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A mathematical model capable of explaining and predicting changes in shrimp catch is one of the objectives of research at the Galveston Laboratory.

Gulf of Mexico Shrimp Resource Research

CHARLES W. CAILLOUET, JR., and KENNETH N. BAXTER

ABSTRACT

This paper describes shrimp resource research presently being conducted by the Galveston Laboratory of the National Marine Fisheries Service Gulf Coastal Fisheries Center. Discussed are plans for development of a mathematical model capable of explaining and predicting changes in shrimp catch, and on-going mark-recapture experiments, prediction of catch, stock identification studies, and study of spawning grounds. Trends in Texas and Louisiana brown and white shrimp catches and catch rates are presented.

INTRODUCTION

Shrimp resources of the Gulf of Mexico are the most valuable fishery resources of the United States. In 1972, Gulf coastal waters of the U.S. yielded 144 million pounds of shrimp (heads-off) with a dockside value of $165 million. The Gulf shrimp fisheries continue to expand, and improved management techniques will be required to assure perpetuation of the resources and to avoid overexploitation.

This paper describes shrimp resource research presently being conducted by the Galveston Laboratory of the NMFS Gulf Coastal Fisheries Center. The main objective of this research is to develop a mathematical model capable of explaining and predicting changes in shrimp catch. A systems analysis approach (Watt, 1966, 1968; Patten, 1971) is being used to develop the model. Such a model would be of considerable use in guiding management decisions. Though the research is concerned with brown shrimp *(Penaeus aztecus)*, white shrimp *(P. setiferus)*, pink shrimp *(P. duorarum)*, and other commercial Penaeidae in the Gulf of Mexico, it is concentrated initially on brown and white shrimp in Texas and Louisiana.

LIFE CYCLE, ENVIRONMENT, AND FISHERIES

The shrimp life cycle and its interactions with environmental variation and shrimp fisheries represent a continuous and highly dynamic system that varies in time and space. For the most part shrimp resources are renewable annually. Shrimp are short-lived animals with a life cycle consisting of oceanic and estuarine phases (Figure 1). Marked fluctuations in the size of shrimp populations can probably be induced by yearly differences in spawning success and survival of young which depend to a large extent on biological and physical environmental conditions.

In addition to being vulnerable to natural mortality at all stages of their life cycle, shrimp begin to enter the catch as juveniles, and they are heavily exploited thereafter by inshore and offshore fisheries which are major competitors for shares of each shrimp crop (Figure 2). The degree to which catch from a given shrimp crop is influenced by allocation between these and other users (domestic sport fishermen and foreign vessels) is unknown. Furthermore, a varying proportion of the catch of small shrimp by the offshore fishery is wasted by being discarded at sea or in port for legal, economic, and other reasons.

RESEARCH IN PROGRESS

Gulf Coast Shrimp Data

As an initial step toward development of the model, we have begun preparation of the Gulf Coast Shrimp Data (from Division of Statistics, NMFS) for computer processing. Published monthly summaries of catch (by species, size class, area, and depth) and fishing effort (trips and days, by area and depth) for the years 1956-1972, are being transferred to punched cards. Kutkuhn (1962) has described many of the limitations of these data.

Mark-Recapture Experiments

A mark-recapture method using short-term sequential sampling is being tested to estimate population size, fishing mortality, other losses (natural mortality, emigration, marking mortality), and immigration of shrimp in tidal marsh ponds. It is anticipated that this or similar methods eventually will be tested in large areas where commercial and recreational shrimp trawling occurs. Such methods depend upon a decrease in the population of marked and unmarked animals caused by fishing during the course of the experiment.

Charles W. Caillouet, Jr., joined the staff of the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, in 1972. Kenneth N. Baxter, also a member of the Galveston staff, has conducted research on various life history stages of shrimp for 15 years. This paper is Contribution No. 365 from the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. 77550.

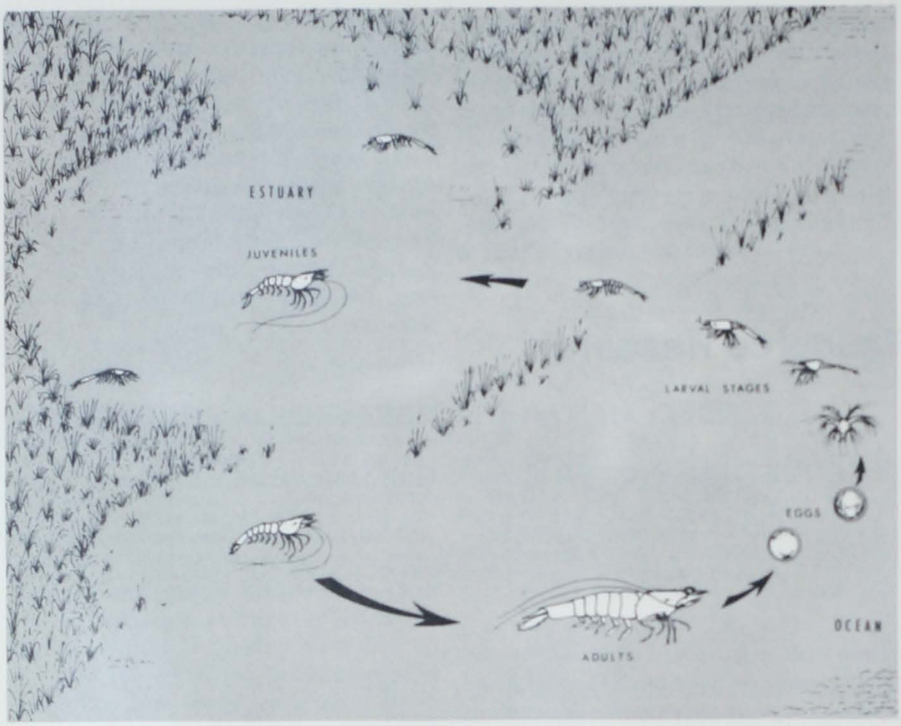

Figure 1 —Life cycle of shrimp (*Penaeus* spp.).

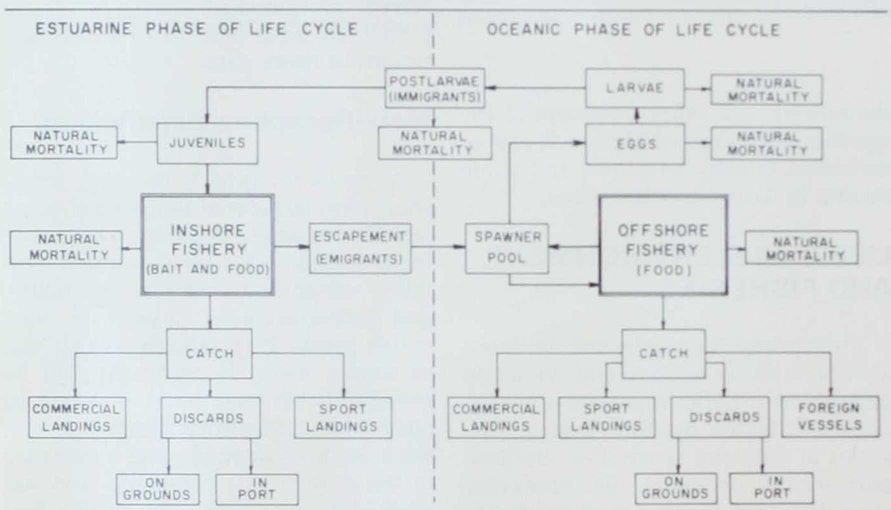

Figure 2.—Relationships among components of the life cycle of shrimp (*Penaeus* spp.) and components of the inshore and offshore shrimp fisheries.

Prediction of Catch

Indices of abundance of postlarval and juvenile shrimp have been used for more than a decade as predictors of shrimp catch (Berry and Baxter, 1969). Sampling of postlarval and juvenile shrimp in Galveston Bay is continuing for this purpose. The juvenile index (catch of brown bait shrimp/hour) for Galveston Bay has been an especially good predictor of offshore catch of brown shrimp in Texas waters (Table 1, Equation 1). Offshore and inshore annual catches are also correlated.

Based on annual summaries of Gulf Coast Shrimp Data, offshore catches have increased as inshore catches increased for both brown and white shrimp in Texas and Louisiana (Table 1). In other words, good shrimping years usually produced high catches offshore and inshore, and poor shrimping years usually produced low catches in both areas. The low correlation (Table 1, Equation 2) obtained for the relationship between offshore and inshore brown shrimp catch in Texas is probably due in part to legal limitations on inshore shrimping in Texas.

Spawning Grounds

An attempt is being made to determine if abundance of adult shrimp in certain areas offshore is related to chemical characteristics of recent bottom sediments. Grady (1971) has shown that shrimp abundance is greater in areas where sediments contain high concentrations of organic carbon. It is known that the ovaries of female shrimp do not ripen until the animals leave the estuaries, and this ripening seems largely a matter of deposition of yolk in the eggs (Caillouet, 1973; Lee and Lee, 1970). It is likely that female shrimp obtain lipids required for yolk synthesis from a diet of materials from these sediments. The sediments also might contain materials (hormone analogs) that stimulate ripening of ovaries. Among the food items that would be expected to occur in recent sediments would be phytoplankton. Diatoms have been shown to contain lipids which are assimilated rapidly by shrimp (Condrey, Gosselink, and Bennett, 1972).

Research plans include identification of lipids in shrimp ovaries and in the recent sediments on the offshore spawning grounds. Ovarian lipids of pink shrimp have already been identified (William Gehring, University of Miami, Florida, personal communication), and our analyses are being conducted on brown and white shrimp. Stage of ovarian development in samples of brown and white shrimp is also being determined.

Stock Identification

To determine whether or not separate stocks of a species can be identified by zone electrophoresis of protein extracts, various tissues from brown

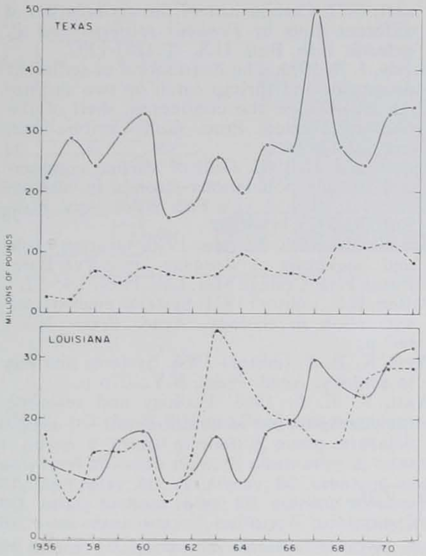

Figure 3.—Changes in annual catch (millions of pounds, heads-off) of brown shrimp (solid line) and white shrimp (dashed line) in Texas and Louisiana (Mississippi River to Texas).

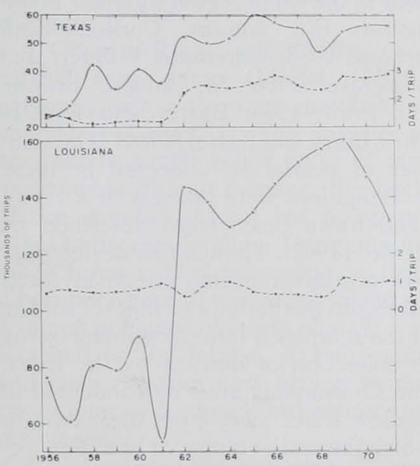

Figure 4.—Changes in annual fishing effort (thousands of trips, solid line) and annual number of days per trip (dashed line) in Texas and Louisiana (Mississippi River to Texas). (Note: Thousands of trips x days per trip = thousands of days, to estimate annual fishing effort in terms of days of fishing.)

Table 1.—Least squares regression relationships between offshore and inshore catches of brown and white shrimp in Texas and Louisiana (Mississippi River to Texas)[1]

Equation No.		Definition and Range of Variables Y and X	Least Squares Regression Equation and Correlation Coefficient, *r*
1	*Y*	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 15,345,700-48,526,900)	$\hat{Y}=9{,}959{,}700+356{,}200X$ $r=0.85$
	X	Average Weekly Catch (pounds, heads-on) per hour of brown (bait) shrimp in Galveston Bay, Texas (based upon the period April 25-June 12 each year) (range:18-91)	
2	*Y*	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 15,345,700-48,526,900)	$\hat{Y}=23{,}593{,}700+3.6231X$ $r=0.28$
	X	Annual Inshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 9,700-1,853,500)	
3	*Y*	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Louisiana (range: 2,129,900-17,659,500)	$\hat{Y}=2{,}767{,}500+0.8136X$ $r=0.73$
	X	Annual Inshore Catch (pounds, heads-off) of brown shrimp in Louisiana (range: 2,793,600-16,073,900)	
4	*Y*	Annual Offshore Catch (pounds, heads-off) of white shrimp in Texas (range: 405,600-6,479,800)	$\hat{Y}=1{,}636{,}500+0.6576X$ $r=0.58$
	X	Annual Inshore Catch (pounds, heads-off) of white shrimp in Texas (range: 782,200-6,072,300)	
5	*Y*	Annual Offshore Catch (pounds, heads-off) of white shrimp in Louisiana (range: 3,823,800-20,601,900)	$\hat{Y}=3{,}446{,}300+1.4105X$ $r=0.86$
	X	Annual Inshore Catch (pounds, heads-off) of white shrimp in Louisiana (range: 1,748,500-13,793,600)	

[1] Equation 1 is based upon data from 1960 to 1972, and all other equations are based upon data from 1956 to 1971.

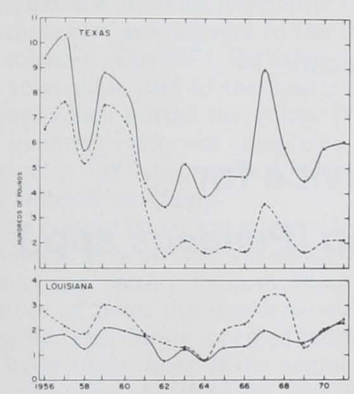

Figure 5.—Changes in annual catch per day (dashed line) and annual catch per trip (solid line) for brown shrimp in Texas and Louisiana (Mississippi River to Texas). Catch rates are expressed in hundreds of pounds, heads-off.

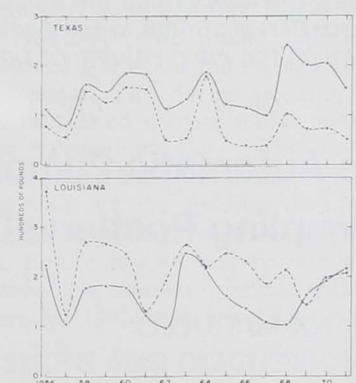

Figure 6.—Changes in annual catch per day (dashed line) and annual catch per trip (solid line) for white shrimp in Texas and Louisiana (Mississippi River to Texas). Catch rates are expressed in hundreds of pounds, heads-off.

and white shrimp are being tested. Trace metal composition of shrimp tissues is being determined also, because it might provide a means for identifying the estuarine origin of particular offshore shrimp populations.

Texas and Louisiana Trends

Based upon annual summaries of Gulf Coast Shrimp Data, there have been apparent trends of increase in total catch (Figure 3) of brown and white shrimp and in fishing effort (Figure 4) in both Texas and Louisiana. The average duration of a shrimping trip in Louisiana was near 1 day, and this reflected the preponderance of inshore fishing in that state. The increase in average duration of a shrimping trip in Texas reflected the increase in offshore fishing (Figure 4).

Apart from observed fluctuations in catch per trip for brown and white shrimp in Texas and Louisiana there seems to have been no pronounced trend (Figures 5 and 6), and the same is suggested for catch per day for white shrimp in Texas and Louisiana and for brown shrimp in Louisiana. However, there has been an apparent decrease in catch per day for brown shrimp in Texas (Figure 5). These apparent trends do not take into account the known increases in size and efficiency of shrimp trawlers over the years covered by these data, nor have they been corrected for possible trends of improvement in the collection and analysis of catch and effort data. An in-depth analysis of the Gulf Coast Shrimp Data is planned to resolve some of these problems.

State-Federal Coordination of Research

Certain aspects of the research are being coordinated with similar research conducted by the Texas Parks and Wildlife Department and the Louisiana Wild Life and Fisheries Commission. Gulf Coastal Fisheries Center biologists are participating in shrimp research cruises of the Texas Parks and Wildlife Department's research vessel *Western Gulf*, and they are working closely with biologists of the Louisiana Wild Life and Fisheries Commission in conducting mark-recapture experiments in estuarine areas.

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A new device permits the sampling of postlarval shrimp in the passes in which the main volume of tidal flow occurs.

An Automatic Pumping Device for Sampling Postlarval Shrimp (*Penaeus* spp.)

FRANK MARULLO

ABSTRACT

Described is an automatic sampling device used to collect and preserve postlarval shrimp (Penaeus *spp.). At timed intervals, seawater is pumped through collecting nets which retain samples of organisms including shrimp. A maximum of 12 samples can be collected in 24 hours. Each sample is preserved immediately in 10 percent Formalin. These samples may be removed once after each 24 hours of operation, or they may be accumulated with similar samples over a longer period of time. Comparison is made between catches with the automatic device and those made with the Renfro beam trawl.*

INTRODUCTION

In the early 1960's, studies were initiated to investigate the possibility of predicting brown shrimp (*Penaeus aztecus* Ives) commercial landings from indices of abundance of postlarval shrimp collected during their movement into Gulf coastal bays (Baxter, 1963). A similar approach has been used in the same region by other investigators (St. Amant, Corkum, and Broom, 1963; Christmas, Gunter, and Musgrave, 1966; St. Amant, Broom, and Ford, 1966; Baxter and Renfro, 1967; Berry and Baxter, 1969). The samples of postlarvae collected in these investigations were taken with a 1.5-m, hand-drawn beam trawl described by Renfro (1962). Though this device samples postlarval shrimp effectively, it is subject to the limitations that (1) sorting of the samples is time-consuming owing to collection of detritus by the trawl, and (2) sampling must be conducted in shallow water away from the passes in which the main volume of tidal flow occurs. In addition, the sampling operation is often time-consuming and difficult.

The present paper describes an automatic sampling device that was designed to alleviate these problems. This sampler has been tested near Galveston Bay, Texas, for extended periods and has proven to be satisfactory for the collection of small, detritus-free samples from the main tidal flow at frequent intervals.

DESCRIPTION OF GEAR

The automatic sampler consists of a pump, a diesel engine, an electronic control panel, and a turntable equipped with a series of nets for collecting, preserving, and storing samples. Numbers