Behavior of Shrimp in an Electrical Field[*] (Abstract)

JAMES B. HIGMAN

The Marine Laboratory, University of Miami,
Coral Gables, Florida

The response of pink shrimp, *Penaeus duorarum*, to pulsed direct current was investigated.

Shrimp were shown to respond to electrical stimuli by flipping tail first toward the positive pole.

Electrical conditions necessary to produce optimum response in shrimp are given.

Using these optimum conditions to calculate the power required to electrify a conventional shrimp trawl, it is shown that commercial shrimping with electricity is impractical at this time.

Comportamiento de lo Camarones en un Campo Eléctrico

JAMES B. HIGMAN

The Marine Laboratory, University of Miami,
Coral Gables, Florida

Abstracto

La reacción de los camarones rosados, *Penaeus duorarum*, a la corriente directa pulsada se investigó.

Al principio los camarones respondieron a estímulos eléctricos lanzándose con la cola hacia el polo positivo.

Condiciones eléctricas necesarias para producir el mejor efecto se dan en este manuscrito. Se usaron estas condiciones óptimas para calcular la fuerza requerida para electrificar una red de camarones de arrastre, y se ha demostrado que la pesca de camarones comercialmente por medio de electricidad no ofrece posibilidades prácticas en esta fecha.

Laboratory Experiments with Shark Repellents

STEWART SPRINGER

U. S. Fish and Wildlife Service,
Pascagoula, Mississippi

During the course of an investigation of shark repellents, one phase of the study was carried out at Woods Hole, Massachusetts, during the summer of 1942, on live dogsharks, *Mustelus canis*, held in tanks. The results of the study formed a basis for a continuation of the development of a shark re-

---

[*] To be published as a Technical Bulletin, Florida State Board of Conservation.

pellent. It is the purpose here to report briefly only on methods used in experiments with the live dogsharks in tanks, and on some of the conclusions that are of more interest to biologists than to those concerned with practical applications of shark repellents.

This experimental phase in the development of a repellent was carried out under contract to the Committee on Medical Research of the Office of Scientific Research and Development by Marine Studios, Inc., of St. Augustine, Florida, under the personal supervision of W. Douglas Burden as responsible investigator. Since quick results were essential and since no previous work had been done toward the development of a repellent, the first action was to cover the field as broadly as possible to find any chemical or physical means that would keep sharks from attacking men in the water. A great number of possibilities were set down as being worth some testing on dogsharks in tanks. With the late Arthur F. McBride, the writer was assigned to make a preliminary evaluation of these possibilities. It was soon found that the services of a chemist were required, and Dr. David Todd was added to the team.

A general design for experimental procedures was set up within a week after our arrival at Woods Hole, about the first of July. This was done after consultation with several people, and the primary consideration was expediency. It was apparent that a large number of dogsharks would be required because of the probable loss during experimentation through use of devices or materials injurious to dogsharks. Of course, practical considerations limited the kind of device or material to be tried to something reasonably safe for use by a man in the water.

Our collection and handling of the dogsharks in sufficient numbers would not have been successful except for the fine help given by the authorities of the Marine Biological Laboratory and the Woods Hole Oceanographic Institution, particularly Mr. James McInnis and Mr. William Schroeder. Throughout the period of planning and experimentation assistance was given freely by so many that listing them is impractical.

Laboratory Experiments

Suggestions given by experimentalists that very young dogsharks might give evidence of erratic behavior (see Parker, 1914, p. 64), inconsistent from day to day, and therefore unsuited to our purposes, proved correct. At least, all of our attempts to get reproducible results with dogsharks under 18 inches long failed. We did not collect a sufficient number of adult dogsharks for our work and nearly all of the sharks used in regular laboratory experiments were from 18 to 30 inches in total length.

The dogsharks were collected by hook and line fishing near the laboratory docks, and were transported to the laboratory in live cars. They were immediately transferred to holding tanks in the laboratory where running sea water was available. The supply of sea water remained within one degree of a constant temperature during the experimental period from July to Septemper and may have been an important factor in the success of experimentation. At least a subsequent attempt to repeat experiments at LaJolla, California, with a related species of *Mustelus,* failed, and a notable difference in the situation was a fluctuating temperature of the water supply.

The dogsharks at Woods Hole were kept in the holding tanks for a few days and were fed sparingly on pieces of fresh mackerel. Small sharks, sharks with apparent injury, or sharks that refused food for several days, were discarded. Lots of four to six individuals were selected for experiments and transferred to the experimental tank. The experimental tank, located in the basement of the Woods Hold Oceanographic Institution, was of wood, painted white inside, and about five feet wide by 15 feet long, with running sea water maintained at a depth of about three feet. The dogfish put into the experimental tank were fed regularly at ten o'clock each morning with one-inch square pieces of filleted fresh mackerel, placed on the outside of a wire mesh box, which was about a four-inch cube situated near an end of the rectangular tank. After it became apparent that the dogfish were feeding regularly and appeared to be in good physical condition they were used for experiments.

Parker and Sheldon (1913) and Field (1907) reported no success in getting *Mustelus* to feed in tanks and their experiments were undertaken in open pools. The explanation of our success in getting *Mustelus* to feed voraciously in tanks may be in the better water supply available in 1942 at Woods Hole. In retrospect, however, it seems more probable that our selection of uninjured fish that appeared alert and especially active may have been of paramount importance. Parker and Sheldon note that their *Mustelus* were caught in traps. Ours were taken on hook and line. Personal experiences in keeping marine fishes alive in tanks suggest that fish taken by hook and line, if not severely injured by the hook and if carefully handled, show less evidence of shock than trapped or netted fish. The above authors also kept *Mustelus* in a pool for a period of 10 days in order to bring about a state of hunger. Our fish, on the other hand, were offered food as soon as they reached holding tanks, although feeding often did not take place until the second or third day after capture.

At the beginning of our observations we found that our experimental group of dogfish would normally be swimming slowly on an elliptical course around the tank at the approach of feeding time and furthermore that spacing of the individuals was random, or about uniform. That is, the sharks did not exhibit a tendency to keep together as a group. We also found that a piece of mackerel sinking past their eyes did not interest them immediately and that a delay in reaction to the food could be explained on the assumption of an olfactory stimulation. Some experiments of Parker and Sheldon (1938, p. 39) using baits and blanks (pieces of rock) wrapped in seaweed were reproduced. The work of Budker (1938) indicating a gustatory stimulation in sharks through special receptors on the head was overlooked at the time, but shows that we were not correct in assuming that all of the stimulation initiating a feeding response by our experimental sharks was olfactory. However, the organ, or organs, through which a stimulus for feeding was received by our groups of experimental sharks was of less importance for our study than the fact that the stimulus was produced by diffusion of juices through the water, as shown not only by the work of Budker but by earlier experiments by Sheldon (1909), Parker (1914), and others. Later observations during field studies carried out by Springer and others, that several species of sharks characteristically bump floating inanimate objects with their snouts while searching for food, are easily explained if it is assumed that the shark is testing for juices that indicate the object is edible.

We found by watching our experimental groups after food (always a one-inch square of mackerel fillet) had been put inside of the wire cage and placed in the tank, that the reactions of the dogfish could roughly be classified by the apparent intensity of their response. The first response of each shark after apparent first detection of the presence of food was an abrupt turn out of the normal elliptical course around the tank into a tight circle around the food. We called this a hunting turn, although it probably is the normal response to any stimulus leading to investigation on the part of the shark. Frequently the shark would return to the elliptical course around the tank without an attempt to close in on the bait, but sometimes would approach and bite the wire mesh box, or even pick it up and shake it.

Since it was necessary to determine the effectiveness of a great many materials, at least on a comparative scale, a kind of biological assay was set up to compare the effectiveness of various substances in stopping the feeding of our dogfish. To do this we arranged a series of tests, each test to run for ten minutes. The first test and alternate tests thereafter were made using a piece of mackerel inside the wire box. The second test and alternate tests thereafter were made with a piece of mackerel inside the box in addition to the material being tested. A rest of ten minutes or more was allowed between each test and the wire box with its content was removed from the water at the end of each test. Fresh food was used for each test. The turnover of water in the tank during the period between tests was far from complete and the accumulation of dissolved materials from the food and from the materials being tested probably were sources of error. For each test one or two observers who had watched the dogsharks long enough to recognize them as individuals were given score cards. They were told to score numerically the results at the end of each minute on the entirely arbitrary basis of one for each hunting turn made by any dogshark during that minute, two for any dogshark biting the wire box, and five for any dogshark picking up the box and shaking it.

The figures were convenient because the total for a ten minute test using food alone was always a figure near 100, and because the results were reasonably consistent from day to day with different observers. The figures also were convenient because by comparing the figure for any given substance being tested with the mean of the preceding and following tests which were always made with food alone, we could arrive at a figure which we regarded as the percentage of effectiveness for that particular series of tests.

There were several interesting trends in these test series. Testing was ordinarily started at ten in the morning and a series of tests were made without interruption except for ten minute rest periods. The values obtained for controls; i.e., for tests with food alone, increased regularly for one to two hours and then decreased. The increase, reflecting increasing response on the part of the dogsharks, normally reached a figure about 20 per cent higher than the starting figure. Ordinarily we stopped testing for the day after figures for control tests returned to the starting figure. Only once were the tests continued beyond this point. On that occasion, reached about four hours after the testing started, the dogsharks' responses became very weak so that there was no sharp distinction between controls and tested materials.

In each 10 minute test with food alone or in each test of materials relatively ineffective in inhabiting feeding, the greatest scores were obtained during the third or fourth minute and again between the seventh and ninth minute. That is, during each test period there were two flurries of attack on the food in which all of the experimental group of dogsharks took part. Whatever the explanation, the pattern is similar to attacks by groups of predators. Tests with feeding inhibitors present were characteristically without flurries of concerted attack. Our method permitted the comparison of a large series of materials for effectiveness in stopping the sharks from feeding.

High and low frequency sounds, fish poisons such as rotenone, irritants such as chlorine, metallic poisons, chemical stenches, and poison gas generators were tried on our experimental groups of sharks, with no success. A great many of our sharks were killed, but either the amount of material required to protect the food was excessive or the sharks ate or tried to eat the food before dying, or while dying. It became evident that we needed a substance that would be effective even in very small concentrations.

In general, our tests indicated that almost any substance even slightly soluble in sea water, and not a food, reduced the feeding responses of the dogsharks. A few substances were neutral or even slightly attractive. Very few substances strongly reduced the responses. Several of the organic acids, notably maleic acid and malic acid occasionally inhibited feeding completely but results were not consistent. The most consistent results were obtained by use of shark flesh allowed to stand at 20° centigrade for four to six days, and with small concentrations of copper salts. Ethyl alcohol extracts of four to six-day-old shark flesh inhibited the dogshark feeding responses, but the results with extracts were not so dependable as those with shark flesh.

General Observations from Experimental Procedures

The importance of the use of dogsharks that had become adjusted or conditioned to the tank environment was obvious throughout this experimentation. By the use of properly conditioned dogsharks of sufficient size a predictable behavior pattern in the presence of food was observed. No material was found that in small concentrations had such an obviously irritant effect as to drive the sharks away from the food. However, it was observed that many soluble materials inhibited the feeding responses of the dogsharks. Considerable difficulty in obtaining consistent results with feeding inhibitors was encountered, perhaps due to the complications of diffusion of complex chemical materials in sea water. Consistent results were obtained by the use of shark flesh that had been allowed to stand for four to six days at room temperature. This material inhibited all feeding responses.

The test procedures indicated that all responses of the experimental sharks to the presence of food were initiated by the diffusion of juices in the water affecting either or both the olfactory or gustatory organs. However, there were also indications that a secondary stimulus, provided by a change in the rate of movement of the first shark turning on the food, produced a group response resulting in concerted attacks.

LITERATURE CITED

1938—BUDKER, PAUL, Les cryptes sensorielles et les denticules cutanes des Plagiostomes. Ann. Inst. Oceanog., vol. 18, pp. 207-288, pl. 1.

1914—PARKER, G. H., The directive influence of the sense of smell in the dogfish. Bull. U. S. Bur. Fisheries, Document 798, pp. 63-68.

1913—PARKER, G. H., and SHELDON, R. E., The sense of smell in fishes. Bull. U. S. Bur. Fisheries, Document 775, pp. 35-45.

Experimentos en el Laboratorio con Repelentes de Tiburones

STEWART SPRINGER

U. S. Fish and Wildlife Service, Pascagoula, Miss.

Abstracto

Se describen los metodos usados en experimentos hechos en el laboratorio con tiburones vivos, *Mustelus canis* con énfasis en la descripción del procedimiento usado en la colección de los tiburones en Woods Hole, Mass. en el verano; también se describen los métodos de acondicionamiento de los tiburones para trabajos experimentales. Se hicieron ensayos biológicos de la eficacia de varias substancias que inhiben la alimentación de los tiburones.

Some Problems Concerning the Management of the Shrimp Fisheries

MILTON J. LINDNER

Technical Advisor, Fisheries, U. S. Foreign Service, Mexico, D. F.

The purpose of this paper is to point out some of the problems encountered in management of the shrimp fisheries. For orientation purposes, a few general statements about shrimp fishing in estuarine waters, and overfishing will be mentioned.

Although natural conditions, such as severe freezes, like the one of January 1940, may cause a sufficient reduction in spawning individuals to affect the crop produced, we have not seen any indication where trawling at sea can do this. Apparently, up to now, fishing becomes unprofitable before the numbers of spawners can be reduced sufficiently to affect the crop produced by these spawners. Consequently, if a depleted level is defined as the point below which there is a direct relation between the number of spawners and the resultant crop, it is not necessary, under present conditions, to fear depletion in the shrimp fishing.

The environmental requirements of different species of shrimp are quite distinct. The white shrimp, *Penaeus setiferus*, is rarely found in depths greater than 35 fathoms, whereas the brown shrimp has been taken at around 100 fathoms. The white, and probably the brown and pink shrimp in the Gulf of Mexico require an estuarine phase early in their lives. On the west coast of Mexico we find that *P. stylirostris and P. vannamei* seem to require an estuarine phase, but that *P. californiensis* may not require more than a coastal phase and, perhaps, *P. brevirostris* spends its entire life at sea.

Tagging experiments have shown that there are separate and distinct stocks of white shrimp. It is likely that there are also distinct stocks of pink and brown shrimp. As a consequence, it seems evident that shrimp cannot be treated as a unit when we consider their management. Probably each species and each stock of a species will have to be treated as a separate entity.