Expanded Research on Gulf of Mexico Shrimp Resources[1]

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Abstract

Given impetus through action taken in 1959 by the Gulf States Marine Fisheries Commission to reinforce a resolution it had passed 5 years earlier, the Federal program of research on shrimp supporting commercial fisheries in the Gulf of Mexico has since undergone considerable expansion. This is reflected in the size of its budget which in Fiscal Year 1959 stood at about $200 thousand but today, Fiscal Year 1963, amounts to nearly $750 thousand.

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Carefully outlined are the current program's objectives as well as the general scheme of research being followed to attain them. Classed under the headings "Biology" and "Dynamics", individual projects are discussed in terms of the research techniques involved and the more significant findings that have resulted.

VERY QUIETLY beginning just before the outbreak of World War I and in response to early concern over the future of developing interests in a marine resource, which today supports the nation's most valuable commercial fishery, biological research on Gulf of Mexico shrimp stocks has since been characterized by alternate periods of vigor and lapse.

Throughout its history, however, we do see a thread of continuity maintained by responsible State governments, particularly as evidenced from the documented efforts of pioneer biologists such as Viosca, Gowanloch, Burkenroad, and Gunter, among others. Unfortunately, limited funds consistently prevented their undertaking the large-scale research programs necessary to solve the numerous and complex problems that arise with the harvest of any renewable resource. But lack of money certainly didn't deter them from playing major roles in the erection of a firm base from which future generations of biologists might launch such programs.

It wasn't until the early 1930's that the Federal Government, with its somewhat greater financial strength, entered the shrimp research picure. This venture, provoked by the shrimp industry's solicitude for the resource itself, marked the start of a period of considerably heightened research activity. Supplementing, yet sharply contrasting with modest investigations already underway by local conservation agencies, the program conducted by the United States Bureau of Fisheries sought to reveal the intricacies of shrimp biology on a scale heretofore too broad and expensive to be undertaken. The program's results are well known and may be readily identified with a host of workers from among which the names of Weymouth, Lindner, Anderson, Pearson, and King may be ranked with those mentioned above as the pioneers of Gulf coast shrimp research.

Regrettably, this increased interest in shrimp biology and in the manifestations of resource exploitation failed to develop beyond the plateau reached in the mid-1930's. With the advent of World War II it waned perceptibly and finally ceased altogether.

It must be remembered, however, that up to this point in the history of Gulf shrimp research, the commercial fishery itself had not yet realized peak production or efficiency, and had by no means exhausted its potential for expansion into new areas and the utilization of new species. Recall further that the early (1880-1948) fishery and attendant biological research centered on the white or common shrimp, *Penaeus setiferus*, with populations in the Delta (Louisiana-Mississippi) area yielding practically the entire domestic production. Statistics show that annual production of white shrimp did not reach a maximum until 1945, but later history has also recorded, as many know all too well, that this likewise signaled the start of a gradual to sharply downward production trend that has not yet seen a reversal.

Concern over failure of the northern Gulf's white shrimp fishery and, as an outgrowth, a keen desire for the development of any measures that might offset a similar fate in new fisheries (particularly those for brown shrimp, *P. aztecus*, off Texas and northern Mexico, and pink shrimp, *P. duorarum*, off southwestern Florida and in the Bay of Campeche), rekindled interest in shrimp research generally. This renewed interest culminated in 1953 when the Gulf States Marine Fisheries Commission, an interstate compact ratified into law four years earlier,

invited marine scientists to outline a course of action best calculated to improve the status of the shrimp resource, and hence solve many of the problems then facing the shrimp industry. A resolution passed the following year requested the Federal Government to underwrite, develop, and participate in an expanded shrimp research program which featured in large degree the collective ideas presented by experts the year before.

The 1954 resolution did meet with some success in the form of a modest increase in research funds but, unfortunately, not in the degree of participation that might have been expected. Research activity by the Bureau of Commercial Fisheries, designated as the Commission's principal research arm, lagged for the next four years, and it wasn't until 1959 that this agency drew up a research program that merited Commission sanction. We can't escape the fact either that during this period the Gulf coast shrimp industry experienced several of its worst production years.

Amid the flurry of industry activity in 1959-1960, which saw an excellent recovery in production from the two previous years (record-high production of brown shrimp in 1960), the Commission quietly pursued the task of expediting procurement of implementing funds (roughly $500 thousand), the task to which it committed itself upon endorsing the Bureau's new biological research program. Initial attempts were only partly successful, however, with an additional $175 thousand in Fiscal Year 1962 bringing the total shrimp research appropriation for that year to $450 thousand — the highest level yet attained but still well below that agreed upon as being necessary. Bolstered by outcries arising from sharply reduced shrimp production in 1961, subsequent attempts proved completely successful, the $325 thousand appropriated in Fiscal Year 1963 (on top of the $175 thousand level established the previous year) just meeting the amount called for by the new program. With both old and new programs now being fully subscribed, the amount budgeted for shrimp research by the Bureau of Commercial Fisheries in Fiscal Year 1963 approached three-quarters of a million dollars, nearly a fourfold increase over that budgeted in 1958.

The Bureau's present shrimp research program, containing most if not all of the study items proposed at the Commission's 1953 meeting of experts, represents a series of working revisions dictated by successive changes in funding levels. The practical need for this is readily appreciated as is the fact that with each revision, new problems and theories may be posed for consideration. Their acceptance tends to strengthen and at the same time clarify the approaches as well as objectives documented in the original or basic program. To a degree this also reflects research progress.

Acting on behalf of the Gulf States Marine Fisheries Commission in such matters is its Shrimp Research Committee, a standing group of Federal and State biologists established in 1961 to coordinate the technical activities of government agencies engaged in shrimp research. With the acquisition of a substantial increase in its 1962-63 appropriation for shrimp research, the Bureau called upon this Committee to adjudge the latest revision of its working program, necessitated by the new level of funding. Meeting in New Orleans in September 1962, the Committee passed favorably on this "expanded" program, the details of which are outlined below.

PROGRAM OBJECTIVES

Objectives of the Bureau's enlarged program of biological research on Gulf

of Mexico shrimp resources are essentially the same as those designated today for investigations of fishery resources the world over. Broadly speaking, they are: (1) to promote efficient utilization of commercially important shrimp stocks; (2) to define, as well as understand the mechanics of, those factors principally responsible for fluctuations in supply and yield; (3) to predict the magnitude of supply; and, accordingly, (4) to prescribe by means of flexible regulations the kind and amount of fishing that will result in maximum continuing yields consistent with optimum resource maintenance. Attainment of these objectives relies in very large measure on proper application of currently accepted theories of fishing as well as population ecology (dynamics), and, to the extent that such theories reliably portray the complex nature of events in the history of exploited species, results in regulatory measures conducive to high-level maintenance and utilization of fish and shellfish resources.

For convenience, our research objectives may be classified as either long range or intermediate. To the long-range category we assign those which involve a detailed knowledge of the marine (and estuarine) environments and, in a sense, an ability to predict not only how environmental changes will affect commercial shrimp stocks, but also the changes themselves. We do not, of course, possess the latter capability and will only do so when reliable methods for the long-range prediction of weather and other factors are devised. In the meantime and until the principal factors are determined, our search for causes of unexplained fluctuations in shrimp supply and yield must entail the long-term serial observation and systematic elimination of environmental variables and combinations thereof. Prediction of supply and subsequent regulation of fishing effort must therefore be set in terms of limits which reflect the environment's greater and lesser combined effects on stock survival (natural mortality), as observed over a relatively long period of time. The question naturally arising in the minds of these underwriting research programs is: What length of time is implied by the term *long range*? In the situation being discussed, it could amount to 10, 15, or even 20 years, depending on how well founded the research program is at its inception, how well we can assess all features of the environment, how much the environment varies, and how capable we are of handling the mass of data that will accumulate.

Objectives classed as intermediate are those which may or may not by themselves constitute the final solution to a specific question or problem, but which generally play a major role in the attainment of long-range objectives such as discussed above. They are many as well as varied and, like the long-range type, usually focus attention on some sort of relationship, the complete understanding of which is prerequisite to sound fishery regulation. The following may be cited as the more important ones set forth in the Bureau's new shrimp research program: (1) to determine the relationships between size of spawning stock and number of resulting progeny; (2) to assess the serial effect of fishing on size of (spawning) stock and hence yield; (3) to define the relationship between rates of growth and natural mortality so as to predict the average size (or age) of shrimp at the moment population weight reaches a maximum, and thereby acquire the information needed to promote efficient resource utilization; (4) to ascertain for each of the important shrimp species the spatial relationship between offshore (marine) spawning areas and inshore (estuarine) nursery areas, an understanding of which would provide insight into the question of whether or not parent stocks are discretely subdivided; and (5) as required by (1) and

(2), to develop accurate methods for determining population size and (age) structure.

GENERAL SCHEME OF RESEARCH

As indicated above, stocks of three species sustain the Gulf coast shrimp industry. Ranked according to the order in which they contribute to overall Gulf landings, they are the brown, pink, and white shrimp. With a moderate amount of seasonal overlap, each of these exhibits in shelf waters a well-defined distribution both bathymetrically and geographically. Accordingly, each species represents at the center of its distribution the main objective of fishing interests located in the same general region, e.g., the brown shrimp in Texas, the white shrimp in Louisiana, and the pink shrimp in Florida. Moreover, these shrimps are characterized by a distinctive life history whose sequence of events more or less dictates how large-scale investigations into their biology and dynamics should be organized.

Briefly, protracted spawning takes place in the truly marine environment offshore. The demersal eggs hatch within a few hours after spawning with the resulting larvae being planktonic for a short period thereafter, and hence subject to the prevailing pattern of ocean currents. In most cases, the larvae are transported, or move in some as yet unexplained manner, toward and through passes between barrier islands into broad and shallow estuaries. During transport they quickly undergo morphological transformation and, by the time they reach the bay entrances, are no longer planktonic larvae but rather postlarvae that have taken on a bottom-living existence. Once in the bays, or so-called nursery areas, the young shrimp grow rapidly to juvenile and sub-adult size. Within a few months they begin to migrate seaward to the spawning grounds where the life cycle, which takes between 1½ and 2 years, is completed. Depending on the locality, successive spawning groups or "broods" of shrimp may be subjected to continual fishing from the time the juvenile stage is reached in the estuaries, to the time the broods pass out of existence on the offshore fishing (and spawning) grounds. In most Gulf areas, however, fishing effort is largely concentrated on the sub-adult and adult shrimp inhabiting oceanic waters from the surf to about 50 fathoms.

The general scheme of research adopted in 1959 and later enlarged upon in 1961 and 1962 by biologists headquartered at the Bureau's Galveston installation, takes advantage of the shrimp's somewhat unique life history outlined above. Four distinct areas for study may be readily defined, each representing a phase in the continuing process of shrimp population development, and therefore being separable on the basis of space and time criteria. These study areas are: (1) spawning populations (as treated separately from each species' "fishable" population, which may consist of immature as well as mature shrimp); (2) eggs and larvae — oceanic; (3) postlarvae and juveniles — estuarine; and (4) commercial (or fishable) populations. Such a breakdown greatly facilitates program organization as well as operation, and helps to maintain program integrity in situations where expansion or curtailment become necessary.

Each study area may, in turn, be subdivided further according to whether the work being undertaken is largely qualitative or descriptive in nature, or whether it can be classed as principally quantitative. This is not meant to imply that the two kinds of work are not closely complementary, but rather that they differ widely in the type of professional talents required. For convenience, the terms "Biology" and "Dynamics," respectively, will be used to differentiate them.

BIOLOGY (LIFE HISTORY) STUDIES

Spawning Populations

The emphasis here is on defining and describing concentrations of spawning shrimp, with such work on the three major species as well as on several of minor and potential importance now underway. Specifically sought is information regarding the areal distribution of spawning units, and the intensity and chronology of spawning activity itself. This information will aid in future attempts to determine the size of spawning units; in predicting egg production; in more accurately identifying the broods (or age classes) associated with periods of heightened spawning activity; and in determining age at maturity in both male and female population segments.

Two approaches are being employed to secure this information. In the case of pink shrimp studies, conducted off southwest Florida under contract with the University of Miami since 1959, the results of systematic sampling for eggs and early larvae (Fig. 1) provide a basis for drawing inferences on the probable distribution of the parent shrimp and the extent of their spawning activity. In the case of studies on brown, white, and other shrimp off the northwestern Gulf coast, a similar approach is supplemented by directly sampling commercial-size specimens in a systematic manner and then histologically examining their gonads to determine the exact stage of development. The probable centers and periods of greatest spawning activity can be mapped from the resulting data with more accuracy than by the first method alone. Other information secured incidentally relates to the spawning frequency of individual shrimp; the sex ratio in spawning populations; fecundity; the physical characteristics of spawning grounds; and environmental conditions at the time of spawning.

The Florida pink shrimp studies continue much as they have since their inception. A modest increase in 1962 funds together with a slight alteration in contract scheduling will permit examination of year-to-year variation in spawning sites and intensity.

A sizable increase in funds for studying brown and white shrimp spawning populations in conjunction with the distribution and density of resulting larvae is permitting greater sampling coverage in the northern Gulf, and thereby enhancing the kind and quantity of information being obtained. The enlarged scope of this project is illustrated in Fig. 2 where we note that initial field activity in 1961 involved biological sampling only within that area offshore to 60 fathoms and lying between Freeport, Texas, and Cameron, Louisiana. Following expansion, the project now involves the same coverage bathymetrically but embraces the much greater area extending roughly from Brownsville, Texas, to Pensacola, Florida.

Distribution and Abundance of Eggs and Larvae

We share the widely held view that it is in the egg and larval stages of population development where answers to the vital question of what causes major fluctuations in shrimp supply and yield are most likely to be found. Projects under this heading therefore constitute some of the more important of those making up the overall research program. They are organized in such a way that different types of information serving different purposes may be gathered simultaneously.

Thus, measures of larval density obtained systematically along with various kinds of oceanographic data provide a basis for (1) serially correlating abun-

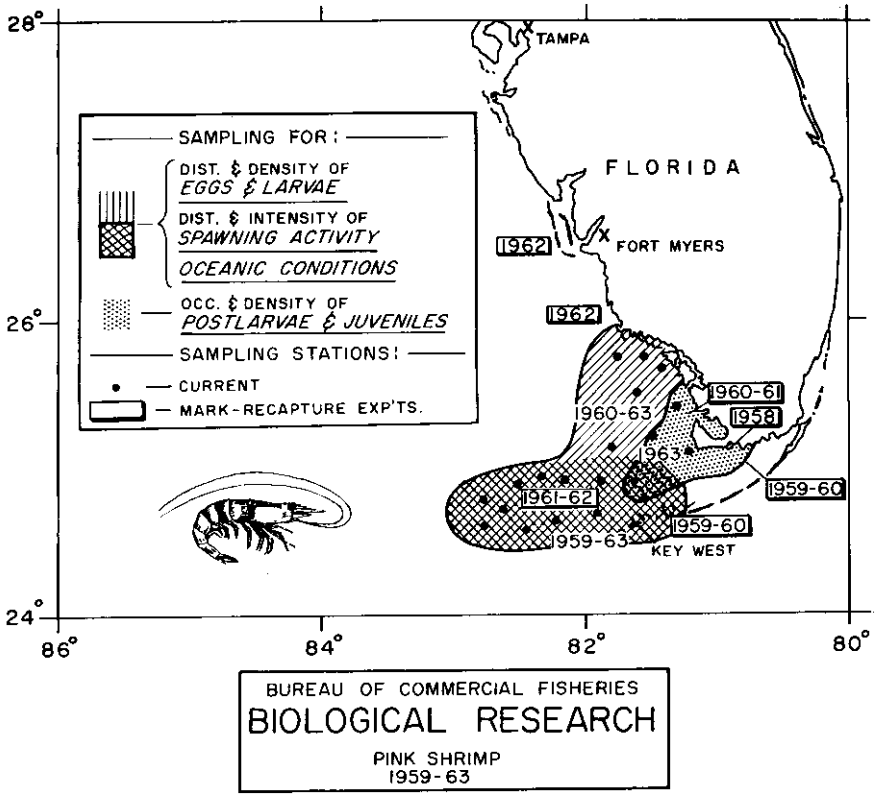

FIG. 1. Field operations off the Florida coast of the Gulf of Mexico.

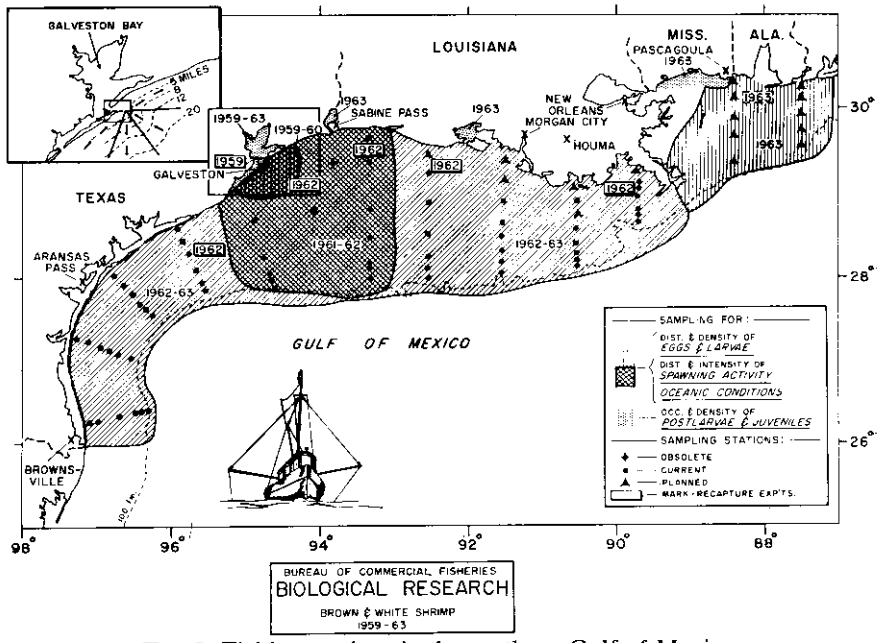

FIG. 2. Field operations in the northern Gulf of Mexico.

dance of larvae with environmental parameters to determine which govern to the greatest degree the amount of spawning activity and the survival of shrimp broods during their early oceanic phase; (2) computing survival from larval to postlarval stages and determining the magnitude of variation in brood success; (3) determining the patterns through which larval shrimp are dispersed from centers of spawning; and (4) deriving abundance indices with which to predict probable supplies of commercial-size shrimp four to six months later.

As indicated earlier, one such study being conducted under contract by the University of Miami since 1959 has yielded valuable preliminary information concerning the distribution of larvae (as well as the location and intensity of spawning) for a population of pink shrimp off southwestern Florida (Fig. 1). A similar but yet more intensive study on the eggs and larvae of brown, white, and other less important shrimp comprising stocks fished in northern Gulf waters has also been underway since 1959.

The latter investigation developed from a rather small-scale though detailed survey which involved one chartered research vessel and was restricted to Lower Galveston Bay and the nearby Gulf, to a much broader survey which now employs two vessels and covers the Gulf's continental shelf from the vicinity of Brownsville, Texas, eastward to Pensacola, Florida, an expansion of considerable magnitude (Fig. 2). This project, as well as the one investigating spawning populations with which it is closely associated, depends entirely on biological and oceanographic data obtained once every three to four weeks at each of 50 to 60 stations distributed over the area just defined. Biological material in the form of commercial-size (mature) shrimp and contemporary fish fauna is sampled by means of conventional trawling gear. Shrimp eggs and larvae are taken in carefully metered plankton samples using the high-speed, all metal, Gulf V plankton sampler. Checks on variation in vertical and diurnal distribution of both larval and adult forms are made as time and conditions permit. Physical and chemical features of the environment are measured during biological sampling, with water temperature and water-mass dynamics now receiving top priority. Special recording instruments and bathythermographs aid in constructing temperature profiles, and electronic (Savonius type) meters provide data on the direction and velocity of currents at all levels of the water column. The current-meter data are supplemented by those resulting from the retrieval of drift bottles and bottom-drifters which are systematically released during each sampling cruise.

Though having undergone only partial analysis, the biological data thus far obtained from the histological examination of gonads and the analysis of plankton samples tend to corroborate an earlier finding based on the distribution of weight-frequency modes in commercial shrimp landings, that the annual spawning cycle in the brown shrimp is characterized by two well-defined periods of heightened activity. Preliminary analyses also suggest a strong correlation between relative density of larvae and prevailing (bottom) temperature. On the other hand, the possible role of water-mass movements in the distribution of eggs and larvae cannot yet be reliably conjectured due to the short amount of time this particular phase of study has been in progress.

Taxonomy of Immature Penaeidae

Beginning in 1959, this project arose out of a need by biologists working on larval distribution and abundance for a means of separating the many species of shrimp that occur together as similar-appearing larvae and early postlarvae

in the plankton. Best material to date has been secured by rearing and carefully describing successive developmental stages of larvae hatched from eggs spawned in laboratory aquaria by parents of known identity. However, because of difficulty in carrying larvae beyond certain intermediate stages, only specimens of the very early forms have been so obtained. Those morphological stages to which rearing in the laboratory has not yet proved possible are described from plankton material surmised upon close scrutiny and comparison of external features to represent the stages in question.

By means of these methods, tentative generic keys to immature Gulf of Mexico Penaeidae have been constructed and are in use. The larval forms of several species, namely the pink shrimp (under contract with the University of Miami) and seabob, *Xiphopeneus kroyeri*, have been described in some detail. The larvae of other species, particularly the brown shrimp, are receiving similar treatment, with the descriptions of several nearing completion. Present plans call for continuing this important project at about its present level of funding until the immature stages of all overlapping species are satisfactorily described. The resulting information will be of inestimable value to all future workers in shrimp research.

Movement and Density of Postlarvae

In the continuing process of population redevelopment, it is easily recognized that there is and, in fact, quite logical that there be, a high serial correlation between the numbers of shrimp surviving from one life history stage to the next. The practical utility of this fact is, however, directly proportional to the cost and general feasibility of identifying and sampling each stage in order to reliably assess it. If a situation exists where costs appear justified and the size of a shrimp brood can be measured at a reasonably early stage in its development, we are provided with a device through which the availability of later supplies and success of the incident fishery may be predicted with a fairly good degree of certainty.

Such a situation has always existed in the case of each of the three species supporting our extensive Gulf of Mexico shrimp fisheries, but its real potential was not explored until initial efforts to do so were made in the Galveston area at the start of the 1960 shrimp season. The life history event meriting close attention is the concentrated movement of young shrimp toward and through entrances to estuarine nursery grounds as they undergo transformation from larval to early postlarval stages. Combined measures of their relative abundance, obtained by frequently sampling these postlarvae in an efficient and consistent manner just inside a series of entrances or passes, exhibit considerable promise as valid indices to the later abundance of juveniles on the inshore nursery grounds, and commercial-size shrimp on the offshore fishing grounds. Should such indices eventually prove their worth as predictive devices, the next consideration will be their relative cost which, ultimately, would have to be borne annually by the State agencies responsible for resource management. Costs (primarily of sampling) could be expected to vary from area to area along the coast depending on the topographical nature of the estuarine-marine transition zone, but every effort will be made to minimize these by giving sufficient prior attention to the problem of expected variation in results, and the development of the most efficient sampling gear.

A good start in this direction is exemplified by the results of a three-year study (1960-1962) with brown shrimp in the Galveston area (Fig. 2). Re-

ported elsewhere in these proceedings, they reveal very good correspondence between postlarval indices as obtained by sampling systematically inside Galveston Entrance, subsequent indices of juvenile abundance throughout the Galveston Bay system, and still later indices of adult abundance off the upper Texas coast.

The success of this very modest investigation has prompted its expansion to consider index refinement as well as application in other coastal areas. Accordingly, additional funds appropriated for shrimp research in Fiscal Year 1963 are being used not only to assess sources of index variation in the Galveston area, but also to implement similar projects in western Louisiana, Mississippi, and Florida. As of this writing, contracts have been awarded to the Gulf Coast Research Laboratory to investigate the occurrence and density of brown and white shrimp postlarvae in Mississippi Sound, and to the University of Miami to investigate the relationship between the density of postlarval pink shrimp in Florida Bay estuaries and the later abundance of fishable adults on the Tortugas fishing grounds (Figs. 1 and 2).

The prospects seem bright that the postlarval index will prove increasingly valuable as an aid to the shrimp industry in its annual task of preparing for the forthcoming shrimp season. And although our current efforts are directed toward the development of postlarval indices that would predict conditions within rather large coastal areas as a whole, it is quite likely that individual indices would adequately serve corresponding interests on a local scale.

Laboratory Studies — Physiology and Behavior

Rounding out the program of research listed under the heading "Biology" are several projects concerned with evaluating the effects of, and hence determining the relative tolerances of shrimp to, varying levels in each of a variety of simulated environmental factors. Growth, survival, metabolic rate, and general performance are the experimental criteria employed, with postlarval or juvenile shrimp in most cases making up the experimental populations. Factors being tested include temperature, salinity, light, diet, dissolved gases, and velocity of water currents. Circulating sea-water systems and specially constructed rooms in which temperature and light can be precisely controlled facilitate experimentation.

Most recent findings suggest that juvenile (brown) shrimp can tolerate a wider range of temperatures than can postlarvae. They indicate further that postlarvae and juveniles adapt equally well over a wide range of salinity levels but that the range of tolerance to salinity narrows considerably as the temperature decreases. Such information as well as the results of other research will be of great value in predicting the effects of environmental changes, especially those resulting from extensive engineering projects proposed for Gulf coast marshes. Much of this information and, even more important, the research techniques now being developed to obtain it, will also prove useful in the event plans materialize to undertake basic research in shrimp culture, a topic receiving more and more attention.

DYNAMICS STUDIES

Classed under this heading are those projects which, because of their very nature, rely to a much greater degree on the use of mathematical and statistical techniques than do those listed above under "Biology Studies." Mainly involved

are the estimation of population parameters (especially those of growth and mortality) and their substitution in applied theories of resource dynamics. Statistics of catches and fishing (sampling) operations, whether they arise from the activities of research vessels or commercial fishing fleets, play a major role in these processes as do the results of systematically executed mark-recapture experiments.

Juveniles — Inshore Fisheries

Reliable measures of postlarval density also constitute, in addition to their potential as predictive aids for the shrimp idustry, basic elements in the calculation of brood survival from the egg to postlarval stage, and, again, from the postlarval to late juvenile or seaward-migrant stage. Statistics of inshore (particularly bait-shrimp) fisheries that operate in most areas provide the means for obtaining rough measures of juvenile density against which corresponding measures of postlarval density may be compared.

Although the adverse effect that inshore harvest of small sub-adult shrimp may have on the immediate supply of commercial sizes offshore is of some interest, of far greater concern in terms of future shrimp supplies are the long-range effects of man-induced environmental changes in the estuaries, particularly those due to pollution and other causes of reduced water quality. In attempts to ascribe and measure these effects, it would seem quite logical wherever brood identity can be maintained, that the ratio of postlarval density to the subsequent density of seaward migrants serve as the primary variable to which should be related appropriate measures of those environmental characteristics believed to exercise greatest control over brood survival during inshore phases.

Assisting such attempts are established or planned surveys that gather the statistical data without which meaningful results could not be obtained. For example, a continuing sample survey of the Galveston Bay bait-shrimp fishery, begun in 1959 as a cooperative venture with the Bureau's Branch of Statistics, has more than paid for itself in terms of the valuable information on juvenile density that it has since yielded. Not only has this information served to substantiate the validity of the postlarval index discussed in an earlier section, but it also stands to aid in completing studies of the kind just mentioned—those involving assessment of changes in the estuarine environment. Plans to give similar coverage to comparable fisheries in other areas are now being developed. In regions where such fisheries do not exist, projects which would undertake the sampling of juveniles to obtain the desired information will soon be implemented. Thus, the seasonal density of juvenile pink shrimp in Florida Bay, as related to both the corresponding densities of late postlarvae in the Everglades and commercial-size adults on the Tortugas grounds, will be examined by different techniques and in different localities by a new Bureau project, as well as by a study proposed in connection with the new research contract awarded to the University of Miami.

Parent Stocks — Commercial Offshore Fisheries

Studies grouped under the general project heading "Population Dynamics," are or will be mainly concerned with refining and then employing shrimp catch and effort statistics to derive reliable indices of relative abundance for fishable stocks, which represent in part the spawning populations discussed earlier. Analysis of abundance trends and definition of factors governing them

will also continue to receive attention, as will the problem of age assessment and, accordingly, the usefulness of commercial statistics in estimating mortality. Also of interest here are data suitable for the comparative study of fishing powers of different vessel and gear arrangements. All this information is to be used to evaluate the effect of fishing on the magnitude of shrimp supplies.

Sampling Commercial Catches

Commercial production and effort statistics are now made available monthly by the Bureau's Branch of Statistics. These are obtained by means of a continuing and rather intensive canvas (established in 1956) of all industry installations located on the United States Gulf coast. Statistics of shrimp landings, obtained by inspection of dealer records, are broken down according to area and depth of capture, and species and size composition. Effort statistics, obtained by interview, are recorded on the basis of number of fishing trips, time spent fishing, and fishing position.

Although the collection system and resulting statistics represent an admirable effort, and the statistics themselves constitute extremely valuable information even in their present state, there have arisen recognizable defects that it was agreed could be largely remedied with but a moderate amount of the right kind of effort. Improper identification of species, questionable validity of size composition data, and unreliable effort estimates have been designated as the major weaknesses. To check these and, in general, to aid in improving the statistics overall, assignment of strategically located catch (port) samplers was proposed. These persons would work closely with the statistical agents located in their respective areas and be responsible for sampling landings for species and size composition, and interviewing additional trawler captains for information on fishing position and effort. Other duties would include: checking on the extent to which small shrimp are discarded at sea during seasons when this is widely practiced; aiding in the handling of marked shrimp recaptured during growth and mortality experiments; and providing miscellaneous biological data that might be required in the execution of other research projects.

Although the proposal to establish a pool of catch samplers was introduced by the Gulf States Marine Fisheries Commission as early as 1954, lack of funds precluded action until seven years later (1961) when a supplemental budget permitted assignment of samplers at Port Aransas and Galveston (Texas), and Morgan City (Louisiana). With the additional funds allocated in Fiscal Year 1963, similar positions are now established at Brownsville (Texas), Houma (Louisiana), Pascagoula (Mississippi), and Tampa, Fort Myers-Everglades, and Key West-Marathon (Florida), thus completing the pool (Figs. 1 and 2).

Mark-Recapture Experiments

Development of the stain-injection technique for marking shrimp, now acknowledged as being far superior to the method of tag attachment, has greatly broadened the scope of research on shrimp dynamics and expedited the measurement of key population parameters, namely, growth and mortality. Successful feasibility studies involving determination of dispersal patterns for

sub-adult pink shrimp migrating from various points in Florida Bay (1958-61), and small brown shrimp migrating from Galveston Bay, Texas (1959), led in 1961 to the technique's first large-scale application to measure growth and mortality in fishable portions of commercial populations. Receiving initial attention was the well-known Tortugas (pink shrimp) population off southwestern Florida. Carefully planned and executed, this study yielded very good growth data, preliminary though useful measures of fishing and natural mortality, and some indication that, because growth evidently cannot compensate for losses due to high natural mortality, regulations involving an increase in minimum shrimp size would not lead to greater production.

With the increased research funds provided in Fiscal Years 1962 and 1963, similar experiments involving other species elsewhere in the Gulf have already been completed, are underway, or are being planned. During 1962, mark-recapture experiments with brown and white shrimp off Louisiana and Texas, and pink shrimp in the Sanibel (Florida) area, will have terminated and analysis of their results begun. In addition to these, attempts will also be made to define for the same species the spatial as well as seasonal (and annual) variation in estimates of growth and mortality parameters. Planned earlier as a repeat of the 1961 experiment mentioned above, the first such effort was scheduled for the Tortugas pink shrimp population in late 1962.

In all mark-recapture experiments executed to date, vessel facilities provided on a charter basis by the Bureau's Exploratory Fishing Base in Pascagoula, Mississippi, have been used for shrimp capture and marking operations. Also in this connection, the generous assistance of industry and Branch of Statistics personnel in the recapture and recovery phases of each experiment merits acknowledgement.

At its present rate of progress, dynamics research incorporating the mark-capture experiment as its primary tool should, together with concurrent analyses of fishery statistics, soon produce results which will permit preliminary application of the population theory referred to earlier. This, in turn, will make possible at an earlier date than hitherto anticipated, rational decisions regarding the kind and amount of fishing best calculated to serve the interests of maximum continuing yields of shrimp consistent with optimum resource maintenance.

SUMMARY

Following a brief resumé of the early history of biological research on commercial shrimp resources in the Gulf of Mexico, attention is focused on events occurring over the period 1959-62. Given impetus through action taken in 1959 by the Gulf States Marine Fisheries Commission to reinforce a resolution it had passed 5 years earlier, Federal participation in this activity has since undergone considerable expansion. This is reflected in the size of the Bureau of Commercial Fisheries shrimp research budget which in Fiscal Year 1959 stood at about $200 thousand but today, Fiscal Year 1963, amounts to nearly $750 thousand.

Carefully outlined are the current program's long-range and intermediate objectives, as well as the general scheme of research being followed to attain them. Program continuity and the quantitative approach are stressed throughout, as is the fact that in several instances, independent means are employed to achieve the same objective and thereby serve to cross-check the validity of intermediate or final results.

Classed under the headings "Biology" and "Dynamics" individual projects are discussed in terms of the research techniques involved and the more significant findings that have thus far resulted.

Breaded Alaskan Shrimp

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Abstract

The colored slide presentation showed a trawl catch of Alaskan shrimp; all of the various phases of the handling of the product in a plant at Seward, Alaska, beginning with the storage of the raw material, peeling of the shrimp, grading for size, dewatering, inspection, stuffing into plastic "sleeves", and freezing; method of shipment to a breading plant in Louisiana, unloading of the master cartons on arrival, tempering the product, cutting the molded formed logs into uniform slices, breading, packing, weighing, freezing; preparation of the final product by the consumer, i.e. deep frying; and the finished product as served to the ultimate consumer.