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AN EVALUATION OF METHODS FOR DETERMINING
MOVEMENT OF SHRIMP

PHASE I: SHRIMP MOVEMENT STUDIES

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TABLE OF CONTENTS

	<u>Page No.</u>
Introduction	1
Tagging and Marking Methods	2
<u>Introduction</u>	2
<u>Petersen Disc Tags</u>	2
<u>Loop-Type Tags</u>	3
<u>Biological Stains</u>	4
<u>Fluorescent Pigments</u>	5
<u>Polyvinyl Chloride Tags</u>	6
<u>Coded-Wire Tag</u>	6
<u>Recovery of Marked Shrimp</u>	7
Inferential Methods	10
<u>Introduction</u>	10
<u>Inferential Techniques Used</u>	10
<u>Application of the Inferential Technique to Oregon Data</u>	13
<u>Introduction</u>	13
<u>Methods</u>	13
<u>Results</u>	14
<u>Discussion</u>	14
Serological and Biochemical Methods	17
<u>Introduction</u>	17
<u>Serological Methods</u>	17
<u>Biochemical Methods</u>	19
<u>Discussion</u>	19
Recommendations	20
Literature Cited	22

LIST OF FIGURES

<u>Figure No.</u>		<u>Page No.</u>
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.	14a
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.	14b
3.	Average Catch Per Unit of Effort for Shrimp Study Boats by Month in Northern Oregon, 1969 and 1970.	15a

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PHASE 1: SHRIMP MOVEMENT STUDIES

Introduction

The management policy of the Fish Commission of Oregon concerning the Pacific pink shrimp, (*Pandalus jordani*) has resulted in regulations which apply to all shrimp along the Oregon coast and do not recognize separate populations. There are several shrimp grounds along the 300-mile length of the continental shelf off Oregon which may support distinct populations of shrimp. Until recently, it was believed that the shrimp fleet has been underharvesting the resource on these grounds. However, in the last few years the fleet and the intensity of the fishery has increased and concern has arisen that certain areas are being over-exploited. At present, we do not have enough information to determine if certain areas are inhabited by discrete populations of shrimp.

The importance of determining this is that a distinct and discrete population of shrimp may have their own characteristics of behavior, recruitment, mortality, growth, etc., and may need to be managed in a manner different from other stocks. If, on the other hand, shrimp from two stocks intermingle and are fished on together, we need to know the extent of interchange if the stocks are unequally exploited; the effect of environmental variables on interchange; changes in behavior and recruitment, etc.

Shrimp research planning by the Fish Commission of Oregon is directed towards answering questions of this nature. The first step is determining quantitatively the movements of shrimp. Several methods have been used by fishery agencies in research on the movements and migrations of shrimp populations. These include tagging, marking and inferential determination of movement by research fishing and/or sampling the commercial fishery. Two other methods,

serological and biochemical, have been of value in establishing the discreteness of populations and may have limited application in assessing movements in certain circumstances. This report evaluates the feasibility of these methods for defining possible movements and migrations of pink shrimp.

Tagging and Marking Methods

Introduction

Mark-recapture studies have proven useful for obtaining information on the migration, growth, population size and mortality rates of many species of aquatic animals. The successful development of techniques using tags and marks centered on various species of fish. The development of these methods for shrimp presented a different and more difficult problem, but biologists have been successful in adapting tagging and marking techniques for use on shrimp. These techniques have proven to be feasible as demonstrated by numerous laboratory and field studies. However, the success of these methods are totally dependent on a well-executed recovery program. Without this, the effort of a tagging or marking study is wasted.

Tags developed for use on shrimp have been small pieces of plastic or wire, numbered or color coded and attached either externally or internally. Marking shrimp involves the injection of a stain or fluorescent pigment rather than removing or mutilating appendages.

The following discussion reviews the type of tags and marks found most satisfactory for use on shrimp.

Petersen Disc Tags

One of the earliest studies using Petersen disc tags involved a project investigating the migrations of the white shrimp (*Penaeus setiferus*) in the

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 first 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 interfere 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 coloration. 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.

Three stains, Trypan Blue, Niagara Sky Blue 6b, and Fast Green FCF, were found to be satisfactory 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.

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This technique was used in many different studies in the Gulf of Mexico, Klima (1963), Klima and Osborn (1964), Klima and Benigno (1965) and Knight (1966, 1967). Because juveniles could be successfully marked by staining, studies utilizing this method demonstrated that juveniles migrate from the estuaries to off-shore waters. Relatively little has been reported by investigators in areas other than the Gulf of Mexico, in using stains for mark-recapture studies. George (1967) mentions the use of stains on two species of shrimp (*Metapenaeus dobsoni* and *Penaeus indicus*) in India. For *Metapenaeus dobsoni*, the staining method was not considered suitable because of the "small size" of the shrimp (further explanation was not available), but for the larger species, *Penaeus indicus*, it offered some promise for field use. Apollonio and Dunton (1969) experimented with biological stains on the shrimp harvested in the Gulf of Maine, (*Pandalus borealis*). The results were not encouraging. The stain did not impart a clear distinctive mark in the shrimp gills and they felt it would be confused with a normal mud-covered shrimp. Slack-Smith (1969b) mentions the migrations of two species of Penaeid shrimp in Shark Bay, Western Australia as determined by the results of dye marking experiments.

The equipment used in the field during stain-marking experiments is described by Costello (1964), Neal (1969) and more recently by Emiliani (1971). These reports discuss the capturing, holding, marking and releasing of shrimp. According to Emiliani, 1,500 to 3,000 shrimp can be marked per day.

Fluorescent Pigments

Even though the staining method was used extensively, only two colors of stains were usable and this restricted the number of experiments which could be undertaken in a study area. To overcome this, fluorescent pigments were

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 ECF Galveston Laboratory (Neal, 1963). This tag, of polyvinyl chloride (0.127mm 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 Petersen 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 horseshoe 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) estimated 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 hypothesized 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,

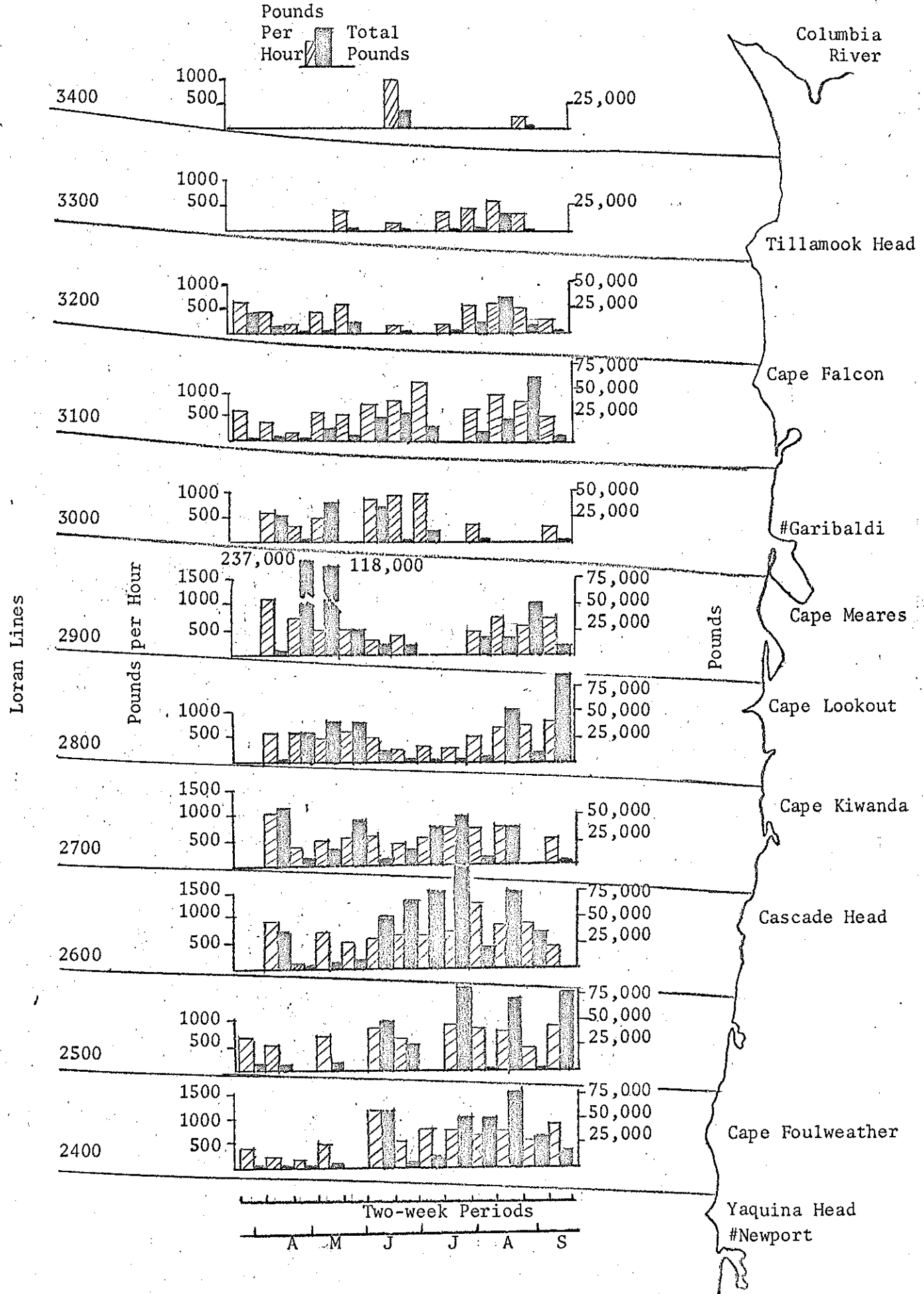


Figure 2. Catch Per Effort and Total Catch of Nine Shrimp Trawlers by Two-week Period and by 100 Microsecond Loran Area, March 29-September 26, 1970

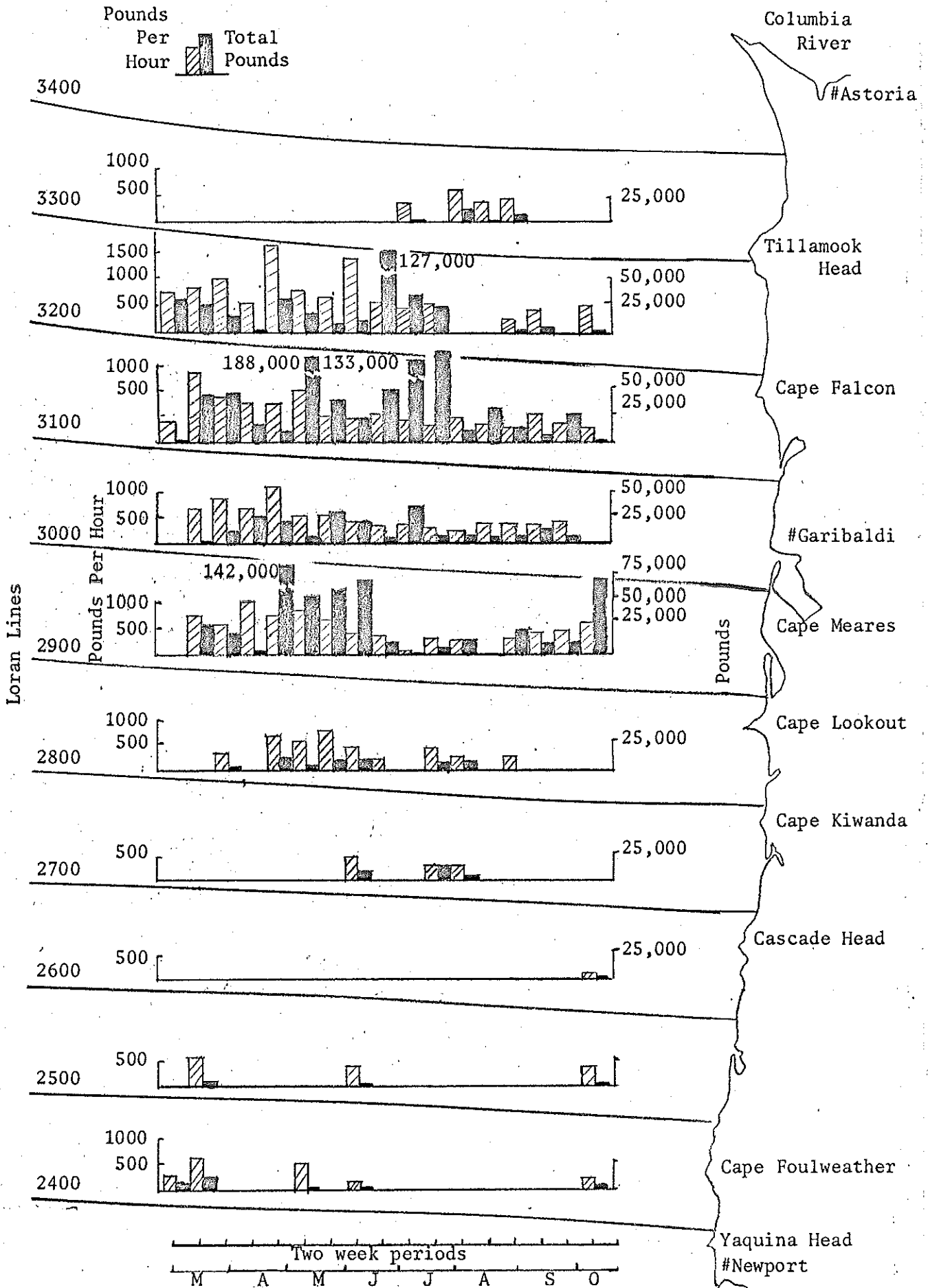


Figure 1. Catch Per Effort and Total Catch of Seven Shrimp Trawlers by Two-Week Periods and by 100 Microsecond Loran Area, March 2 - October 25, 1969.

During the 1969 season, the catch per effort was high at the beginning of the season and gradually decreased from June through August (Figure 3). In some sub-areas, it increased in September and October and in other sub-areas, it remained low through the end of the season. The decrease in the catch rate is a typical occurrence during a shrimp season (Jack Robinson, personal communication). When the shrimp became less available in the area between Tillamook Head and Cape Meares during July and August, it was not possible to determine if they moved to other sub-areas. The population may have dispersed both north and south, but if they did they were not in concentrations high enough for commercial fishing. As the shrimp catch rate in the sub-area between Loran lines 2900 and 3000 (the 2900 block) decreased, some effort was made in the 2700 and 2800 blocks. The same thing occurred to the north. Fishing Effort shifted to the 3300 block, from the 3100 and 3200 blocks, during August and September. These efforts apparently were fruitless as the results show and the fleet was not able to locate commercial concentrations of shrimp. The only sub-area which increased in production at the end of the season was the 2900 block. Shrimp from other sub-areas may have been moving to this sub-area, but it is difficult to substantiate this.

The data suggest two stocks of shrimp with a break in the distribution in the 3000 block, but this is not the case. Certain portions of the 3000 block have reefs and a rock bottom and only a few fishermen who know the area well fish there.

The data in Figure 2 offers some evidence of possible shrimp movement. At the beginning of the season, the 2600 and 2700 blocks and then the 2800 and 2900 blocks produced large quantities of shrimp. During June and July, the catch rates decreased in the 2800 and 2900 blocks, but in the 2600 and 2700 blocks to the south they remained high and the fleet shifted to the south. Catch rates in the 3000, 3100, 2400 and 2500 blocks increased during this period. In late August and September, the 2500 and 2800 blocks had greater catch rates than the 2600 and 2700 loran blocks. The 1970 season was not typical in respect to catch rates. During 1969 when the catch rates decreased in one area, the fishermen were not able to

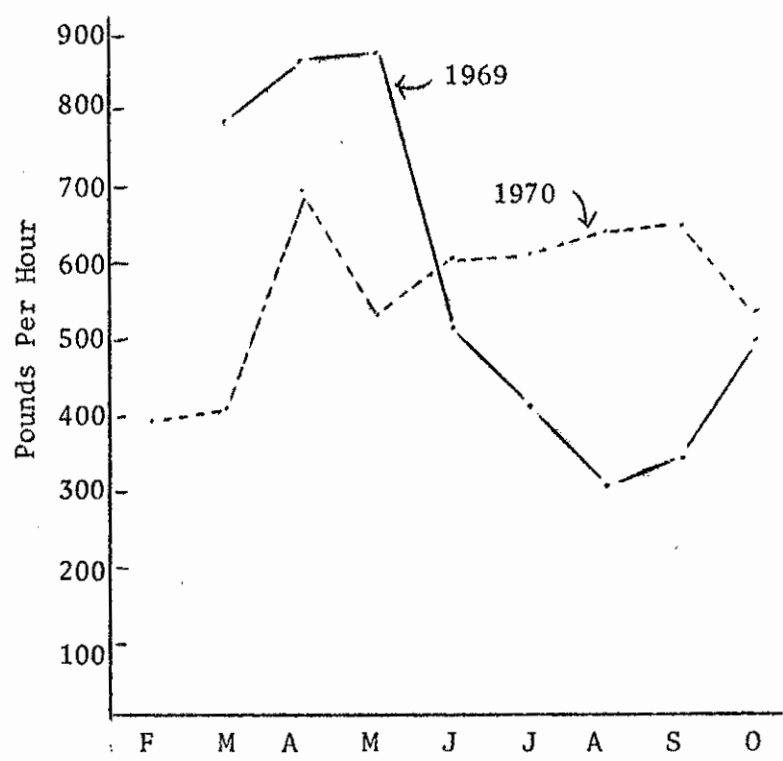


Figure 3. Average Catch Per Unit of Effort for Shrimp Study Boats by Month in Northern Oregon, 1969 and 1970.

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 population 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 erythrocytes, 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 perform 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-Weinberg 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 perform 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 performed 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 (Phosphoglucumutase, PGM) showed evidence for genetic variation. One form occurred 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, marking 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. Preliminary 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.

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