TECHNICAL PAPERS

Reproductive Cycles of Five Species of Texas Centrarchids[1]

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During 1941 and early 1942 data were taken from approximately 2,350 centrarchids from a group of 5 artificial lakes located in eastern Texas. The lakes, owned by a private hunting and fishing club, ranged in size from 75 to 650 acres. The species studied were the largemouthed black bass, *Huro salmoides* (Lacépède); the white crappie, *Pomoxis annularis* Rafinesque; the black crappie, *Pomoxis nigro-maculatus* (LeSueur); the bluegill, *Lepomis macrochirus* Rafinesque; and the redear sunfish, *Lepomis microlophus* (Günther). In this report attention is given to the reproductive cycles of the 5 species between March 1941 and March 1942. Restrictions on travel caused by the war terminated the research program at that time.

TABLE 1

OVARY WEIGHT/BODY WEIGHT RATIOS × 10^3 (GRAMS) FOR 5 SPECIES OF CENTRARCHIDS IN TEXAS DURING 1941 AND EARLY 1942

Date	Species				
	Large-mouthed bass	White crappie	Black crappie	Bluegill	Redear
Mar. 23	32.9 (9)*	56.2 (33)	61.0 (11)	— —	27.5 (4)
Apr. 6	33.8 (13)	29.3 (7)	44.3 (4)	30.3 (3)	62.6 (15)
" 20	30.8 (4)	25.2 (5)	14.3 (3)	41.0 (3)	69.1 (13)
May 10	9.7 (13)	5.9 (15)	5.5 (8)	28.3 (8)	26.8 (9)
" 31	3.8 (4)	— —	4.3 (7)	30.9 (8)	21.3 (7)
June 21	4.2 (9)	2.8 (10)	3.3 (4)	22.4 (5)	17.9 (18)
July 19	3.5 (4)	3.0 (1)	2.6 (3)	19.7 (13)	5.8 (13)
Aug. 29	2.4 (16)	2.5 (5)	2.8 (20)	14.6 (20)	5.0 (13)
Oct. 5	3.6 (7)	4.5 (9)	4.2 (21)	— —	— —
" 31	1.9 (2)	— —	— —	— —	— —
Nov. 18	2.4 (11)	— —	— —	— —	— —
Jan. 24	11.5 (26)	17.3 (14)	25.5 (15)	9.0 (2)	11.1 (11)
Mar. 1	8.3 (2)	— —	— —	14.4 (3)	14.4 (4)
" 18	21.5 (2)	28.1 (2)	40.7 (1)	5.6 (2)	11.6 (4)
" 28	38.6 (12)	— —	— —	22.8 (4)	49.5 (11)

* Figures in parentheses indicate frequencies.

All the data upon which this study is based were taken from fish caught by the club members and included material essential to the study of food habits and age and rate-of-growth determinations, as well as the reproductive organs. The viscera were preserved in a 5 per cent solution of formaldehyde. At a later time the ovaries were weighed to the nearest .1 gram, and the ratio of ovary weight/body weight multiplied by 10^3 was determined for 525 individuals. These ratios and the frequencies arranged according to the date of collection are presented in Table 1.

When presented graphically, as in Fig. 1, several interesting points are brought out with respect to the reproductive cycles of the species considered. If it is assumed that the period covered by the decline in the slope of the curve represents the spawning period for each species, considerable variation in the length of the spawning periods is evident. The bluegill population, for example, spawned well into September after reaching a peak of gonadal development around April 20. The largemouthed black bass, on the other hand, spawned from the middle of April until the end of May. The white and black crappie populations spawned from the latter part of March until the early part of May, while the redear sunfish held an intermediate position among the populations, the spawning period extending from around April 20 to the end of July. Expressed in terms of spawning intensity, it is also evident that in 1941 the maximum decline in the value of the ovary weight/body weight ratio for the bass, redear sunfish, and bluegill populations occurred approximately one month after the crappie populations showed their maximum decline in the value of the ratio. The mean air temperatures during the months of March and April in this locality were 53° and 67°F., respectively.

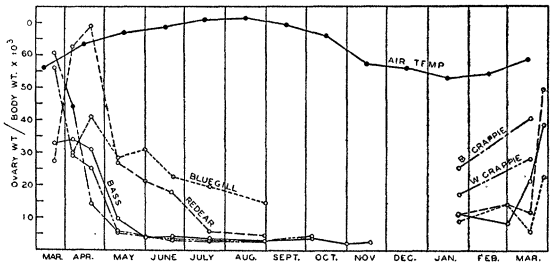

FIG. 1

Fig. 1 also indicates that the ovary weight/body weight ratio remains at a low level for several months, followed by a gradual and then abrupt increase in value. For example, in the largemouthed black bass population the ratio dropped from 30.8 in late April to 3.8 in the latter part of May and remained approximately at this level until the middle of November, beyond which point no data were available for 1941. The next collection, however, showed an increase in the ratio from the November low of 2.4 to the January level of 11.5, and an abrupt increase occurred during the month of March, when a high of 38.6 was attained. This abruptness in gonadal development was also evident in the redear sunfish population in both 1941 and 1942. The collections of January and March in 1942 also show the crappie populations to be ahead of the other species in ovary development. The

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mean monthly air temperatures for the first three months of 1942 were 46°, 49°, and 58° F., respectively.

Studies such as this, if carried on over an extended period of time to determine the degree of variation which undoubtedly exists in the length of the spawning periods, the periods of maximum decline in the ovary weight/body weight ratios, and the causes of such variation, would assist materially in providing a more scientific basis for the establishment of "closed seasons" if the evidence justified restrictive fishing measures.

Intercellular Surface Phagocytosis[1]

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Pathogenic microorganisms with protective capsules are ordinarily considered resistant to phagocytosis unless previously opsonized by specific antibody (*1*). Evidence has recently been presented that both encapsulated pneumococci (*3, 4*) and Friedlander's bacilli (*2*) are readily phagocyted in the absence of antibody by a mechanism referred to as surface phagocytosis. Direct visualization of this nonantibody form of phagocytosis in the lung has shown that the leucocytes phagocyte the encapsulated bacteria by trapping them against the surface of the tissue. Once taken into the cytoplasm of the phagocytic cells, the bacteria are rapidly killed (*2, 4*).

During experiments in which surface phagocytosis of Friedlander's bacilli in lung sections was being observed directly, phagocytosis was occasionally noted at some distance from the alveolar walls. The phagocytosis occurred whenever bacilli

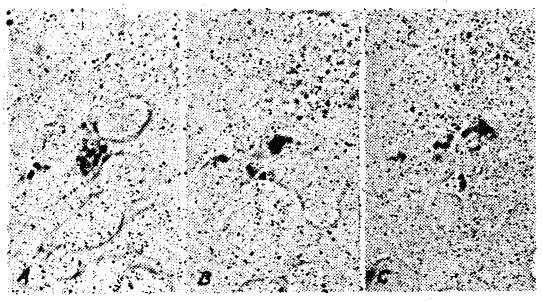

Fig. 1. Intercellular surface phagocytosis: (A) Leucocytes surrounding a group of encapsulated Friedlander's bacilli in a medium devoid of antibody (time, 2:10 P.M.); (B) Leucocytes have closed in on the bacilli so that they are trapped between the surfaces of the phagocytic cells (time, 2:23 P.M.); (C) The trapped bacilli have been phagocyted and can be seen in the cytoplasm of three of the leucocytes (time, 2:40 P.M.).

happened to get caught between the surfaces of two or more colliding leucocytes. On such occasions the surface of the adjacent leucocyte appeared to act in the same capacity as did the alveolar wall in the previously described form of surface phagocytosis. When the number of leucocytes in the phagocytic mixture was increased, the intercellular surface phagocytosis was noted frequently (see Fig. 1).

From these direct observations it appeared likely that intercellular surface phagocytosis would result whenever the concentration of leucocytes became such that the encapsulated bacteria could be readily trapped between two or more cells. To test this hypothesis, the following experiment was performed:

Friedlander's bacilli harvested from 2 ml. of a 4-hour broth culture (*2*) were suspended in gelatin-Locke's solution along with washed leucocytes obtained from the peritoneal cavities of 4 rats previously injected with starch aleuronat (*2*). The leucocyte-bacillus mixture was then concentrated by centrifugation (2,000 r.p.m. for 5 minutes), and as much supernatant fluid as possible was removed with a pipette and discarded. The concentrated mixture, which now contained a minimum of free fluid, was incubated for 30 minutes at 37° C., and smears of the mixture were stained with methylene blue. Examination of the smears revealed marked phagocytosis of the Friedlander's bacilli, whereas in control experiments, in which the leucocyte-bacillus mixture was not concentrated, little or no phagocytosis resulted.

Similar results were obtained with *Pneumococcus* Type I (A5 strain), *Pneumococcus* Type III (A66 strain)[2], and a mouse-virulent strain of *Staphylococcus aureus* (strain 235). Young cultures of each of these organisms resisted phagocytosis when incubated with leucocytes in dilute solution.

Intercellular surface phagocytosis of a number of pathogenic encapsulated organisms was thus brought about merely by diminishing the amount of fluid in the bacteria-leucocyte mixtures. Although the capsules protect the organisms against phagocytosis when the bacteria are floating freely in a fluid medium, they fail to protect them against surface phagocytosis when the latter occurs on a tissue surface or as a result of the intercellular mechanism just described. As previously stated, bacteria ingested by the nonantibody mechanism of surface phagocytosis are promptly killed by the phagocytic cells (*2, 4*).

The significance of intercellular surface phagocytosis in the mechanism of recovery in pneumococcal and Friedlander's bacillus pneumonias is indicated by the following considerations:

Although the earliest reaction of the lung to acute bacterial infection is the outpouring of edema fluid into the infected alveoli, this first stage is promptly followed by a rapid accumulation of leucocytes at the site of infection. The amount of edema fluid in the alveoli and bronchi diminishes, and the number of leucocytes present increases until the phagocytes are so numerous that they form the solid mass of cells characteristic of the advanced stages of pulmonary consolidation. Such a concentration of phagocytic cells eventually makes it virtually impossible for bacteria in the consolidated areas to escape surface phagocytosis. Those organisms that are not trapped against the tissue surfaces of the alveoli and bronchi are eventually phagocyted by being pinned between the surfaces of two or more of the crowded leucocytes. Thus, leucocytes in the lung may, through these two forms of surface phagocytosis, bring about destruction of even the most virulent encapsulated organisms, in the complete absence of immune bodies.

Conclusions: Encapsulated bacteria are phagocyted by leucocytes in the absence of opsonins, not only by being trapped against tissue surfaces but also by being caught between the surfaces of the phagocytic cells. Because large num-

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