AN EVALUATION OF METHODS FOR DETERMINING MOVEMENT OF SHRIMP

PHASE I: SHRIMP MOVEMENT STUDIES

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Gulf of Mexico and along the south Atlantic coast, beginning in 1935 (Lindner and Anderson, 1956). Disc tags (8.0-9.5 mm in diameter) were attached to the fist abdominal segment with a nickel pin. A total of 46,532 shrimp were tagged and approximately 16% of the shrimp were recovered. The recoveries of these tagged shrimp, along with other data, were used to confirm the seasonal migrations of white shrimp along the Atlantic coast.

Further refinements of the Petersen tag were reported by Neal (1969 a). The disc tag was reduced in weight by two-thirds and had a smaller diameter (6mm). Rather than inserting the pin through the center of the first abdominal segment, the pin was inserted between the first and second segment. This lessened the difficulty in molting for the shrimp. An antibiotic ointment applied to the pin before it was inserted helped inhibit infection and increased the survival rate of tagged shrimp. In a 100-day test, approximately 47% of the shrimp survived when tagged with the antibiotic on the pin, while only 28% of those tagged without it were alive. Survival of controls was 62%.

Even though the use of an antibiotic ointment helped to increase survival of tagged shrimp, the disc tag had other limitations. Two of the major problems were the paucity of recoveries of tagged shrimp less than 100 mm total length (approximately 24 mm carapace length) and the meager recoveries of tagged shrimp "out" more than 80 days.

Loop-Type Tags

Two loop-type tags were developed for shrimp, both basically of the same type. One, the Atkins-type tag (Allen and Costello, 1963), utilized a piece of monofilament line looped through the first abdominal segment. A numbered oblong strip of plastic was attached to the line. No reference could be found

to actual field studies using this tag. Neal (1969 b), mentions the problem of infection where the line passes through the abdominal segment.

A tag developed by Tiews (1967) consisted of a silver wire instead of nylon line. Plastic discs, 6 mm in diameter and cut in half, were attached to the wire. The wire was looped around the body of the shrimp between the carapace and first abdominal segment. In 13 experiments using this tagging method in German waters, 41,236 *crangon* shrimp were tagged, but only 0.5% were recovered. Rather than attribute the low recovery to the tag mortality, Tiews cites other problems in the recovery phase which will be discussed later. The results were deemed sufficient to confirm the general migration theory formulated for this species.

Biological Stains

To overcome some of the limitations of the external tags, research began in the fifties to develop an internal mark that could be readily identified and yet not interfer with the shrimp's normal activities. Dawson (1957) reported on the success of biological stains injected into the shrimp. The stain passes through the vascular system and concentrates in the gills giving the shrimp a distinct mark. The amount of stain injected in each shrimp is important. Costello (1964) demonstrated that survival of stained shrimp varied according to the concentration and amount of stain injected.

Three stains, Trypan Blue, Niagara Sky Blue 6b, and Fast Green FCF, were found staisfactory for field experiments. Trypan Blue could be recognized in the gills for a period of at least 220 days. Fast Green FCF and Niagara Sky Blue 6b lasted over 100 days, (Dawson, 1957). Although the stain imparts an abnormal coloration in the gills for an extended period of time, the shrimp are not handicapped. Allen and Costello (1961) cited in Neal (1969b) concluded after a series of experiments that stained and unstained shrimp are equally vulnerable to predation.

developed for use as secondary marks (Klima, 1965). These pigments were mixed with petroleum jelly and minute quantities were injected into the musculature between the fifth and sixth abdominal segments. It remained at the point of injection and could be detected with an ultraviolet light. Neal (1968) reported that four fluorescent pigments and two biological stains were used for marking shrimp. Combinations of these stains and pigments and use of the two stains alone would yield 10 distinctive marks.

Polyvinyl Chloride Tags

The use of fluorescent pigments as secondary marks offered more combinations which allowed the marking of different groups of shrimp in the same area, but there still remained a need to identify individual shrimp. A small internal, numbered tag was developed at the BCF Galveston Laboratory (Neal, 1963). This tag, of polyvinyl chloride (0127mm by 2 mm by 5 mm), is inserted into the musculature under the first abdominal segment. Because of the placement of the tag, it is not visible and must be used in conjunction with a biological stain. It, like the Peterson disc tag, is not satisfactory for use on shrimp less than 100 mm total length. This method of using internal tags or fluorescent pigments as secondary marks has been used in the gulf of Mexico since they were developed (Neal 1968, 1969a and 1970).

Coded-Wire Tag

A new technique of tagging shrimp was reported by West and Chew in 1968. They successfully tagged spot shrimp *(Pandalus platyceros)* with the Bergman-Jefferts ferromagnetic wire tag. The color-coded wire tag (1mm by 0.25 mm) was implanted into the musculature of the first abdominal segment with a mechanized injector. No difference in mortality was noted between tagged and

untagged shrimp. This technique solves the problems of both the internal and external tag by permitting the biologist to tag shrimp less than 100 mm total (24 mm carapace length). West and Chew tested the tag on shrimp 14-40 mm carapace length. After a shrimp is tagged, it is passed by a horsehoe magnet to magnetize it and then by an electronic detector which emits a tone if the tag was successfully magnetized. This sensing unit is also used to recover tagged individuals from the fishery. Tagged juvenile salmonids have been successfully recovered as adults by utilizing the electronic detector.

The wire tags can be coded with six different colors which offer 4,096 different combinations.

This tagging technique has yet to be field tested on shrimp. Laboratory experiments using this method on penaeid shrimp are being conducted at the NMFS Galveston Laboratory (Bill Welker, Personnel Communication). Results are encouraging, although they feel that there will be major problems in recovering tagged shrimp.

Recovery of Marked Shrimp

While none of the various tagging and marking techniques can be considered perfect, they have been used with favorable results in many studies determining the migration routes of shrimp in the Gulf of Mexico. The bulk of the published tagging and marking experiments have come from studies conducted in the Gulf. It is difficult however, to evaluate this study in comparison with proposed studies on pink shrimp (*Pandalus jordani*) because of differences in life history of the Gulf shrimp and aspects of the fishery which are important to the recovery.

The juvenile penaeid shrimp in the Gulf rear in the estuaries for a period of 3-7 months. They then migrate from the estuaries to off-shore waters where they mature as adults and are harvested by the commercial fishery. In the tagging and marking experiments, biologists concentrated on determining where these juveniles migrated and how important the various estuaries were in contributing to

specific off-shore fishing areas. The recovery rates for stain-marking experiments involving juveniles have been very low. Costello and Allen (1964) report on 12 experiments involving juvenile pink shrimp *(Penaeus duorarum)* off the west coast of Florida. A total of 140,414 juveniles were stain-marked and only 411 were recovered; however, the data was apparently sufficient to describe the migration of the juveniles.

Much higher recovery rates were reported for adults marked and released on the shrimp grounds. A total of 6,937 shrimp were marked and 1,790 were recovered. Other experiments in the Gulf resulted in the same trend with recovery rates on juveniles being very low, while tagged or marked adults were recovered in good numbers. The per cent recovered varied according to the study area and the extent of the commercial fishery.

The success of the mark-recapture studies in the Gulf of Mexico has been the result of two important features in the recovery phase.

One is an extensive publicity campaign to inform all those in the shrimp fishery of the tagging and marking studies which are occurring in their respective areas. The major emphasis is put on personal contact with each fisherman and processing plant employee. Actual tagged or marked specimens are shown and bottles of formalin are provided for the fishermen to preserve the recoveries they collect while they are fishing. Probably the prime inducement for returning tagged and marked shrimp has been the offering of a reward for each shrimp. Rewards have ranged from one to five dollars, the most common amount being two dollars.

Another aspect which aided the recovery phase is the method by which the shrimp are handled after being caught. Virtually all of the shrimp caught in the Gulf are beheaded at sea and so are individually handled. Many of the fishermen typically spread their catch on the deck in an attempt to spot tagged or marked individuals (Costello and Allen, 1968).

Allen and Costello (1966) cited in Costello and Allen (1968) extimated that fishermen accounted for 93% of the recoveries made during mark experiments off the west coast of Florida. After the shrimp are landed, the workers in the

processing plants look the shrimp over a second time. Costello and Allen (1968) "planted" marked shrimp in commercial catches being landed at processing plants. They estimated from the results that 75 to 89% of the marked shrimp entering the processing plants are recovered. Klima and Benigno (1965) also investigated the efficiency of the recovery of tagged shrimp from the catch. Their studies indicated that 83 per cent would be recovered by the commercial fishermen, 14 per cent in the processing plants and that 3% would pass unnoticed.

Even though tagged or marked shrimp escape being caught or die shortly after being tagged or marked, the investigators feel confident that those which are caught in the commercial fishery have a high probability of being recognized and the main incentive for reporting recovered shrimp is probably the reward.

Tiews (1967), who reported on a 0.5% recovery rate in German coastal waters for 41,236 shrimp released has not been as fortunate in recovering tagged shrimp. Apparently, only half of the shrimp fleet cooperated with the biologists in returning tagged shrimp. No mention was made whether all the fishermen were contacted regarding the experiments and shown tagged specimens, nor was any mention made of a reward being offered for tagged shrimp. Tiews cites problems associated with large numbers of shrimp caught in a single days fishing. He makes estimates of 200,000 - 1,000,000 shrimp being caught per tow and perhaps 6,000,000 shrimp being caught in one day. The sheer numbers of shrimp caught, therefore, limit the probability of a tagged shrimp being recovered. In the Gulf of Mexico, the shrimp are larger and catches are much smaller. An average of 4,000 pink shrimp were caught each night in fishing off the east coast of Florida during a March to May period (Costello and Allen, 1968). This probably accounts in part for the relatively high recovery rates in the Gulf.

Tiews also "planted" tagged shrimp in the processing plants. The shrimp are peeled by hand, which insures that each shrimp will be handled. He concluded that only 10-20% of the tagged shrimp would be recovered. No mention is made of whether the plant workers knew there was a tagging experiment being

conducted or if there was a reward being offered. Tiews assumed the recoveries were low because of the monotonous routine involved in the work and, therefore, workers were "blind" to any unusual feature of a shrimp.

Inferential Methods

Introduction

Describing the movements and migrations of a mobile aquatic species as inferred from the results of routine sampling has been utilized by biologists for many years. Typically these patterns of movement are based on data gathered from a series of stations which are sampled at a uniform time interval. The changes in abundance from one area to another of a given species are used as evidence that movement has occurred. Usually, environmental variables are also measured in an attempt to describe why a species moved and perhaps to be used to predict future movements. Many research programs, when possible, incorporate marking of individuals of the species investigated to conclusively establish the patterns of movement and/or migration. Data from the commercial fishery is also used.

The feasibility of using the inferential method to define movements of pink shrimp was investigated by surveying the literature and evaluating the techniques used in various studies. Fish Commission of Oregon data on the commercial shrimp fishery were also examined to determine if it could be used to describe movements of shrimp.

Inferential Techniques Used

In surveying the literature, emphasis was on studies of shrimp populations and on as many different species as possible. It became apparent that the inferential techniques were basically similar in the various studies and, therefore, not all the literature was surveyed.

The basic tool used by researchers to infer movement of shrimp has been a trawl which was used to determine the abundance of shrimp at selected stations or areas. Some sampling of the commercial fishery is also done. The description

of the movements and/or migrations as cited in the various studies has been aided by the fact that the life history of the species was such that migration of ovigerous females or larvae was necessary or that there were measurable and significant changes in the environment which necessitated a migration. None of the studies investigated the discreteness of stocks. They were only concerned with description of movement.

One of the earliest reported studies on shrimp movement was by Berkeley (1930). She used a beam trawl to conduct a routine bi-monthly sampling program to study four species of deep-water *Pandalus* and of *Pandalopsis dispar* found off British Columbia. She was able to trace the inshore-offshore migration of larvae using this method.

Mistakidis (1957) used both research fishing and commercial fishing data to investigate the migration of *Pandalus montague* in the area of the Thames Estuary on the southeast coast of England. Once timing of the migration was established as inferred from research sampling, the reason for it was investigated by collecting data on water temperatures and salinities at selected stations. The change in these environmental variables was concluded to be the probable cause of the migration of the shrimp.

Allen (1966) reported on a seven-year study conducted off the northeast coast of England. He discusses the occurrence and movements of sixteen species of caridean shrimp based on data collected with a beam trawl and Agassiz trawl. He concluded that a few species were non-migratory being restricted by the occurrence of a specific bottom type. For the other species, migration as inferred by research sampling was related to temperature, food seeking and age.

The movement and migration of the three major commercial species of shrimp in the Gulf of Mexico and along the south Atlantic coast have been studied quite extensively in the last two decades. The first efforts towards describing the movements utilized research fishing, but the emphasis shifted to tagging shrimp when it was determined to be feasible.

Lindner and Anderson (1956) summarize the results of the coordinated effort of the south Atlantic coast states and Gulf states in the 1930's on the investigation of the white shrimp (*Penaeus setiferus*). At the beginning of the study, research trawling was conducted to supplement the data from the commercial fishery. In the mid-thirties, a tagging program was initiated. It provided definite evidence on migrations and most of Lindner and Anderson's paper discusses the results of tagging. However, they did use the results of commercial data analysis to support conclusions reached on migrations based on tag recoveries. Additional data on temperature suggested that the shrimp migrate in response to temperature changes.

Offshore-inshore migration of *Pandalus borealis* in the Gulf of Maine was described by Haynes and Wigley (1969) and Apollonio and Dunton (1969). Data from research sampling stations was supplemented with commercial fishing samples to infer movement of the shrimp. The abundance of shrimp, by sex and age, was used to trace the migrations. After the migration pattern was established, additional data showed that timing of the migration was related to changes in water temperature.

The above review of studies on shrimp movement points out the basic pattern followed by the researchers. Shrimp movement is first inferred based on research and/or commercial fishing. This aids in the gathering of data on the environmental variables which usually account for the cause of the migration. In some areas, however, migration patterns are described, but environmental variables do not change significantly and cannot be correlated to movement.

One example is a Fish Commission of Oregon study off Tillamook Head reported by Lukas and Hosie (1971, a draft report). Sixteen stations were sampled routinely on a monthly basis for a year. The abundance of shrimp fluctuated in the study area, decreasing from an initial estimate of 10.6 million pounds to a low of 1.4 million pounds and then increasing to 10.5 million pounds on the last cruise of the study. Bottom temperature data was not significantly different from station to station or cruise to cruise to be of use in describing movement.

Application of the Inferential Technique to Oregon Data

Introduction To determine if movement of pink shrimp along the coast of Oregon could be inferred from the activities of the commercial shrimp fleet, the logbook data obtained from shrimp fishermen were examined. The fishermen are required to maintain logbooks and record the location, depth, duration and estimated catch of each tow. This data is somewhat comparable to that which would be collected by research fishing. It was assumed that the commercial fleet would fish on the main concentrations of shrimp and that examination of at least two seasons fishing would reveal a pattern, if present, which could be related to shrimp movement.

Methods Logbook data from two seasons, 1969 and 1970, from northern Oregon were used. The northern Oregon area included shrimp grounds extending from the Columbia River to Yaquina Head. This 89-mile long area was divided into 11 sub-areas by using Loran lines to delineate north and south boundaries. Each sub-area included 100 microseconds or approximately eight nautical miles on a north to south basis. No attempt was made to sub-divide these areas east to west. The resultant data, therefore, could only be used to trace shrimp movements north or south along the coast. In the discussion, each sub-area is also referred to as a Loran block with southern Loran line identifying the sub-area.

Shrimp boats which had fished in this area during most of the season and boats for which nearly complete logbook data was available were selected. These included boats which fish out of Astoria, Garibaldi and Newport. During the 1969 season, seven vessels had usable data and for 1970 there were nine vessels.

We analyzed data for the periods March 2 to October 25 and March 29 to September 26 in 1969 and 1970, respectively. The catch and catch per effort of each vessel in each sub-area fished was totaled by two-week periods. It was hypotheized that the total catch data would show where the largest concentration of shrimp was on the grounds. The catch per effort data might indicate if dense schools of shrimp move from one sub-area to an adjacent sub-area.

Results The seven shrimp vessels had logged landings of 1.9 million pounds in 1969. Commercial shrimp landings in northern Oregon totaled 5.3 million pounds. These seven boats caught 36% of the shrimp taken off northern Oregon.

In 1970, the logs from nine shrimp boats showed a total of 2.5 million pounds. Commercial landings totaled 5.1 million pounds of shrimp. These 9 boats landed approximately 50% of the total catch in northern Oregon. These figures are minimal because of the incomplete data in some logbooks.

Figures 1 and 2 depict the catch per effort and total catch of the boats sampled by sub-area for 1969 and 1970.

Discussion Gross examination of the two figures reveals the differences in the apparent overall shrimp distribution between the 1969 and 1970 season. The main concentration was apparently in the northern part of the area in 1969 and it appears that the main concentration of shrimp had shifted southward during the 1970 season. This could very well be the case, but the evidence is not conclusive. Relatively little effort was expended in the area south of Cape Lookout in 1969. Two of the seven shrimp vessels were landing at Garibaldi or Newport up to the end of June, the rest were landing at Garibaldi or Astoria after June, only one boat was consistently landing at Newport. Good shrimp fishing may have been available between Cape Lookout and Yaquina Head, but the majority of the fleet was fishing between Cape Lookout and Tillamook Head. Rather than "prospect" for other possible good shrimping areas, the fleet remained in this area of known commercial concentrations of shrimp.

In 1970, six of the nine shrimp boats were unloading their catches at Newport. This may have had some effect on the results. Catch rates were high in the area between Cape Falcon and Cape Meares, but they were nearly as high in the area between Cape Kiwanda and Yaquina Head. Rather than fish in the area off Garibaldi, it was more opportune for the shrimp vessels to trawl in the area between Cape Kiwanda and Yaquina Head. The fleet, therefore, had shifted most of their effort to the southern portion.

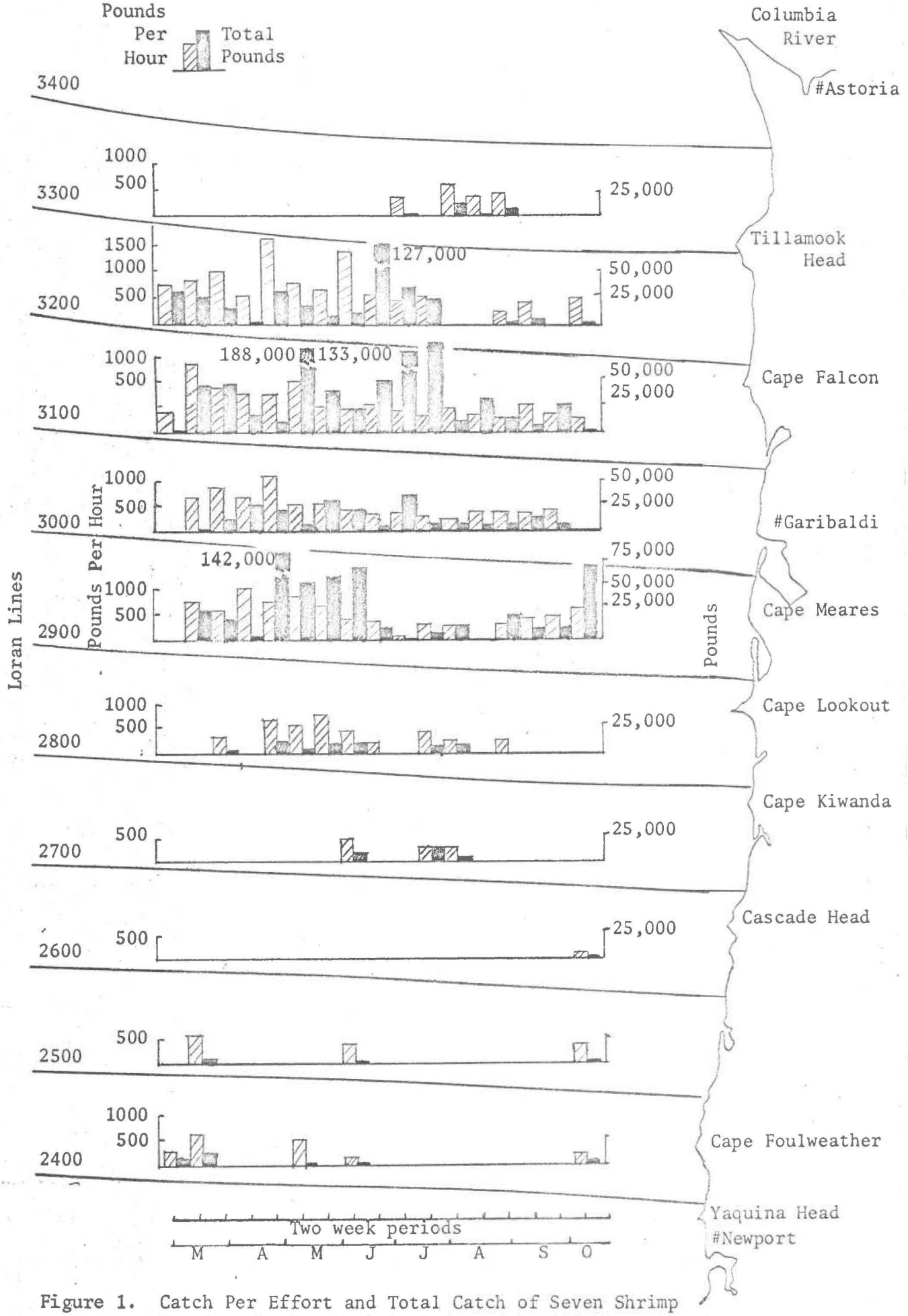

Figure 1. Catch Per Effort and Total Catch of Seven Shrimp Trawlers by Two-Week Periods and by 100 Microsecond Loran Area, March 2 - October 25, 1969.

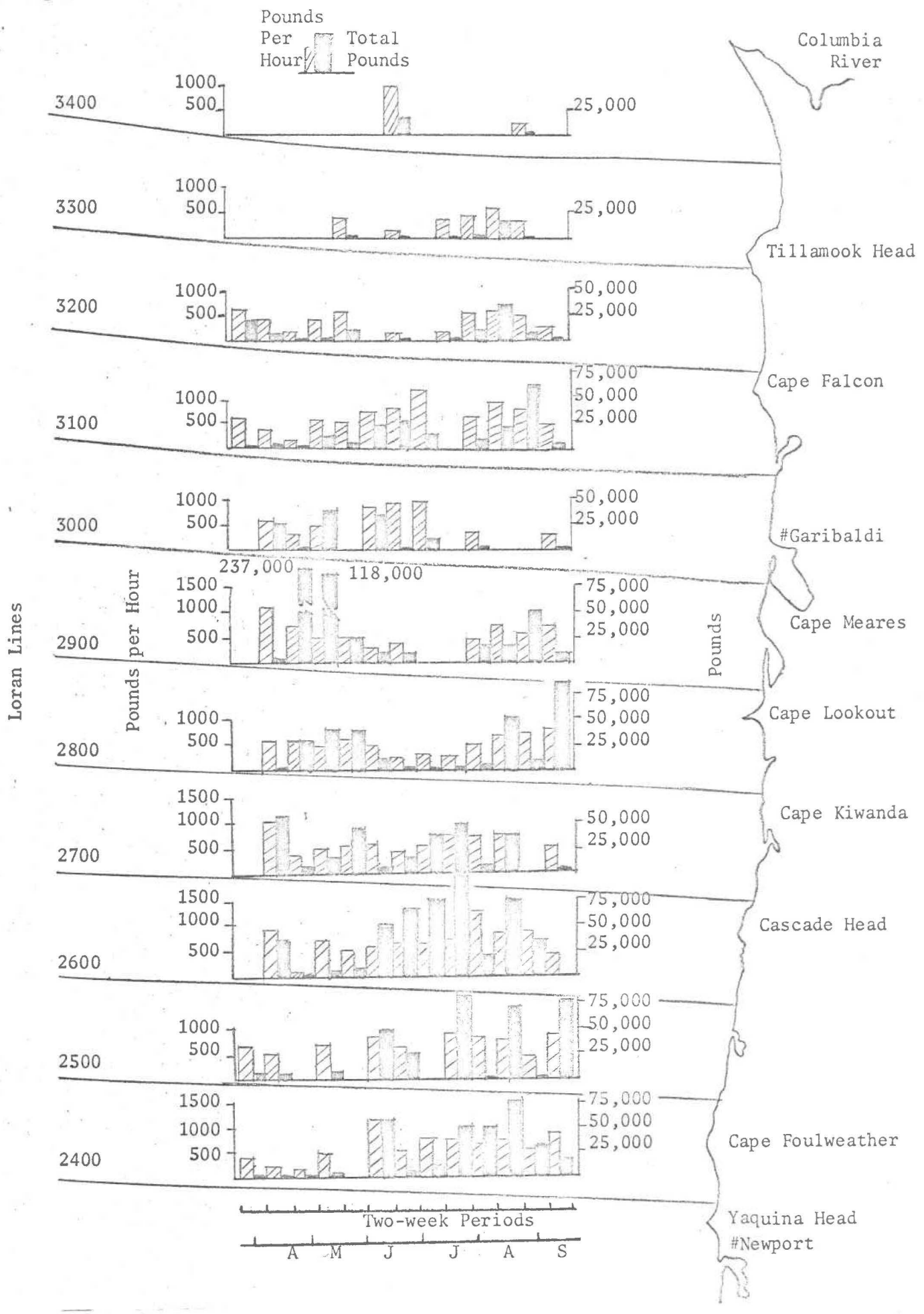

Figure 2. Catch Per Effort and Total Catch of Nine Shrimp Trawlers by Two-week Period and by 100 Microsecond Loran Area, March 29-September 26, 1970

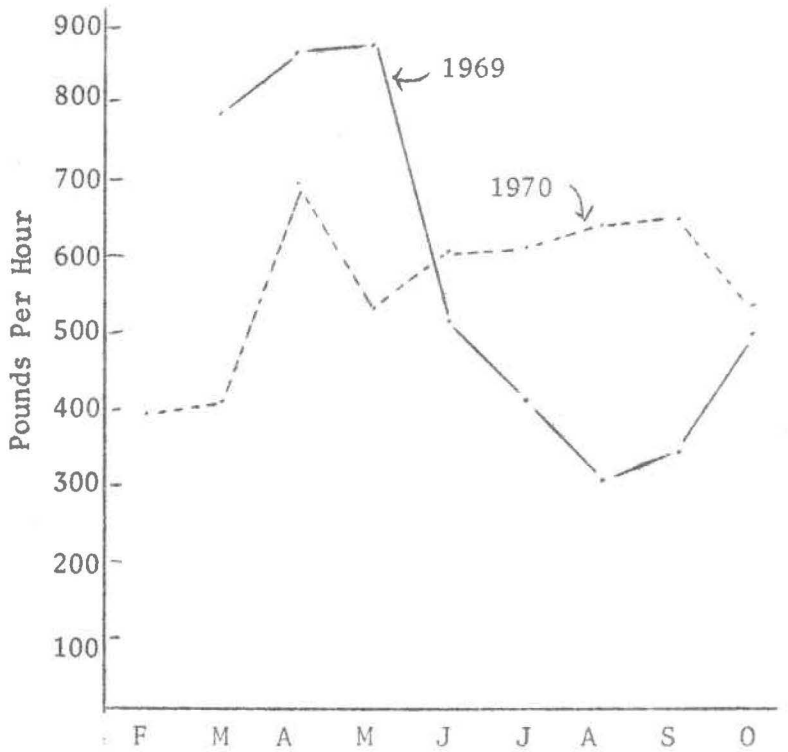

Figure 3. Average Catch Per Unit of Effort for Shrimp Study Boats by Month in Northern Oregon, 1969 and 1970.

locate good concentrations of shrimp in other areas. In 1970 when the catch rates decreased in the 2800 and 2900 blocks, the fishermen shifted their effort to other areas and were able to locate good concentrations of shrimp. As a result, the catch rates remained at a high level during the entire season (Figure 3).

From the 1970 data, it appears the main school of shrimp was in the 2600 to 2900 block at the start of the season, then concentrated in the 2800 and 2900 blocks for a six-week period, then split with the main concentrations moving south to the 2600 and 2700 blocks and a smaller school moving north. The shrimp school in the 2600 and 2700 blocks apparently split again in August and September moving to the 2400, 2500 and 2600 blocks.

The analysis of data for the 1969 and 1970 seasons show that shrimp distribution does not follow a pattern. However, the two years selected may not have been typical, if there is such a thing as a typical year. Data from years prior to 1969 indicate a general trend of distribution, i.e., a shifting of the main concentration of shrimp from north to south in alternate one or two year periods.

One of the weaknesses of using commercial data exclusively is that the commercial fleet will tend to trawl in areas which produce high catch rates, or the fishermen will avoid an area which may be producing large quantities of shrimp, but also includes large amounts of trash fish in the catch. Another weakness was that the logbook data were not complete. For example, the data for one or more trips or part of a trip would not be recorded. Also, the vessels may have made occasional trips during the season to other areas. This occurred mostly with the Astoria boats who frequently shrimp off the Washington coast. On several occasions, vessel breakdown forced a boat to remain in port which curtailed his normal effort. Therefore, these data may indicate movements of the fleet rather than the shrimp.

In other studies on the migrations of various species of shrimp, the movements were described in terms of a response to a change in the environment or as a result of the pattern of the life history of the species or a combination of both. To be better able to evaluate the changes in distribution of pink shrimp based on commercial catches, data should be collected on bottom temperatures and salinity and compared for possible correlations.

Serological and Biochemical Methods

Introduction

Serological and biochemical techniques have proven to be valuable tools for defining sub-population units. They have been used in studies involving both aquatic and terrestrial vertebrates and invertebrates. These methods have limited value however, for use in describing movements or migrations of a species unless the population moves as a unit such as schools of tuna or sardines. A sub popultaion is defined as having unique genetic polymorphism which is not comparable with other sub-population units. If interbreeding occurs between populations, the genetic characteristics will be similar and each ceases to be distinct. Some sub populations may retain their discreteness even though they may intermingle with other sub populations of the same species. They remain distinct because each population returns to a specific area at the time of spawning such as occurs with salmon.

These techniques have been directed to problems in marine fisheries biology where identification of sub populations are important so that proper management techniques can be applied. A comprehensive work by de Ligny (1969) reviews these techniques and summarizes the results of studies where they were applied. The following discussion considers briefly only the basic concepts of these two methods.

Serological Methods

Most of the serological concepts and techniques were initially developed for use on humans and domestic animals. In the 1950's, investigators began using these

techniques to identify racial populations of fish. Relatively little work has been done on crustaceans.

Blood contains several components all of which are genetically controlled. These include blood groups; hemoglobins; serum proteins, transferrins, albumin and enzymes. They may exhibit genetic variants which can be used to distinguish one population from another population of the same species.

Blood group types are determined by the reactions of antigens on the erythrocytes with antibodies. Serums or reagents are developed by the investigator and contain antibodies which will agglutinate specific types of antigens. Once the blood groups are identified, their frequency which is genetically controlled can be established.

Although shrimp lack cells comparable to erthrocytes, serums of invertebrates have been used in the agglutination of specific antigens of vertebrates. Cushing (1964) feels that there are substances in the blood of invertebrates which will also react in a manner similar to antigens.

The other components of blood are analyzed for polymorphism by utilizing electrophoretic techniques. Relatively little work has been done on crustaceans in studying these components in relation to racial identification. One study on lobsters, (*Homarus americanus*) reported by Barlow and Ridgway (1969), determined that the total serum protein fluctuates in amount during various phases of the molt cycle and may be present or absent in electrophoretic analysis depending on the molt phase. It would be difficult therefore, to determine if the differences in serum proteins in shrimp are associated with the molt cycle or to actual genetic polymorphism. The physiological changes involved in the molt cycle could result in differences in the other components of the blood.

Biochemical Methods

The biochemical analysis of tissue proteins and enzymes using the electrophoretic method has revealed polymorphisms which are genetically controlled. As with serology, these techniques have been used almost exclusively on fish and higher vertebrates. The variations detected in the proteins and enzymes in the tissue and serum result from differences in their chemical make-up. Each type of protein and enzyme molecule typically has a specific size, shape and charge. In one given population, a specific protein or enzyme (can be one or more) may have two slightly different types of molecules. Even though they may preform the same function, they will react differently when subjected to electrophoresis. Any differences which may occur in specific proteins or enzymes are typically genetically controlled. Therefore, the phenotypes which are detected by electrophoresis frequently can be related to genotypes. If a population is an isolated interbreeding unit (with random mating), the specific protein or enzyme will exhibit a genetic polymorphism which will exist generation after generation in accordance with the Hardy-Weinburg Law. Comparing the gene frequencies of this variant with the same protein or enzyme of another population may reveal significant differences. The conclusion would be that each population is a discrete interbreeding unit.

Discussion

In respect to determining the movements of shrimp stocks along the Oregon coast, serological or biochemical methods probably are not applicable. However, as pointed out in the general introduction, there may be stocks of shrimp certain areas which are discrete populations. Rather than embark upon a tagging program, for example, to determine if immigration or emigration of shrimp occurs in a specific area, it would be more appropriate to initially preform a biochemical analysis on a sample of the population. If genetic variants occur which are significantly different from other areas, biochemical analysis would offer a quick and simple method of verifying that a specific stock is a discrete population.

In a discussion with Dr. Fred Utter of the NMFS Technological Laboratory in Seattle, Washington, regarding the possible discreteness of certain stocks of shrimp, he suggested that a preliminary analysis be preformed on samples representing selected stocks.

Samples of shrimp from Astoria and Coos Bay were obtained and analyzed by Dr. Utter. He screened the samples for possible variants of 24 enzyme systems and non-specific protein. Only one enzyme (Phosphoglucomutase, PGM) showed evidence for genetic variation. One form occured in three of 90 Astoria shrimp and did not occur in 90 Coos Bay shrimp. He concludes; "If this trend persists, this variant may be useful as a racial marker if sufficiently large samples are tested".

On the basis of this preliminary analysis, it appears that the biochemical method may be of value in defining sub populations along the coast if they exist.

Recommendations

The diverse methods which have been developed to enable biologists to define populations and their movements and migrations have been successful in numerous studies on a wide variety of living organisms. Each of the techniques reviewed in this report could be feasible in determining the movements of shrimp given the right amount of time, money and expertise. All have certain advantages and disadvantages, but a few do stand out as being more practical than others.

The preliminary success of Dr. Utter's biochemical analysis of shrimp enzymes offers the first logical step. This method offers an opportunity to define a racial unit, if such units exist in our shrimp stocks, in a quick and relatively simple procedure. A program should be developed to sample all populations of shrimp along the Oregon coast and northern California and southern Washington stocks. These samples should be taken during the spawning period to insure that individuals are selected from discrete populations if they exist. It may be

possible to obtain samples of female shrimp during the period they are gravid, assuming that they would remain on the spawning grounds until the larvae are hatched. However, there is some evidence that females may move to other areas after spawning. The biochemical analysis could be sub-contracted out to a laboratory which has the equipment and personnel to conduct the tests.

If the biochemical analysis demonstrates that there are discrete sub-populations in some areas and parameters can be defined, this would aid the Fish Commission in designing specific programs for further research on fluctuations of abundance, recruitment, etc., of the distinct sub populations.

In other areas where adjacent populations have similar genetic characteristics, makring studies should be initiated to evaluate movement.

In terms of providing conclusive evidence of movement, marking shrimp with biological stains is probably the best method. Inferential methods using commercial fishing data could be used as evidence to support conclusions reached on marking studies. Research sampling would provide more consistent and reliable inferential data and should be considered if money and time are available.

Because pink shrimp are a smaller and more delicate species than the penaeid shrimp, marking them with biological stains would be superior to tagging with an external disc tag. Preli .inary tests in our laboratory have shown that the survival rate of simulated stained shrimp is much greater than tagged shrimp.

If more precise information is needed on movements of shrimp then internal tags and ferro-magnetic tags should be considered.

These recommended marking and tagging techniques should be evaluated on test animals in the laboratory concurrently with the biochemical analysis of the shrimp population.