 24 males did not differ significantly from the expected 1:1. There were no apparent morphological differences between the sexes, although females tended to be somewhat larger than males. Fork lengths of females ranged from 367 to 497 mm, with a mean of 425.8 mm; fork lengths of males ranged from 340 to 433 mm, with a mean of 389.5 mm.

A random sample of a few ova obtained from freshly captured females was examined. The ova were quite uniform in size, approximately 1.0 mm in diameter, containing a spherical yellow-orange oil globule 0.3 mm in diameter. The surface of each egg appeared to be finely etched or stippled. Eggs left standing overnight in glass containers of sea water had all settled to the bottom by morning. Sanzo (1936) reported that the eggs of *M. cephalus* are bouyant when shed, but

sink after fertilization. We were unsuccessful in attempts to fertilize the eggs of *C. crenilabis* with milt from freshly captured male fish. Arnold and Thompson (1958) reported a similar failure with eggs and sperm freshly stripped from running ripe *M. cephalus*.

By 2330 hr it was evident that the overall level of activity of the mullet school had increased considerably. The swimming rate had increased and the school had changed its swimming activity from the predominantly cyclonic to a more irregular pattern, with sweeps of large segments of the school around the stern of the vessel to the port side and then gradually around the entire vessel. During this period the school broke into two unequal segments which then swept together again after 3 to 5 min. Numerous kyphosid fishes in the water nearby remained undisturbed by this increased activity.

At 0005 hr on 26 June, when all individuals were in a single school, the surface of the water suddenly erupted in a frenzy of jumping, thrashing fish. This spectacular activity was of only 1 or 2 sec duration and was so sudden and violent that the behavior of individual fish within the school was very difficult to follow. There was no apparent crowding of several males around each female as reported by Breder (1940) and Arnold and Thompson (1958) for spawning *M. cephalus*. It appeared as though all individuals jumped from the water at the same instant in a general movement outward from the center of the school. Following this activity the school rapidly moved around the stern of the vessel, leaving an area of very cloudy water behind it. A surface sample was immediately taken from this area and was found to contain eggs identical to those obtained from captured females, at a concentration of 17 eggs per liter of sea water.

Between 0005 and 0200 hr, when the observations terminated, the jumping, thrashing behavior occurred every 5 to 10 min in various locations around the ship. On one occasion three distinct clouds of gametes were observed as the fish swam from the area immediately following the thrashing behavior. The nearby kyphosids immediately moved into the area and began to feed voraciously.

It was reported by those on watch during the night that by approximately 0345 hr the swimming speed of the aggregation had slowed and the fish appeared to show signs of fatigue. At that time three sharks again attacked the school. No further observations were made until 0800 hr on 26 June, at which time there were no signs of the school from the surface. Underwater reconnaissance of the area at 1500 hr on the same day did not reveal the school within a 300 m radius of the R/V ALPHA HELIX.

Eighteen male and eleven female specimens from the spawning school were frozen and saved for later examination of the gonads. Testes ranged from 13.2 to 40.8 g in weight, with a mean of 22.3 g; ovary weights ranged from 32.4 to 127.3 g, with a mean of 78.6 g. The ovaries examined contained only fully developed eggs. Fecundity was estimated on the basis of the number of eggs contained in aliquots taken from various regions of each ovary. Values obtained ranged from 195,000 to 897,000 eggs per female. Values reported for *M. cephalus*

have been somewhat higher; Jacob and Krishnamurthi (1948) recorded 1,320,000 eggs for a single specimen 50 cm in length, while Kesteven (1942) reported values ranging from 1,275,000 to 2,781,000 eggs per female.

The stomachs of the twenty-nine frozen specimens were also examined and all were found to be empty. Several authors (Ghazzawi, 1933; Kesteven, 1942; Thomson, 1951; Roughley, 1966) have reported empty stomachs for *M. cephalus* in spawning condition, suggesting that mullet may cease feeding during their spawning season. Mullet normally feed on microscopic plant and detrital material which they filter from bottom mud and sand.

After the departure of the R/V ALPHA HELIX on 29 June, Japtan Islet was revisited by Allen at irregular intervals throughout the remainder of the summer. No further spawning activity was observed; however, at about 1430 hr on 19 July a large school of mullet was again observed in the same area near the Japtan pier. During a period of 15 min observation the school milled about over the sandy bottom and, as before, none of the fish were engaged in feeding. Unfortunately it was not possible to remain at the site overnight to determine whether spawning ensued. On the basis of indirect evidence, several authors (Hildebrand and Schroeder, 1927; Kesteven, 1942; Gunter, 1945; Thomson, 1951; Broadhead, 1953; Anderson, 1958; *inter alios*) have concluded that *M. cephalus* spawns during the fall and early winter throughout most of its range. Our observations suggest that *C. crenilabis* spawns during the spring and early summer in the northern Marshall Islands.

Spawnings reported in the literature for *M. cephalus* have occurred at night offshore over deep water (Dekhnik, 1953; Arnold and Thompson, 1958). Our observations indicate that *C. crenilabis* also spawns at night, but in shallow water within atoll lagoons, at least in the northern Marshall Islands. The Japtan site may be a regular spawning ground for *C. crenilabis* in Enewetak lagoon. It is to be noted that spawning did not commence until shortly after the low-water slack period. Stroup and Meyers (1974) have shown lagoon water on either side of atoll passes to be drawn into the jet-like flow which may develop as a result of the penetration of ocean water into the lagoon during flood tide. A well developed flood-tide jet apparently occurs through the deep channel immediately adjacent to Japtan Islet at Enewetak; strong currents are often observed extending from this channel at least 3 to 4 km into the lagoon during flood tide. It may be speculated that the flood-tide jet system provides a mechanism by which fertilized mullet eggs are transported far into the atoll lagoon, thereby reducing the risk of eggs and larvae being swept out to sea. Personnel of the R/V ALPHA HELIX had observed mullet engaged in activity similar to that described in this report on several occasions, all at night, during the two months since the vessel had arrived at the Japtan site. Spawning of mullet was also alleged to have been observed near the SW end of Enewetak Islet, adjacent to another lagoon pass, by personnel stationed there. It was noted that juvenile mullet were often seen in the vicinity of the Japtan pier.

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