OREGON STATE UNIVERSITY SEA GRANT

PLEURONECTID PRODUCTION SYSTEM AND ITS FISHERY

ANNUAL REPORT 1979
for Project No. R/OPF-1

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INVESTIGATORS:

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INTRODUCTION

The project has now completed its fourth year, and will carry on for two more years. Development of large group projects, such as this one, is difficult at a university. University scientists have a tradition of independent study, and a tendency for diverse sources of funding for small projects. The Office of Sea Grant has made it possible for us to develop an interdepartmental, unified project by making block funding available to a group of ocean biologists. The participants have specialties in larval and juvenile fish ecology, benthic invertebrate ecology, trophic relationships of fishes, fishery stock dynamics, and eco-systems modelling. The project theme - expressed by the project title - was not merely a modification of existing projects, but a new joint effort selected from among a number of possible research directions. There has been an enormous amount of idea interchange, and inter-investigator influence during the course of the work. This story is interesting in itself and will be documented in a non-technical synthesis of project results to be produced in the coming year.

OBJECTIVES:

1. To define and map the species assemblages associated with Dover and English sole on the trawling grounds of Oregon's continental shelf.
2. To determine ecological interactions among associated species, and factors influencing the productivity of the demersal phase of life history.
3. To identify critical factors in the pelagic, early life history phase of pleuronectids that may influence larval survival and year-class strength.
4. To develop and propose new hypothetical fishery management strategies for problems of pleuronectid stock dynamics, and multi-species trawler fisheries.

EXTENSION OF COMPLETION DATE REQUEST

The project requires a one-year extension because of the following reasons:

1. Project members have been requested by the Sea Grant National Office to develop a non-technical synthesis of the entire project. A series of meetings have been planned in which the four principal investigators will draw together and synthesize the projects' findings around the community food-web structure of the pleuronectid production system.

2. Four GRAs require extra time to finish their theses and publish their findings. Specifically:

   a) G. Kruse, who with A. Tyler has been developing a mathematical model of English sole reproductive timing and year-class success.

   b) T. Hayden, who with A. Tyler has been developing a computer simulation model for stock assessment of the English sole.

   c) C. Hoag, who with D. Carey, has been carrying out a field study of the role of benthic meiofauna in the productivity of juvenile English sole.

   d) R. Brodeur, who with W. Pearcy has been working on feeding and distributional analysis of English sole.

ANTICIPATED BENEFITS:

1. Stock simulations of both Dover and English sole will be useful to the Pacific Regional Council for setting catch quotas that take into account the actual, annual variation in year-class strength, and will prevent reproductive overfishing.
2. Understanding recruitment processes will allow managers to judge whether stock decline is owing to oceanographic factors or to fishing effort effects.
3. New proposals for fish assemblage management in the mixed-species, trawler fishing will be useful to the Regional Councils for preventing the demise of numerous stocks fished for supplementary catch, but which are important in the aggregate landings.

OBJECTIVES:

More than half of the 20 million pounds of groundfish landed in Oregon ports in 1975 were flatfish of which 4.7 million pounds were Dover sole. Though resource agencies and fishermen are concerned about the amount of fishing effort pleuronectid stocks will withstand, there are difficulties in completely assessing fishery potential. The Washington-Oregon coastal trawler fleet lands a complex mix of species. Traditional yield calculations in this multispecies fishery require a body of data so large that it may be unattainable except for major target species. Furthermore, if species of the continental shelf ecosystem interact substantially, and thus cannot achieve maximum productivity simultaneously, applying traditional yield models will not lead to long-term fishery stability. Also, some of the traditional models cannot be applied correctly because shifts in fishing effort in the last 15 years have led to some species' nonequilibrium status. To help resource agencies deal with these problems, we propose: (1) to define and map the species assemblages associated with Dover and English sole on Oregon's continental shelf trawling grounds; (2) to explore ecological interactions among associated species and the factors influencing the productivity of their demersal phase; (3) to identify factors in pleuronectids' pelagic phase that may affect larval survival and year-class strength; and (4) to develop new hypothetical fishery management strategies for problems of pleuronectid stock dynamics, cost-benefit relationships, and multispecies trawler fisheries.

IDENTIFIED BENEFITS TO DATE:

1. Growth studies of Dover and English sole have shown that Dover sole in the stock off the Columbia River are faster growing than other Dover sole stocks off Oregon. This faster production rate should be accounted for in fishery yield estimates. Oregon sampling programs for English sole growth rate changes can be simplified, since no regional differences could be detected. Sampling for the entire Oregon coast could be done with fish off Coos Bay.
2. The upwelling process was shown statistically to influence year-class strength of both Dover and English sole. Trends in upwelling could be used to forecast trends in Dover and English sole productivity.

3. Oregon catch maps of commercial target species have been turned over to the Oregon Department of Fish and Wildlife (ODF&W), and the Northwest Fisheries Center, National Marine Fisheries Service, to form part of the data base for negotiations regarding closure of shelf areas to foreign fishing.

4. Catch maps of commercial target species were supplied to NW and Alaska Fisheries Center (NMFS) for planning research cruises in 1977.

KEYWORDS: Fishery, benthos, icthyoplankton, simulations, modeling, feeding habits, larval fish, distributions, assemblages.

SUMMARY OF SUB-PROJECTS AND INDEX TO PROGRESS REPORT

*See last year's progress report.

Progress in 1978-1979

SUBPROJECT: Distribution and Movements of English Sole Based on

1.a. Commercial Landings

INVESTIGATORS: G. Hewitt, W. Pearcy

Examination of monthly commercial catches of adult English sole off Oregon (excluding Astoria) has been completed for the years 1973, 1975, and 1976. Intervals of monthly maximum CPUE, effort, and landings within 80 fathoms and between Coos Bay and Cape Lookout were plotted for 1973 and 1975 for both depth (5 fathom interval) and 1LO LORAN L100 μ sec interval). The resulting east-west and north-south temporal catch profiles were used to extract local trends of seasonal migration by initially assuming that all effort within the defined area was attributable to English sole. Interferences which caused discrepancies in the effort and CPUE statistics with respect to English sole were filtered out.

Due to its higher market value, petrale sole was the most important factor that affected effort particularly in the summer months when this species moves inshore and overlaps the depth distribution of English sole. In addition, targeting on inshore Dover sole concentrations was found to be a factor in certain spring months. Effects of weather, market variability, and fishermen behavior were also considered.

The seasonal migration patterns of English sole appear to be linked with spawning. The average depth of catches increases and larger and more frequent commercially-exploitable aggregations begin appearing in the fall, just prior to commencement of spawning in late fall and winter. Spring dispersal and slight inshore movement may be a partial reflection of medium-scale longshore migrations which may alleviate intraspecific competition for food. This dispersal results in much decreased fishing pressure.

PROJECT 2C: Intensive study of invertebrate prey of pleuronectids: availability and meiobenthic-juvenile English sole food web.

INVESTIGATORS: A.G. Carey
E.W. Hogue
L. Kaskan

Two research approaches have been taken toward the major goal of further defining the pleuronectid-benthic invertebrate food web: (1) availability to the predators, and (2) the food sources of juvenile English sole. Fieldwork for these projects was completed during October 1979.

During the course of this study, the benthic macro-infauna have been sampled at six stations from selected fisheries environments across the continental shelf to determine their physical availability to the pleuronectid predators. Box core (0.25 m^2 Hessler-Sandia) samples were collected at each station, and the sediment was serially cross-sectioned. Studies on the species composition, faunal abundances and vertical distribution within the sediments have demonstrated that most species live in the upper several centimeters of sediment while a few deeper-living forms have been found at most stations. These vertical distributional patterns will be correlated with sediment characteristics to determine if causal relationships may exist. Particle size and organic carbon analyses have been completed for one station, the 200 meter station at the edge of the continental shelf.

The meiobenthic-juvenile English sole phase of the pleuronectid research has concentrated on the coastal region of Moolach Beach. Four species of pleuronectiformes use the shallow waters of Moolock Beach as a nursery ground; sand sole, English sole, butter sole, and speckled sand dab. The amount and type of food items available to these fish can be of potential importance in determining their growth rates and year-class success. Beginning in July 1978, a field program was initiated to study the relationship between the gut contents of the O-age class pleuronectiformes found on the Moolock Beach nursery grounds and the benthic prey species which they consume. The specific goals of this ongoing program remain 1) to identify benthic species utilized as food by 0-age class pleuronectiformes, 2) to monitor seasonal changes in the gut contents of juvenils fish, 3) to describe the temporal and spatial distribution of benthic food items, and 4) to relate gut contents with the benthos.

From results of this study the following generalizations can be tentatively made thus far:

1) The four species of pleuronectids lie along a trophic continuum. English sole is solely a benthic feeder, butter sole feeds mainly on bottom invertebrates but it also gathers prey in the water column, speckled sand dab generally consumes pelagic food but sometimes takes benthic items, and sand sole feeds exclusively in the water column.

2) The gut contents of English sole change seasonally, reflecting the changes in benthic food items available for consumption.

The field portion of this program has concluded following the completion of 11 cruises between July 1978 and September 1979. The sorting of existing samples, identification of species, and data analysis are in progress.

SUB-PROJECT: Feeding Relationships Within an Assemblage of Demersal
2c-2 and Nektobenthic Fishes on the Oregon Shelf

INVESTIGATORS: W. W. Wakefield and W. G. Pearcy

An investigation of feeding habits of demersal and nektobenthic fishes has been initiated on the inner continental shelf near Newport, Oregon. The study area coincides with the sampling site for a current project examining various aspects of the biology of juvenile flatfishes with an emphasis on English sole. The objectives of this investigation are to (1) describe food partitioning among fishes, (2) study possible predation on juvenile English sole, and (3) examine the species composition and size range of fishes inhabiting shallow and deep water areas.

A suite of trawl samples was collected at 3 stations along a transect off Mooloch Beach, Oregon at depths of 9, 22, and 73 m, during spring and summer, 1979 (Gigure 1). The stomach contents of the fish collected during these trawl surveys are currently being analyzed. An Atlantic Western IV-A trawl and paired 90' shrimp trawls were used on May 21, and June 6 respectively. The cod end of the IV-A trawl was lined with a 1.5" stretched mesh webbing to insure capture of a broad size range of fishes. Duplicate night comparison trawls were made at each station to produce a data set appropriate for an analysis of diel periodicity in feeding. A set of 1.5 and 3 m beam trawl samples, collected along the same transect, will provide samples of small individuals (<100 mm), and schooling species that were not captured by the commercial gear. Epibenthic and infaunal samples from the 22 m station will be utilized for the purpose of examining prey availability and predator selectivity.

A qualitative examination of the May 21 trawl data indicates differences in the assemblage of flatfishes inhabiting shallow (9 and 22 m), intermediate (73) shelf depths. The numerical abundance of each species is summarized by trawl in Table 1. The following flatfish species, listed in order of decreasing abundance, were common in the 73 m trawl catches; Pacific sanddab, English sole, butter sole, Dover sole, petrale sole, rex sole, and rock sole. In contrast, the 9 and 22 m trawl catches were dominated by sand sole, butter sole, and starry flounder. Several non-flatfishes were abundant at the shallow water stations; big skate, ratfish and Pacific tomcod. These three species were not abundant at the intermediate depth.

The majority of the stomach analysis completed thus far has been conducted on fish from the day trawl at the 9 m station. Preliminary results, in the form of histograms of numerical percent composition, are summarized in Figures 2 and 3 for the dominant fish species collected. Big skate fed primarily on the epibenthic decapod shrimp, Crangon stylirostris. Crangon were also a minor constituent in the diet of larger butter sole. Butter sole had the most diverse diet feeding on polychaetes, fish, Crangon, and amphipods of the genus Atylus. Starry flounder also fed on Atylus as well as razor clam siphons (Siliqua), sand dollars, and juvenile Cancer magister. Smaller sand sole (<200 mm) fed primarily on diverse assemblage of epibenthic oppossum shrimp or mysids. Larger individuals (>200 mm) fed on a combination of fish, mysids, and Crangon.

Table 1. Numerical abundance summarized as rankings for the 10 most abundant species collected in a IV-A bottom trawl at 3 depths off Mooloch Beach, Oregon during May, 1979. A ranking of less than 10 is denoted by (+).

species	day			night		
depth(m) =	73	22	9	73	22	9
Pacific sanddab *Citharichthys sordidus*	1	4	6.25	1	-	-
big skate *Raja binoculata*	10	3	4	8.5	1	4
butter sole *Isopsetta isolepis*	3	2	2	3	2	3
sand sole *Psettichthys melanostictus*	-	1	1	-	4	2
Pacific tomcod *Microgadus proximus*	8	9	-	10	3	1
Dover sole *Microstomus pacificus*	4	+	-	2	-	-
ratfish *Hydrolagus colliei*	-	5	6.25	8.5	5	5
English sole *Parophrys vetulus*	2	7	6.25	7	6	6.5
rex sole *Glyptocephalus zachirus*	6	-	-	6	-	-
petrale sole *Eopsetta jordani*	5	+	-	4	-	-
starry flounder *Platichthys stellatus*	-	8	3	+	7.3	6
rock sole *Lepidopsetta bilineata*	7	+	-	5	10	-
speckled sanddab *Citharichthys stigmaeus*	-	6	-	-	-	-
spotfin surfperch *Hyperprosopon anale*	-	+	5	-	-	-
smelt Osmeridae	-	10	5.5	8	9	-
poacher Agonidae	-	+	5.5	-	7	-
lingcod *Ophiodon elongata*	9	+	-	-	-	-
curlfin sole *Pleuronichthys decurrens*	+	-	-	+	-	-
wolf eel *Annarichthys ocellatus*	-	+	6.25	-	-	-
sandpaper skate *Raja kindaidii*	+	-	-	-	-	-
cabezon *Scorpaenichthys marmoratus*	-	-	-	-	1	6.5
staghorn sculpin *Leptocottus armatus*	-	+	-	-	7.3	-
Pacific hake *Merluccius productus*	-	-	-	-	7.3	-
slender sole *Lyopsetta exilis*	+	+	-	-	-	-

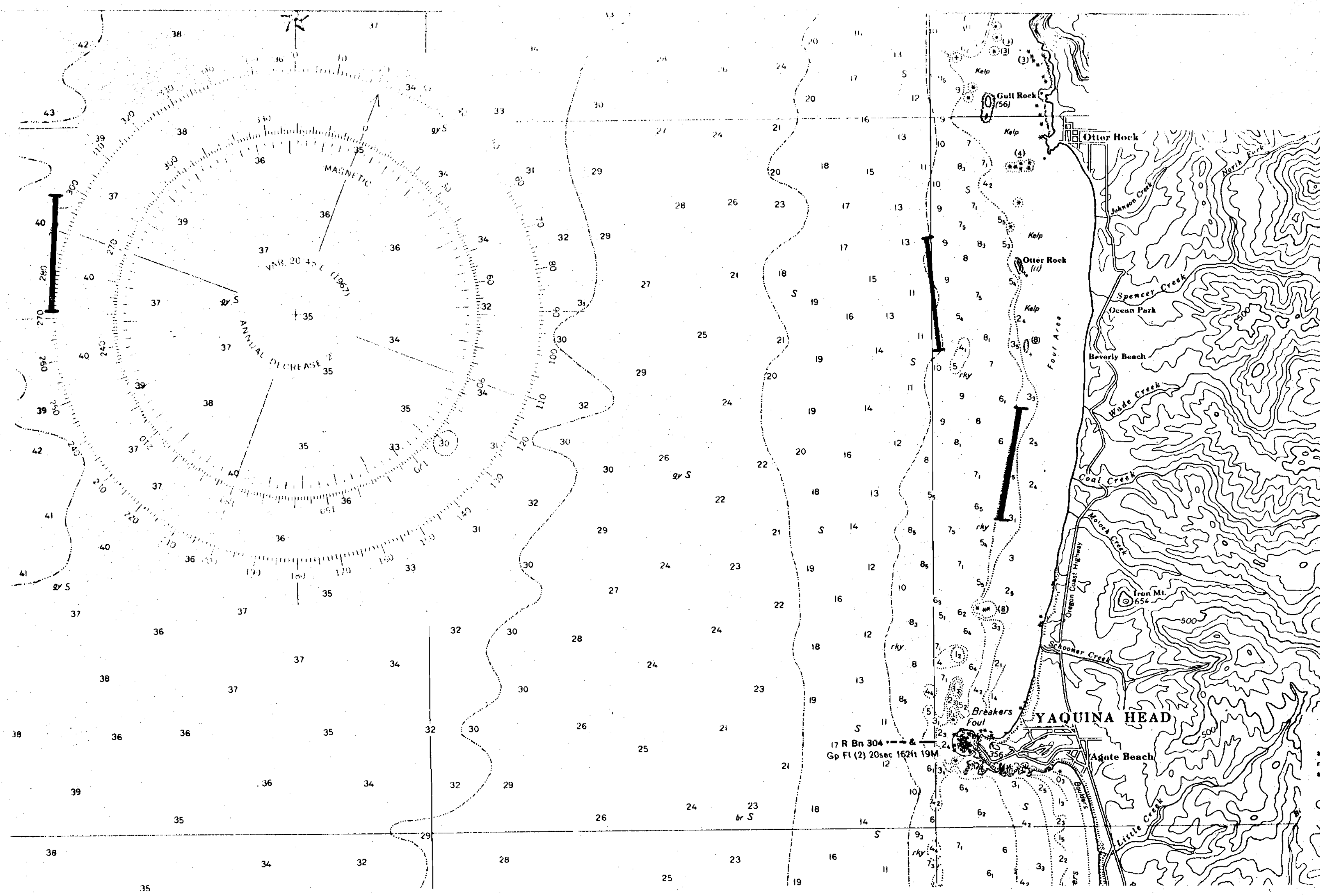


figure 1. Commercial trawling stations off Mooloch Beach, Oregon, May and August, 1979.

Figure 2. Average percent occurrence of prey items in the stomachs of demersal fishes captured at the 9 m contour off Mooloch Beach, Oregon on May 21, 1979.

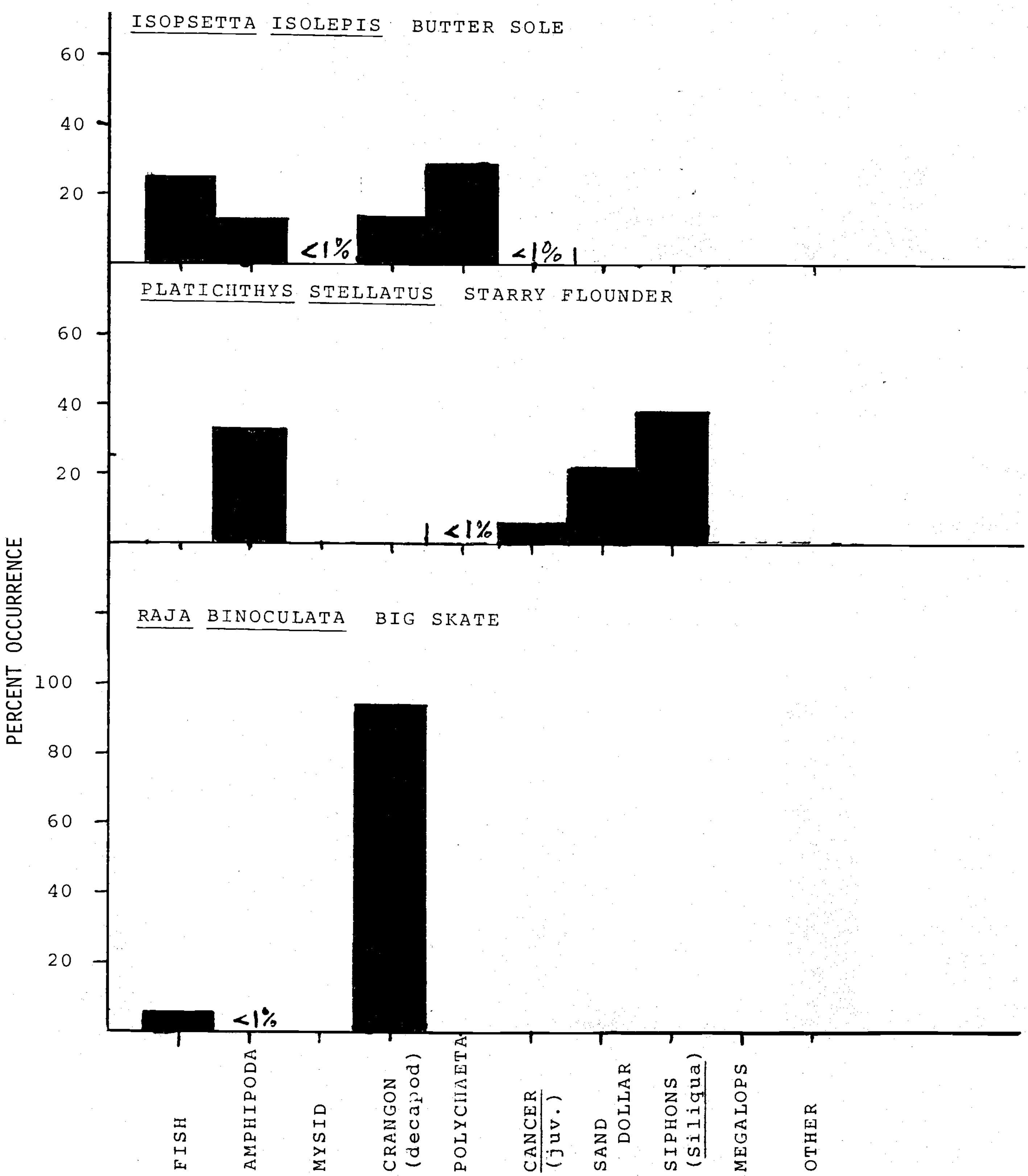
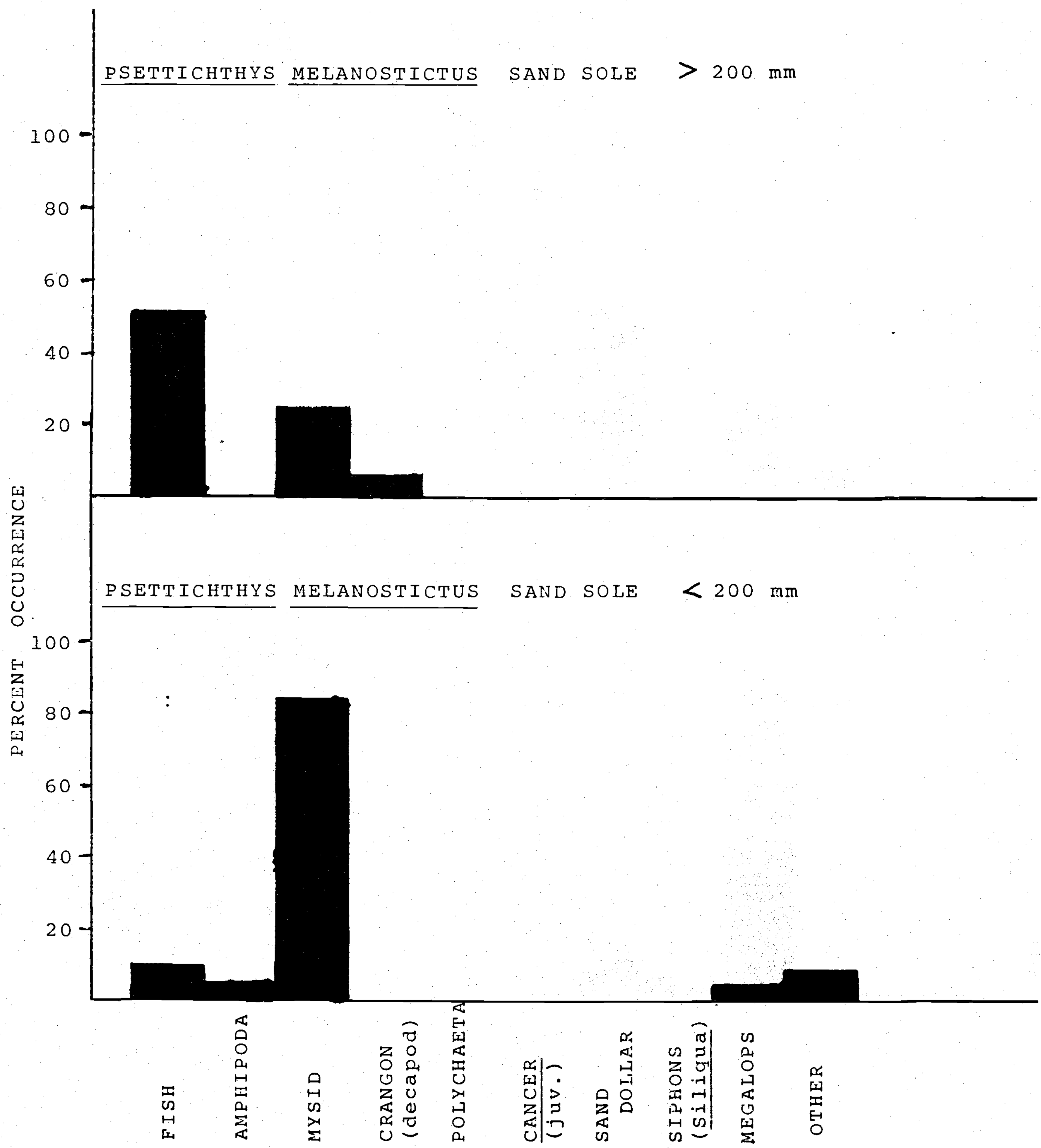


Figure 3. Average percent occurrence of prey items in stomachs of two length ranges of sand sole (Psettichthys melanostictus) captured at the 9 m contour off Mooloch Beach, Oregon on May 21, 1979.



SUBPROJECT: Ecology of 0 Age-Group English Sole
2.e.
INVESTIGATORS: W. G. Pearcy and E. E. Krygier

Length-frequency histograms were plotted by catch per m^2 for 5 mm standard length (SL) increments for English sole from 15 to 155 mm SL collected in lower Yaquina Bay from three stations sampled with our 1.6 m beam trawl, for years 1970, 71, 72, 77, 78, and 79, and from three stations sampled with a beach seine, for years 1977 and 1978.

Recently metamorphosed juveniles or late metamorphosing larvae (< 20 mm SL) usually occurred in these samples from January-June. In some years recruitment of these small fish was noted as early as October or November and as late as July or August. This prolonged recruitment indicates protracted spawning of English sole.

Abundance of 0 age English sole in Yaquina Bay appears fairly similar from year to year, although in 1977 and 1978 catches were larger than average.

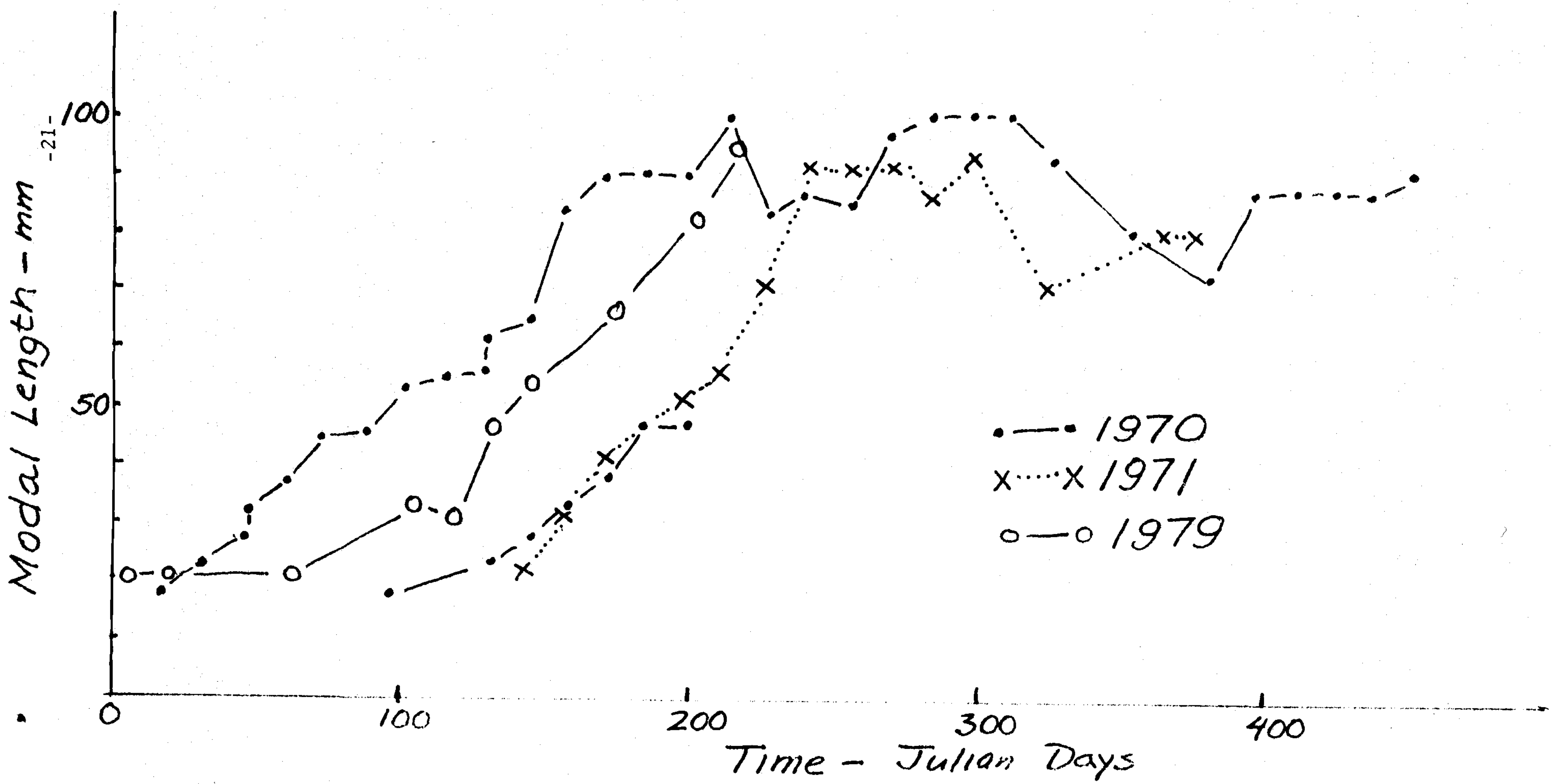
Figure 1 shows estimates of growth based on progression of obvious modal length groups from trawl catches in Yaquina Bay. The average growth rate shown by the 1970 data from January and October averaged 8.4 mm per month. Estimates for the other 1970 progression and the 1971 and 1979 data averaged 8.7, 12.6, and 11.0 mm per month, respectively. These estimates are similar to those shown by Westrheim (1955) in Yaquina Bay but are all higher than the growth rate estimated from daily growth rings of otoliths (see this Progress Report).

Another trend that is obvious from Figure 1 is the decrease in average size of fish during the autumn months in 1970 and 1971. This is apparently caused by emigration of large young-of-the-year fish out of the bay, leaving a residual group of small English sole to over-winter in the bay. These fish are obvious as 60-140 mm individuals during January-April of most years.

Small juvenile English sole (<20-25 mm SL) were also common at the Moolach Beach stations along the open coast. These small fish were often captured a month or so earlier at Moolach Beach than in Yaquina Bay, e.g., in the fall/winter of 1977, 1978, or a month or so later, e.g., and June/July of 1978 and 1979. These data indicate that recruitment of young to the bottom may occur over a longer period offshore than in the bay. Occasionally pulses of these small fish occurred that were several times the highest catches per m^2 of this size in the bay (e.g., May 1977, April 1978). Age-group 0 fish were also found throughout the summer in this region, but generally numbers per m^2 were low and progression of length-frequency modes could not be followed.

The results of our May 1978 sampling of other Oregon estuaries show highest average abundances of age-group 0 English sole in Tillamook Bay ($0.7/m^2$) followed by Yaquina ($0.26/m^2$), Siletz ($0.18/m^2$), Alsea ($0.06/m^2$), and Winchester ($0.02/m^2$) Bays. Trawling along the open coast in the summer and fall of 1978 also caught young English sole. Although the highest densities of young fish were usually in estuaries, shallow water of the open coast is also an important nursery for English sole.

During the next year we plan to: a) examine growth trends in detail, b) construct catch curves to estimate mortality of 0 age-group fish, c) evaluate the importance of estuarine versus offshore nursery grounds, and d) study the assemblages of fishes and invertebrates associated with young English sole.



Modal Length - mm
100
50
0
100
200
300
400
Time - Julian Days
1970
1971
1979

SUB-PROJECT: The Growth of English Sole from Two Nursery Grounds
2.e.-2
INVESTIGATORS: A. A. Rosenberg and W. G. Pearcy

The age and growth of juvenile Parophrys vetulus have been studied over the past year using samples from two nursery areas, Moolach Beach and Yaquina Bay. The daily and fortnightly growth rings on 194 otoliths have been counted and the length at age data for the two areas plotted (Figures 1, 2). Preliminary examination of the data indicates that growth is much more variable among fish that utilize the estuary as a nursery ground during the first year of life as opposed to those that are found in the open coast area off Moolach Beach. An average growth rate of about 10 mm in 20 days was found from both areas. The variability at a given age in Yaqunia Bay fish is up to 20 mm, whereas the variability at Moolach Beach is approximately 5 mm. In the data analysed to date, there does not appear to be an asymptote to growth in this life stage for Parophrys.

The data for juveniles from Moolach Beach has been linked with the larval growth data of J. Laroche to further detail growth during the metamorphic period (Figure 3). There appears to be a prolonged growth plateau between 60 and 120 days of age. During this time, the fish are undergoing extensive morphological change, but are not growing in length.

In the coming year, the rest of the sampled fish (561 have had their otoloths removed) will be aged and a more complete comparison of growth in the two nursery areas conducted. Also, growth will be back-calculated from the otoloths of large young-of-the-year fish. This will be used as a check on the growth rates calculated from size at age data.

Figure 1

Parophrys Growth
Yaquina Bay

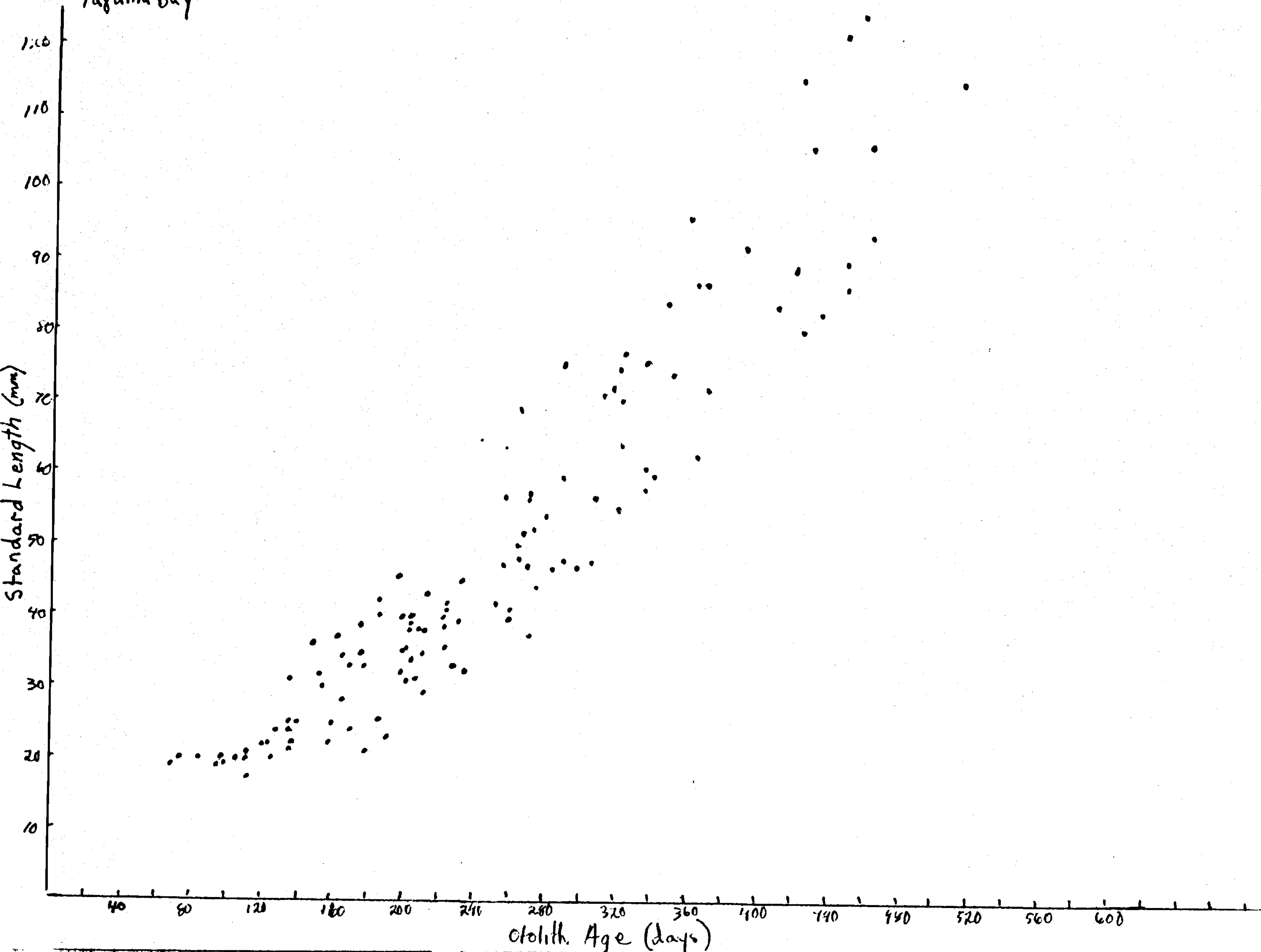
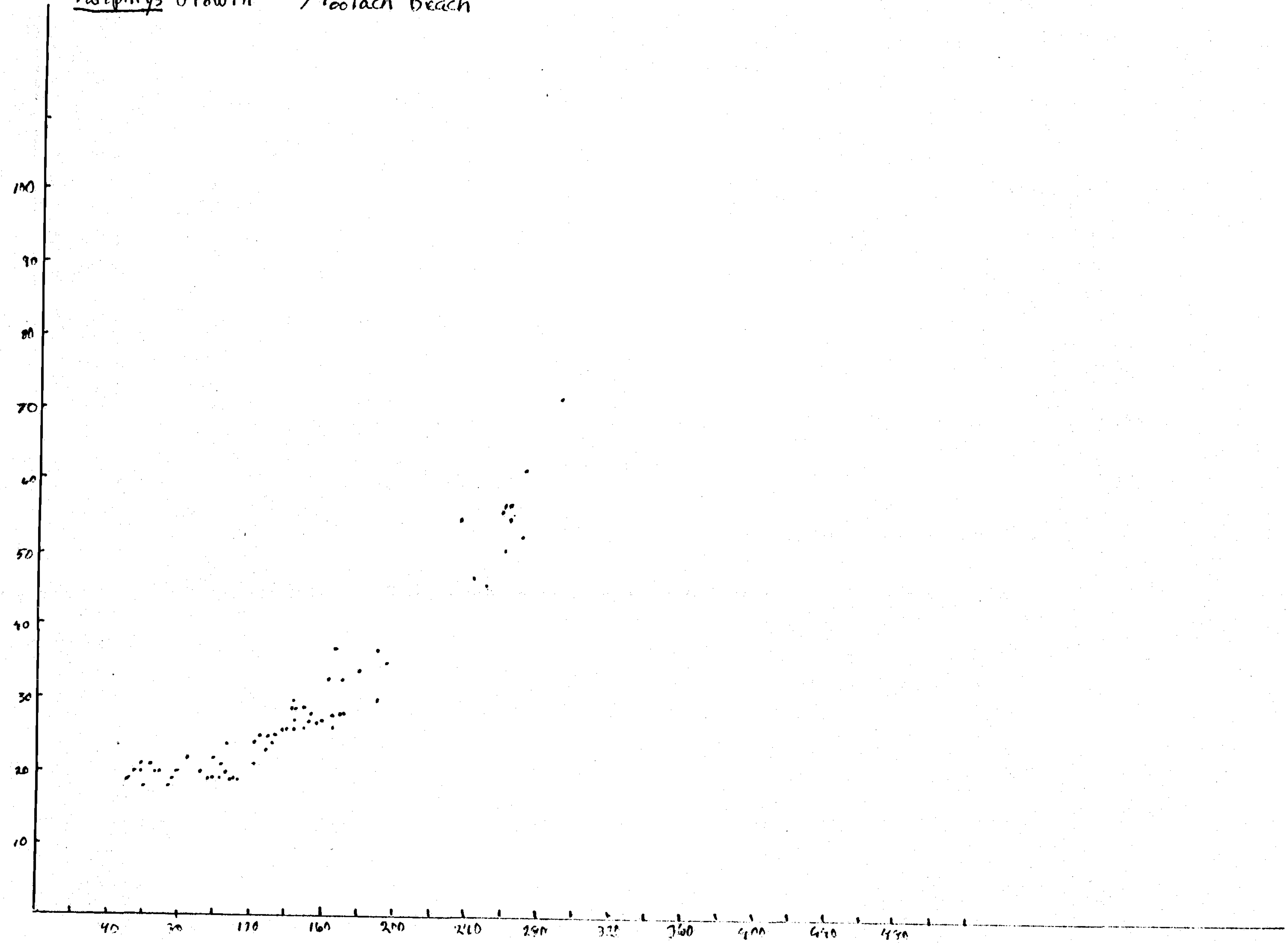


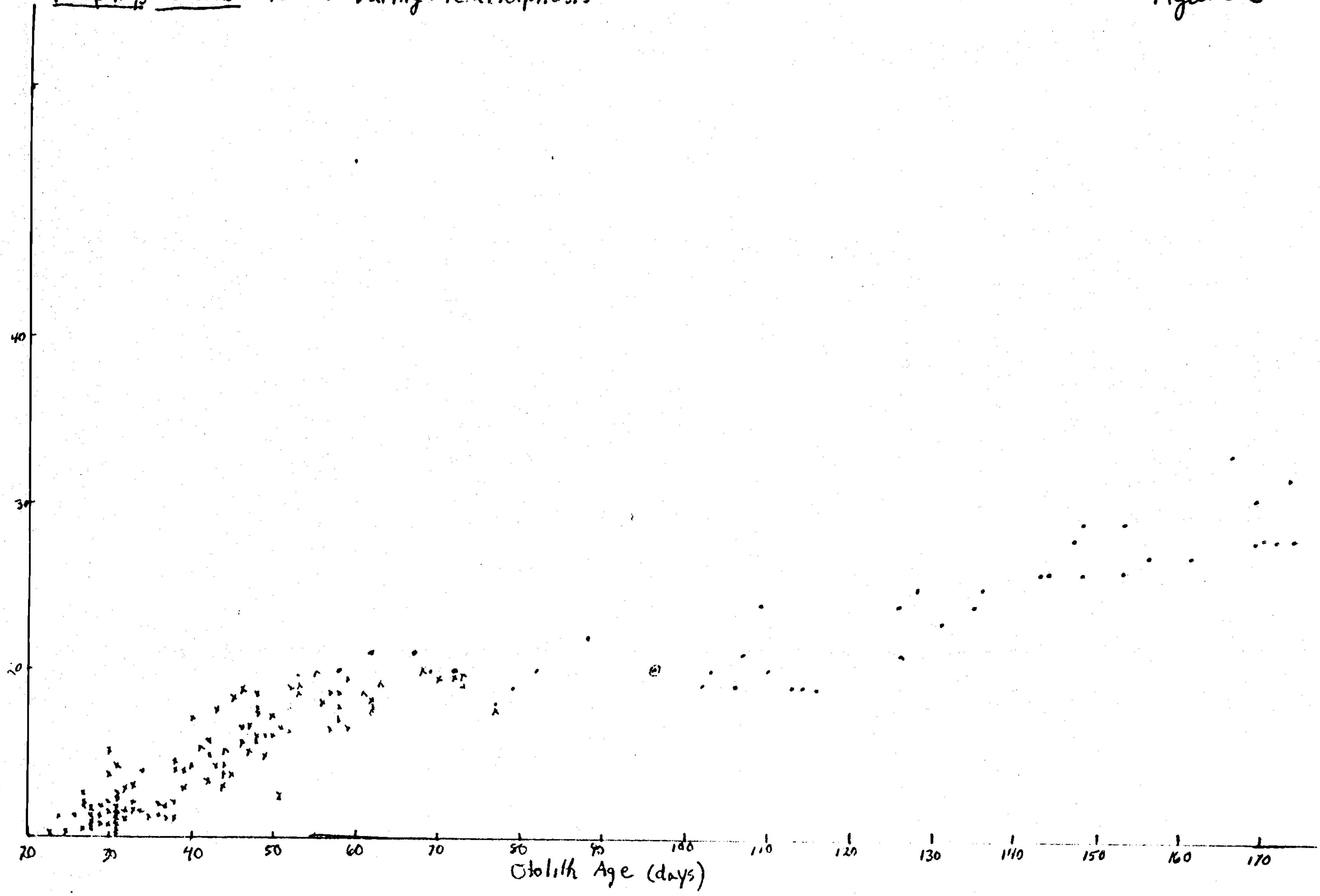
Figure 2

Paraphrys Growth - Moolach Beach



Parophrys vetulus Growth During Metamorphosis

Figure 3



SUB-PROJECT 3B: Age, growth, mortality, and movement of larval and transforming English sole, Parophrys vetulus, off Oregon

INVESTIGATOR: Sally L. Richardson[1]

The major result of this study has been to establish and validate a technique for aging Parophrys vetulus larvae and transforming planktonic juveniles by counting daily growth increments on saccular otoliths.

The otoliths of larvae reared in the laboratory from artificially fertilized eggs provided direct evidence of daily periodicity of growth increment formation in Parophrys vetulus larvae and the age, length, and stage of development at which growth increments begin to form. Larvae reared during the fall and winter 1978-79 came from two separate spawnings, one in mid-October and the other in late November. Eggs from these spawnings kept at incubation temperatures (and subsequent rearing temperatures) of 12.5-13.0°C hatched in 3 to 3-1/2 days. Larvae were maintained in glass gallon jars (closed system) in which a bloom of the green flagellate, Tetraselmis (PSW), was maintained. Gymnodinium splendens, a naked dinoflagellate, was added on the 4th day after hatching and was maintained in the containers for about 1-2 weeks. However, there was no indication that larvae ever fed extensively on this organism. The rotifer, Brachionus plicatilis, was first introduced on day 4 and was added thereafter at regular intervals. Larvae began eating Brachionus on day 5 or 6 and this continued to be the primary food throughout most of the rearing experiments. By day 25 some larvae from the October spawning had begun to feed on Artemia nauplii which had been introduced to the containers the day before. In addition to these prey,

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harpacticoid copepods, Tisbe sp., were introduced early in the experiments and were allowed to establish and maintain populations in the rearing containers. Detailed gut analyses were not made on the laboratory reared larvae, however, nauplii, copepodites, and adults of this copepod probably provided an additional source of food for older larvae after day 25.

Results of these rearing experiments including larval and otolith growth (mean standard length in mm and mean otolith diameter in microns), and growth increment counts based on otoliths taken from 102 and 213 larvae from the October and November spawnings, respectively, are summarized in Tables 1 and 2. Although larvae from both spawnings did exhibit some growth throughout the time they were maintained in the laboratory, plots of mean standard length (mm) versus age (days) indicate that growth after yolk sac resorption, day 4 or 5, was slow and probably not comparable to growth in the field. Despite poor growth in body length throughout the rearing experiments, growth increments were visable on otiliths of almost all laboratory-reared larvae. Growth increments, though extremely narrow and crowded, were even present on the otoliths of the oldest larvae. The apparent wide variability in daily addition of growth increments on the otoliths of laboratory-reared larvae was caused by variability in age at first increment formation, failure of the slowest growing larvae to consistently form growth increments, and increased difficulty in counting increments on the otoliths of older larvae (after day 25 and 16 from October and November spawnings, respectively).

Increment counts on otoliths of field-caught P. vetulus larvae (Fig. 1) were converted to age in days by adding 4, the number of days after hatching to first increment formation, to the individual increment counts (>0). Four days was taken as the best estimate of the time after hatching to the formation of the first growth increment because on day 5, for the first time, a significant number of larvae sampled in the laboratory had one increment on their otoliths. In all rearing experiments day 5 was also the first day that larvae began swimming actively near the surface of rearing containers. In 5-day-old larvae all or most of the yolk was gone, eyes were fully pigmented and the jaws were functional. Active feeding was usually first observed on days 5 or 6. Time until first increment formation did vary in the laboratory, possibly by as much as 10 days and may also vary in the field.

Growth increment counts were obtained from 338 Pharophys vetulus larvae and transforming, planktonic juveniles, 2.4-20.0 mm SL, collected off Newport between November 1977 and June 1978 (Table 4). Growth increments were, in general, clearer and more distinct on the otoliths of field-collected larvae than on otoliths of laboratory-reared larvae. Scatter plots depicting the relationship between standard length (mm) versus number of growth increments, and otolith diameter (microns) versus number of growth increments (Figures 2 and 3) indicate the close correspondence between the addition of daily growth increments on otoliths and overall larval growth. The relationship between age in days (number of daily growth increments plus 4 days) and standard length (mm) is shown in Figure 4.

List of Figures

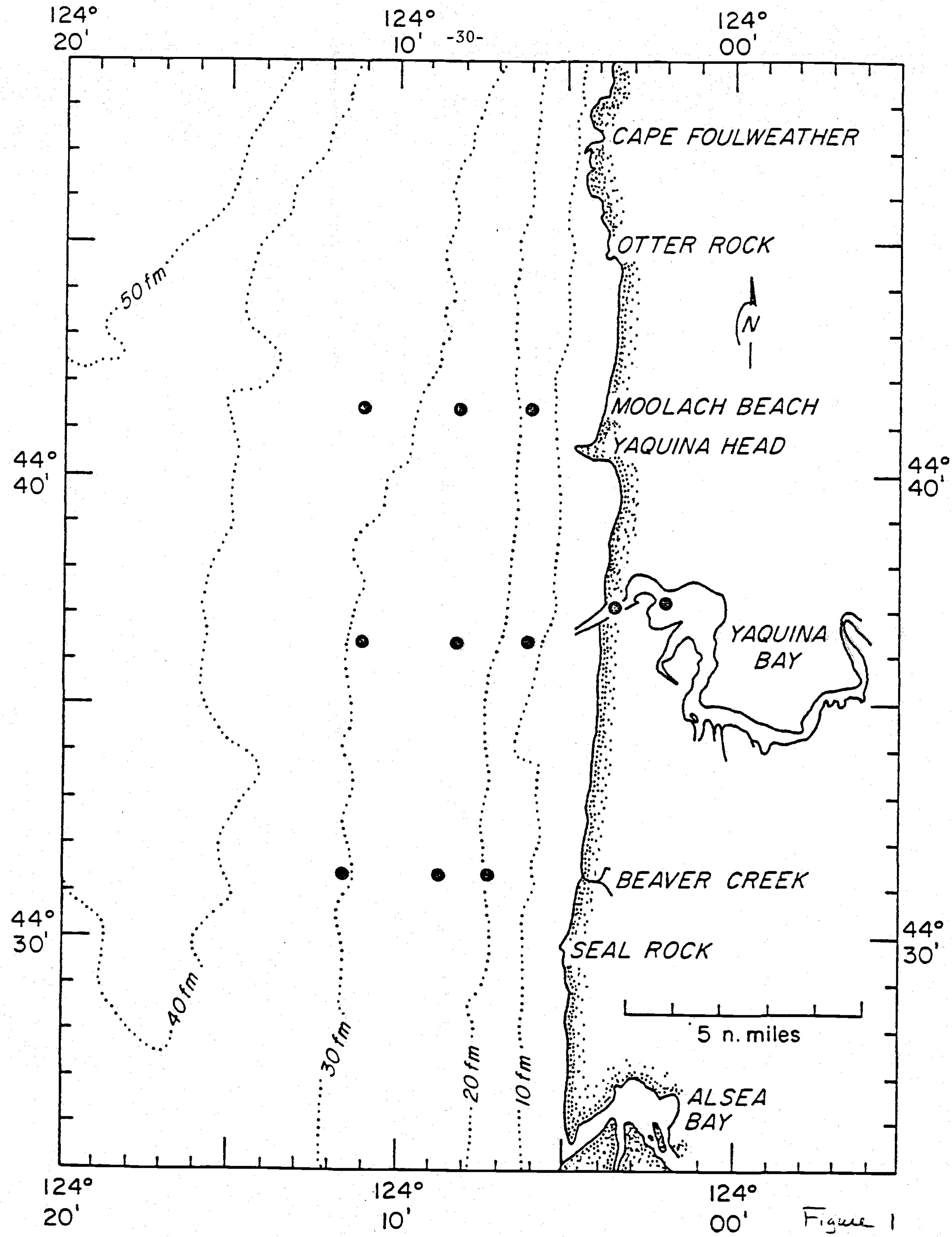
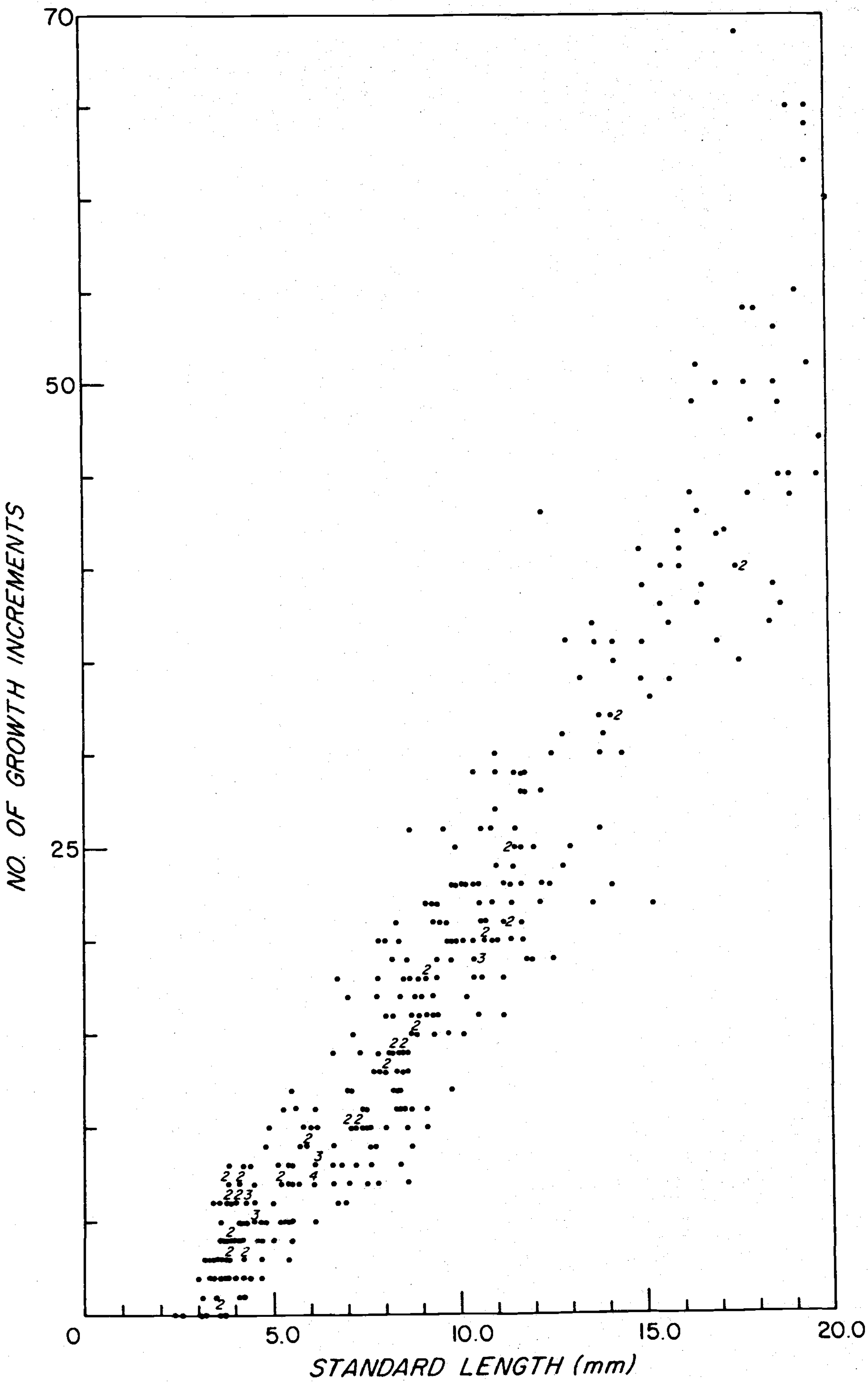
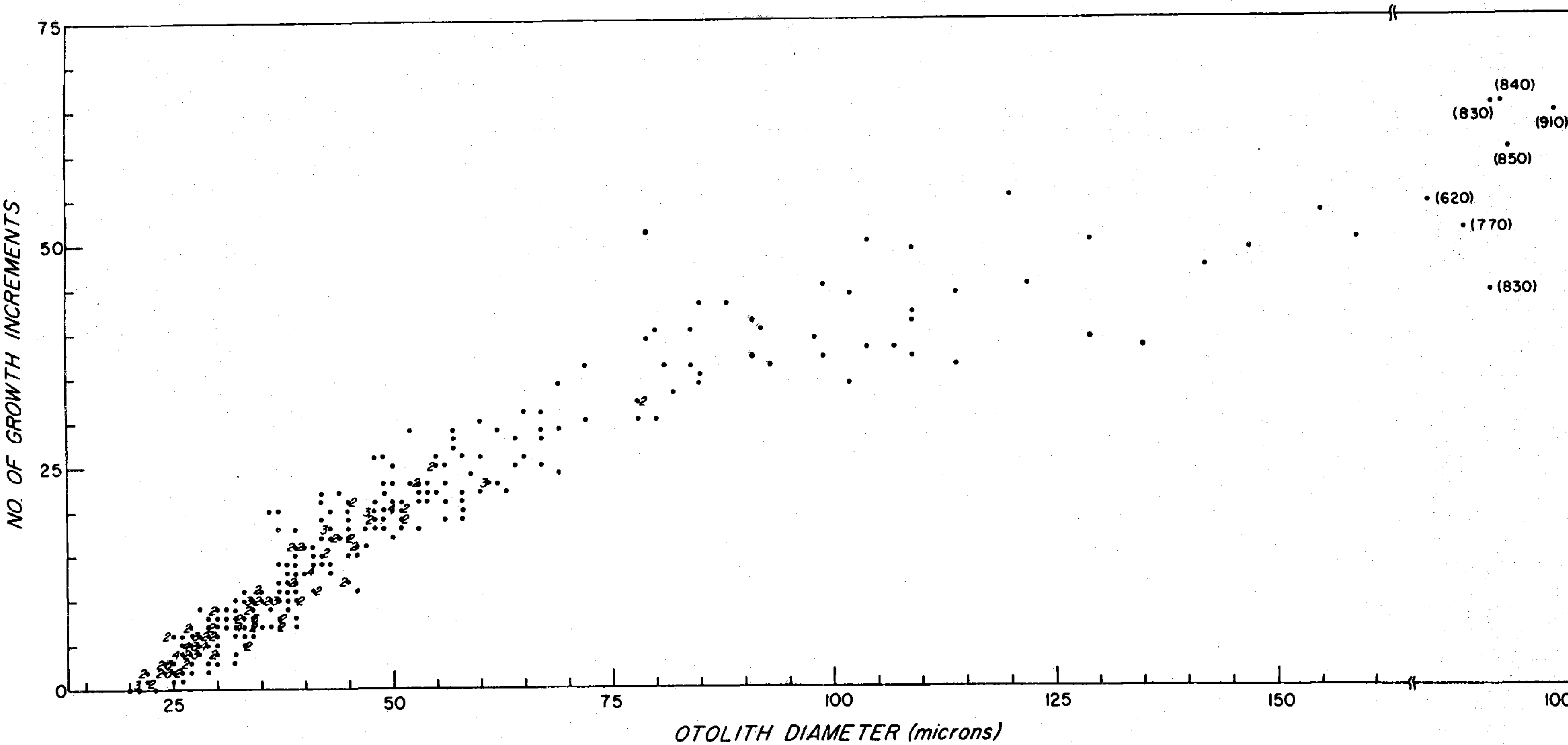
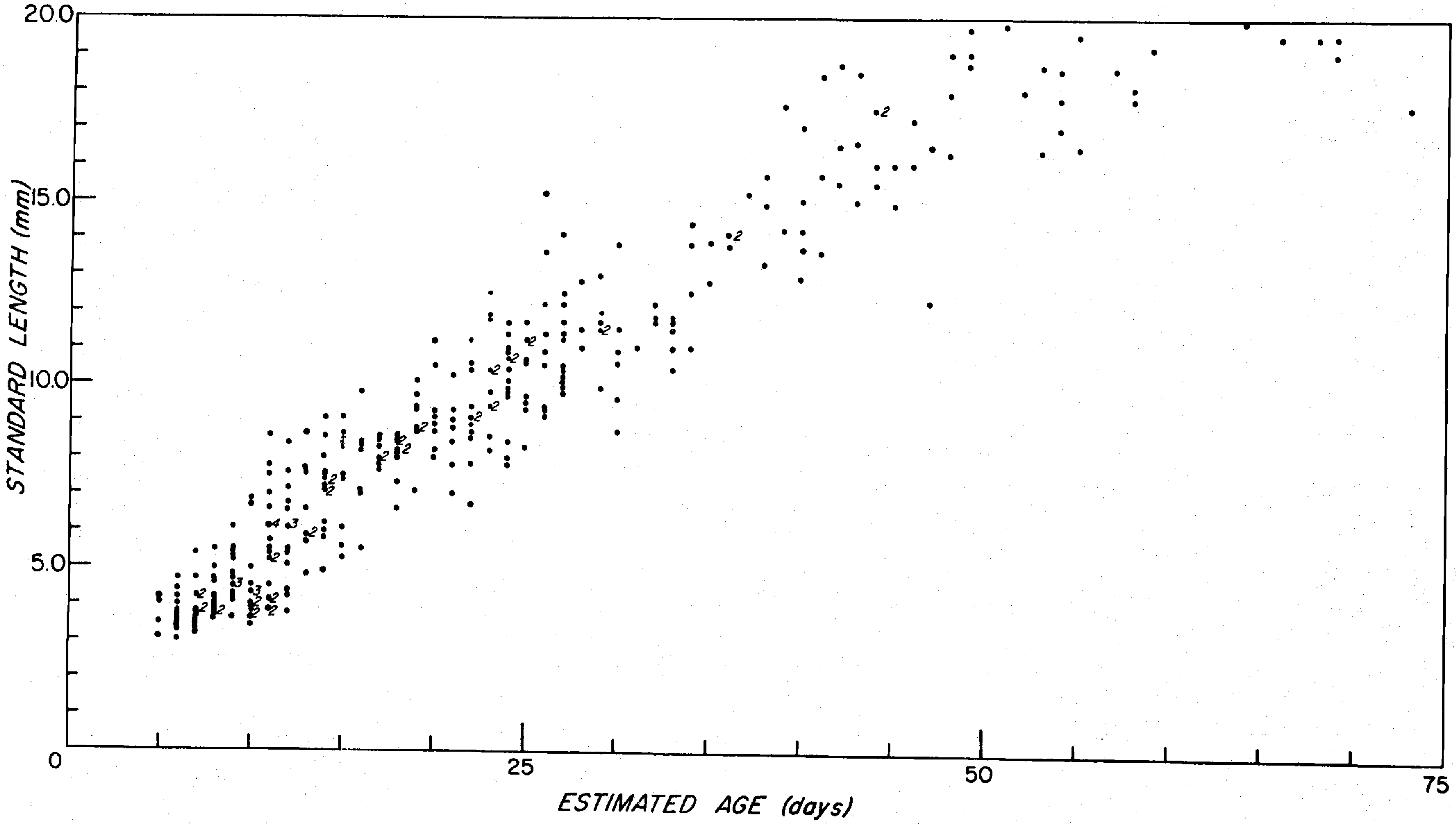

124° 20'
124° 10'
124° 00'
CAPE FOULWEATHER
OTTER ROCK
N
MOOLACH BEACH
YAQUINA HEAD
44° 40'
YAQUINA BAY
BEAVER CREEK
44° 30'
SEAL ROCK
5 n. miles
ALSEA BAY
50 fm
40 fm
30 fm
20 fm
10 fm

Figure 1


70
50
25
0
5.0
10.0
15.0
20.0
NO. OF GROWTH INCREMENTS
STANDARD LENGTH (mm)


NO. OF GROWTH INCREMENTS
OTOLITH DIAMETER (microns)
0
25
50
75
100
125
150
1000
(840)
(830)
(910)
(850)
(620)
(770)
(830)



20.0
15.0
10.0
5.0
0
25
50
75
STANDARD LENGTH (mm)
ESTIMATED AGE (days)

Table 1: Summary of growth in body length (SL) and otolith diameter (OD) and counts of growth increments on otoliths of laboratory-reared *Parophrys vetulus* larvae hatched from artificially fertilized eggs on 19-20 October 1978.

Age (Days)	N	Mean SL (mm)	Mean OD (microns)	Range in OD (microns)	No. Growth Increments 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0	10	2.6	---	---	no otolith observations																					
1	2	3.5	15.5	15-16	2																					
2	5	3.8	---	---	no otolith observations																					
3	2	4.0	*(19)	---	1																					
4	7	4.3	20	---	4																					
5	10	4.3	22.7	20-25	4	3	3																			
6	4	4.2	---	---	no otolith observations																					
7	2	4.2	(27)	---			1																			
8	4	4.4	(29)	---			1																			
9	2	4.3	(26)	---				1																		
10	0																									
11	5	4.4	26.0	24-28				2	2	1																
12	3	4.4	27.5	27-28					1	1																
13	3	5.5	27.5	27-28								2	1													
14	4	5.2	29.0	28-30							1		2	1												
15	6	5.2	28.5	27-30							1		2	3												
16	4	5.2	29.5	28-31									1	1	2											
17	3	5.8	30.3	29-33						1					1	1										
18	3	5.6	30.5	30-31												1		1								
19	1	5.9	(31)	---										1												
20	1	5.1	(33)	---									1													
21	1	6.3	(30)	---																	1					
22	3	6.9	32.0	30-34									1	1				1								
23	1	6.0	(29)	---											1											
24	1	5.6	(33)	---										1												
25	3	7.0	33.7	30-40							1						1						1			
26	18	7.0	33.4	30-37											1	2	1	2	2	2	1	2	1	1	1	
27	6	6.0	33.0	31-35										2	1	1	1			1						
28	2	5.8	31.0	30-32											1		1									
29	4	7.7	34.5	31-37										2			1						1			
30	7	7.5	34.3	33-35															1	1	2	1				1
31	2	6.8	32.0	31-33									1													
32	1	7.7	(36)	---	no count																					
33	2	9.2	34.0	33-35											2											
34	2	8.6	35.0	---													1						1			
35	4	8.4	36.3	32-40										1	1							1				
131	5	12.9	---	---	no otolith observations																					

*( ) = single otolith observation

Table 2 : Summary of growth in body length (SL) and otolith diameter (OD), and counts of growth increments on otoliths of laboratory reared *Parophrys vetulus* larvae hatched from artificially fertilized eggs on 1 December 1978.

Age (Days)	N	Mean SL (mm)	Mean OD (microns)	Range in OD (microns)	No. Growth Increments 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	10	2.9	14.6	14-16	10																	
1	10	3.5	16.8	16-17	10																	
2	10	4.0	18.8	18-20	9	1																
3	10	4.1	20.7	19-23	9		1															
4	12	4.1	22.3	20-25	9		1															
5	15	4.1	23.3	22-25	6	7	1															
6	20	3.9	24.2	23-27	4	4	8	2	1													
7	6	4.2	24.0	23-25	1		2	2	1													
8	12	3.8	25.3	24-27	1		4	5	1													
9	9	4.0	24.5	23-26			3	2	3													
10	15	4.2	25.6	25-27				6	1	5	1											
11	5	4.1	23.7	23-25				3	1	1												
12	4	4.2	27.3	27-28					1	3												
13	5	4.8	27.8	26-30						2	2	1										
14	11	4.7	28.8	27-33						1	1	2	2	1	2							
15	6	5.0	28.8	28-30									3	2								
16	12	4.8	28.4	26-30						2	1	1	1	2		1						
17	10	5.3	29.4	28-33								1	1	1	1	2	1	3				
18	10	4.9	28.0	26-31					1	1	1		2	1	2	1						
19	5	5.5	29.8	28-31									2			1		2				
20	6	5.8	31.6	30-36						2					2					1	1	
21	5	5.9	31.4	30-34											2		1			2		
22	6	5.8	31.0	29-35							2		1		1				1			1
23	6	5.5	31.3	30-33					1		1					1		2				
24	6	6.1	32.0	31-34									2						2			
25	6	5.6	31.2	30-33						1							2					
26	6	6.2	32.7	32-34													1	1				
27	5	6.4	31.3	30-34												1						

Table 3 : Mean standard length (SL), mean otolith diameter (OD) and range in otolith diameters of *Parophrys vetulus* larvae with 0 to 5 growth increments collected off the Oregon coast in fall and winter 1977-78 (N = no. of larvae observed in each increment count category).

Number of growth increments	N	Mean SL (mm)	Mean OD (microns)	Range in OD
0	7	3.2	21.3	20-23
1	4	3.7	23.8	22-26
2	10	3.8	24.6	22-27
3	12	3.9	26.5	24-32
4	12	4.2	27.8	26-32
5	15	4.7	28.7	26-33

Table 4: The mean number, standard deviation, and range in growth increments observed on otoliths of *Parophrys vetulus* larvae collected off the Oregon coast in fall and winter 1977-78. (Larvae were grouped into 1-mm size classes.)

Size Class (mm SL)	No. Larvae	No. Growth Increments Mean	SD	Range
2.0	2	0	--	--
3.0	35	3.3	2.2	0-8
4.0	35	4.9	2.2	1-10
5.0	23	7.3	2.4	3-12
6.0	19	8.6	3.1	5-18
7.0	27	11.6	3.5	7-20
8.0	42	14.5	3.8	7-26
9.0	28	18.6	4.0	10-26
10.0	24	20.8	3.3	15-29
11.0	28	23.7	3.9	16-30
12.0	11	27.6	7.0	19-43
13.0	9	30.3	5.1	22-37
14.0	8	32.9	5.2	23-41
15.0	8	34.9	5.7	22-40
16.0	9	43.0	4.4	38-51
17.0	10	46.0	10.2	35-69
18.0	9	45.9	6.5	37-54
19.0	10	54.3	9.0	44-65
20.0	1	60	--	--

SUB-PROJECT 3D: Recruitment simulation of English sole

INVESTIGATORS: Gordon H. Kruse, Albert V. Tyler

A simulation model has been built to help evaluate hypotheses regarding possible recruitment-regulating mechanisms for English sole. The work of several other Pleuronectid Project members form the basis for many of the hypotheses to be investigated. Included are hypotheses about stock-egg production relationships, temporally-variable spawning activity, ocean transport mechanisms, nursery areas, temperature-related growth and survival rates, storm mortality, and food production. Stock and environmental data used in the evaluation of these hypotheses were obtained from the Oregon Department of Fish and Wildlife and the Pacific Environmental Group (NMFS), respectively.

Preliminary results indicate that both stock and environmental factors are important contributors to English sole recruitment strength. A simple run assuming only a linear relationship between stock size and egg production accounted for 52% of the variability of the observed brood strength for 1960-1966 (see figure). Linking this hypothesis with an earlier regression model (Hayman and Tyler 1980[1]) accounted for 68% of the variability over the same years (see figure). Hayman's model includes a correlation between September and October barometric pressure and year-class strength.

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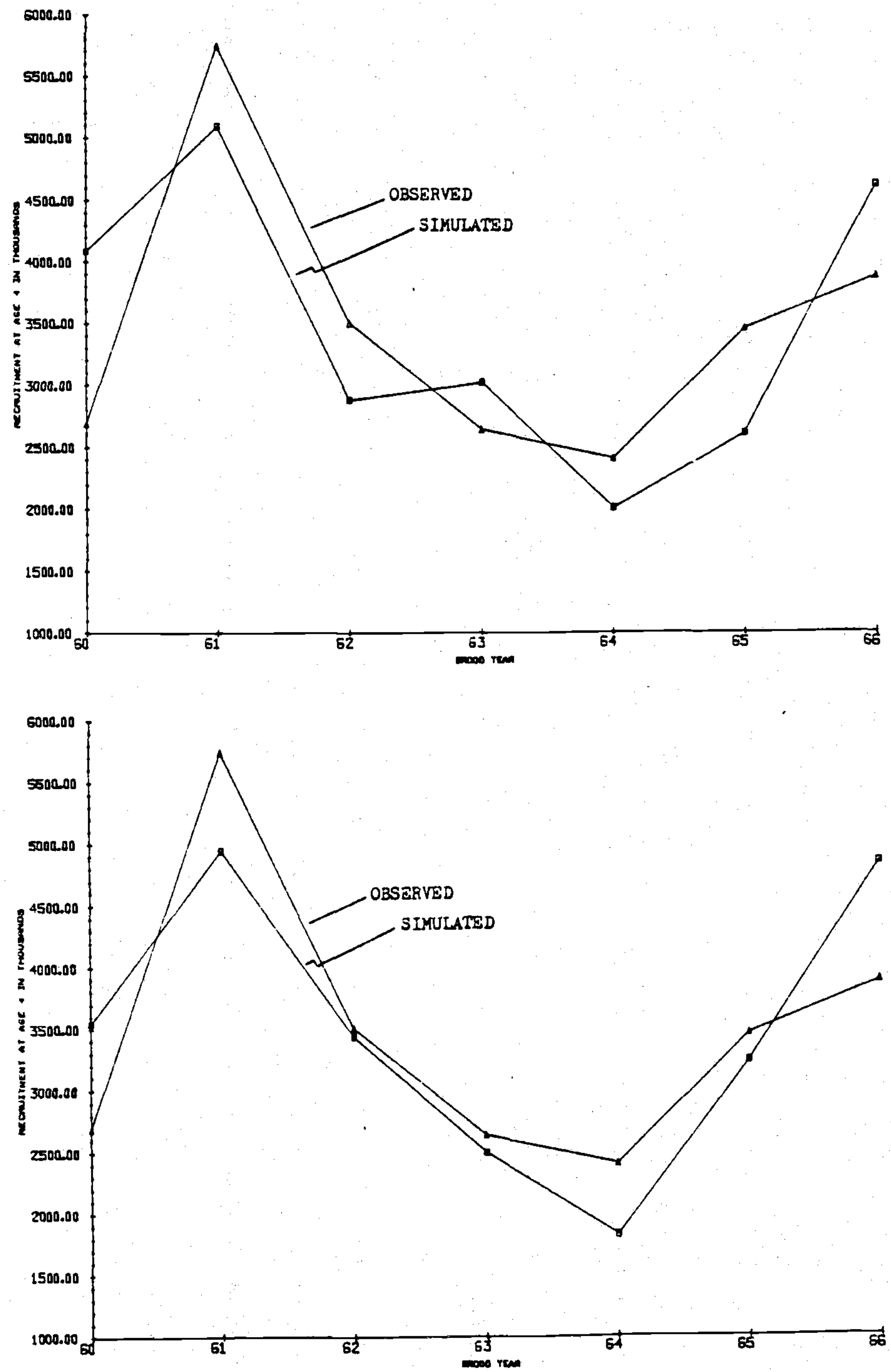
[1] Hayman, R.A. and A.V. Tyler. 1980
Environment and cohort strength of Dover sole and English sole.
Trans. Am. Fish. Soc. In press.



Simulated and observed recruitment records assuming only a linear relationship between stock size and egg production (above) and a linear relationship between stock size and egg production coupled with Hayman's regression model.

SUB-PROJECT 4C: Multi-species fishery analysis

Fishermen's logbook data were collected from the Oregon otter-trawl groundfish fleet for the Port of Astoria during the year 1975 by the Oregon Department of Fish and Wildlife. This data was coded and analyzed for seasonal patterns of effort and catch composition for eight groundfish species; petrale sole, English sole, rex sole, Dover sole, rockfish (Sebastes sp.), starry flounder, sand sole, and lingcod. Using an agglomerative clustering technique, eight catch composition classes were defined and described. These composition classes are being tentatively referred to as "fishing plans."

Each fishing plan is named for the species forming the majority of the landing by the plan. The plans are characterized by; the proportion of the landing of each species represented in the plan, the percentage of the monthly landings (of a given species by the fleet) accounted for by the landings of that species in fishing plan effort, the average rates of catch for the dominant species of each plan (expressed as pounds per individual tow), and the seasonality and proportion of the total monthly effort that the plan effort comprises.

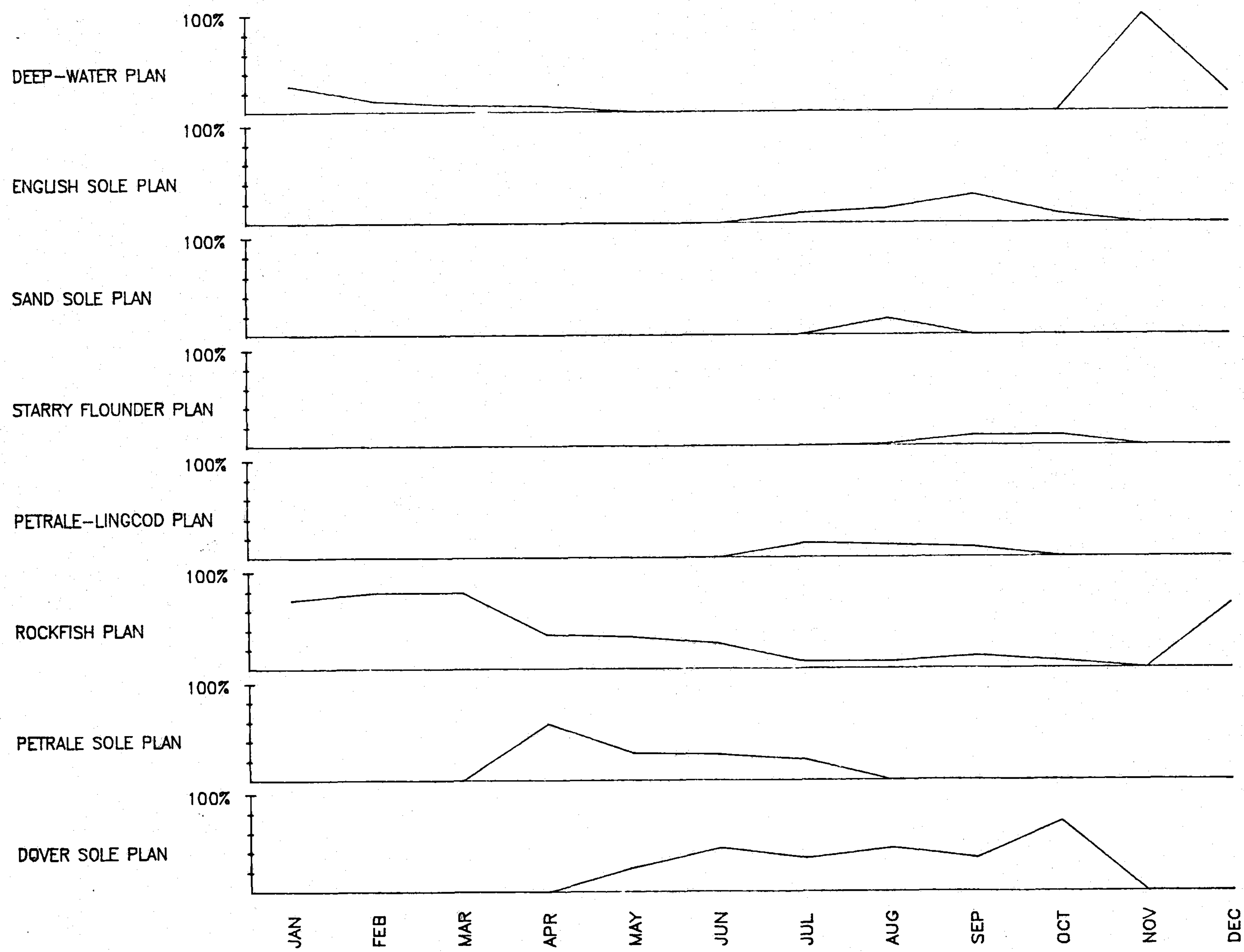
Figure 1 lists the eight defined plans in the 1975 data from Astoria, Oregon, and shows the proportion of the fleet monthly effort accounted for by each plan.

Figure 2 represents the detail of the composition for the Dover Sole Plan, as an example. The solid lines indicate the proportion of the plan's monthly landings made up by each species represented. The dashed line represents the proportion of the total monthly landing of Dover sole that is accounted for by the Dover Sole Plan.

Table 1 is a summary of the catch rates of the dominant species in each plan. (Pounds per haul).

Data from the 1973 logbooks for the Port of Astoria will now be analyzed in the same manner and a comparison of the "fishing plans" for the two years will be made.

Figure 1.


100%
DEEP-WATER PLAN
100%
ENGLISH SOLE PLAN
100%
SAND SOLE PLAN
100%
STARRY FLOUNDER PLAN
100%
PETRALE-LINGCOD PLAN
100%
ROCKFISH PLAN
100%
PETRALE SOLE PLAN
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DOVER SOLE PLAN
JAN
FEB
MAR
APR
MAY
JUN
JUL
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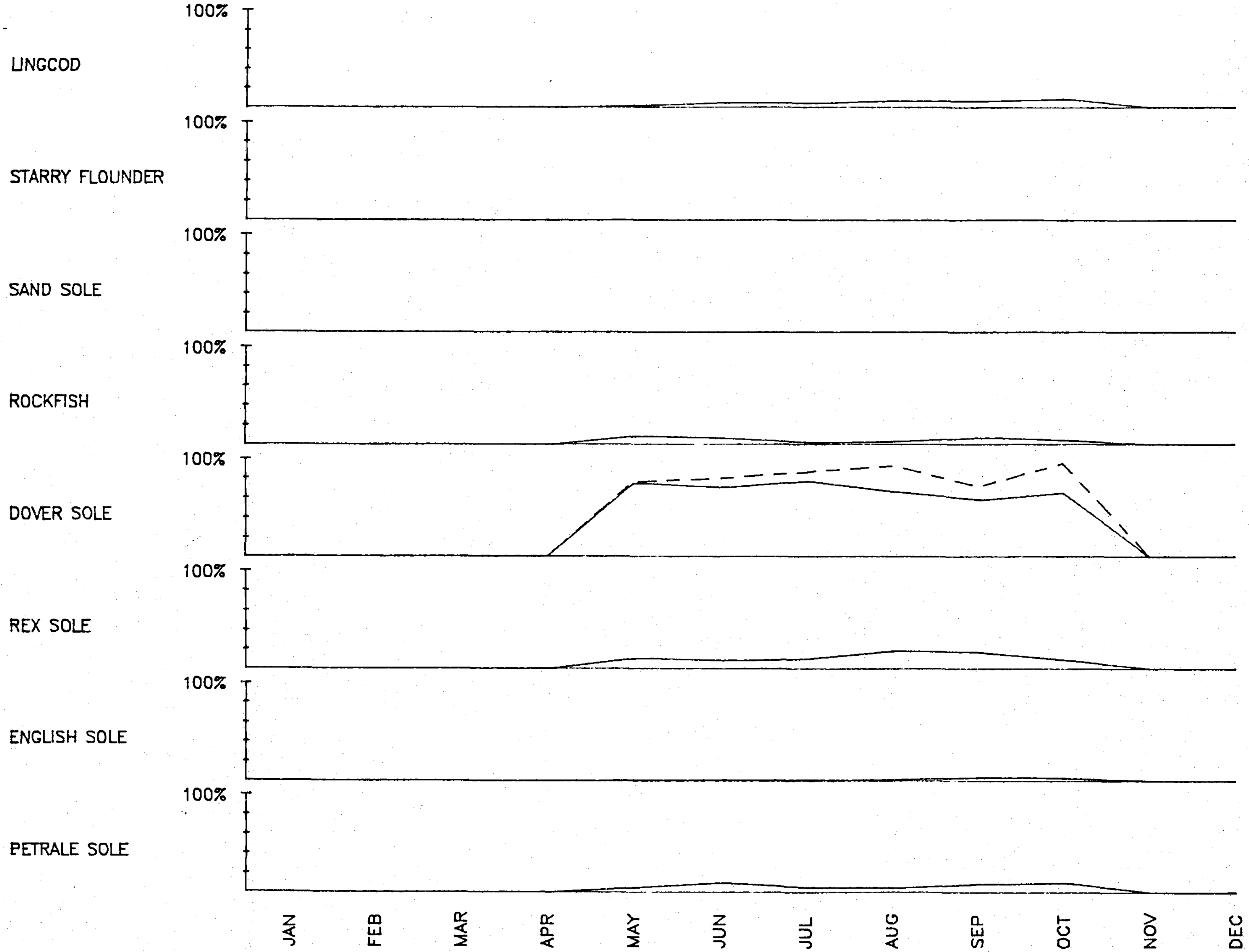
SEP
OCT
NOV
DEC

Figure 2.


100%
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PETRALE SOLE
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Table 1.

Plan	Dominate Species	months:	1	2	3	4	5	6	7	8	9	10	11	12
Deep-Water Plan		hauls:	20	4	11	17	0	0	0	0	0	0	3	4
	petrale sole		2043	1544	507	84.3	0	0	0	0	0	0	2001	1374
	Dover sole		0	29.3	1040	1855	0	0	0	0	0	0	2832	125
Starry Flounder Plan		hauls:	0	0	0	0	0	0	0	6	41	7	0	0
	starry flounder		0	0	0	0	0	0	0	1918	2741	1531	0	0
English Sole Plan		hauls:	0	0	0	0	0	0	26	40	116	6	0	0
	English sole		0	0	0	0	0	0	669	1311	708	1789	0	0
	rex sole		0	0	0	0	0	0	401	76.5	447	100	0	0
Rockfish Plan		hauls:	50	27	146	101	119	70	20	20	56	5	0	14
	rockfish		854	355	546	1740	1756	1984	1186	1880	1204	3287	0	67.3
	petrale sole		91.7	118	226	155	118	69.1	123	20.0	57.3	231	0	166
	rex sole		87.4	116	92.9	65.7	30.7	27.3	64.8	33.8	72.1	9.8	0	246
	Dover sole		0	0.37	0.03	65.7	73.7	240	200	232	334	552	0	2.9
	lingcod		19.8	0	46.7	71.3	369	154	52.5	304	67.5	200	0	107
Dover Sole Plan		hauls:	0	0	0	0	93	115	89	114	139	47	0	0
	Dover sole		0	0	0	0	961	696	919	870	719	1154	0	0
Petrale Sole Plan		hauls:	0	0	0	164	100	70	55	0	0	0	0	0
	petrale sole		0	0	0	246	377	317	597	0	0	0	0	0
	lingcod		0	0	0	166	60.4	97.6	9.1	0	0	0	0	0
	rex sole		0	0	0	76.8	342	252	62.7	0	0	0	0	0
Petrale-Lingcod Plan		hauls:	0	0	0	0	0	0	38	31	39	0	0	0
	petrale sole		0	0	0	0	0	0	511	879	483	0	0	0
	lingcod		0	0	0	0	0	0	1563	391	1058	0	0	0
Sand Sole Plan		hauls:	0	0	0	0	0	0	4	44	0	0	0	0
	sand sole		0	0	0	0	0	0	1500	1080	0	0	0	0

SUB-PROJECT 4C-2: Alternative Assemblage management approaches

INVESTIGATOR: A. V. Tyler

We propose that management concerns must include not only traditional goals on target species (modified by social concerns to OY), but also fish assemblage maintenance goals. We suggest (as have others) that the paramount goal for renewable resource management is the maintenance of management options. MSY oriented management has been shown to simplify fishery systems toward species with highest productivity rates. There is no assurance that simplified, high production portions of formerly species rich assemblages can persist in ocean systems.

Analyses of research trawling surveys have indicated there are geographic fish species associations or assemblages (Sub-project 1.a). Most of these assemblages are associated with depth strata. There may be four to six assemblages over a depth range of 20 to 400 meters seaward from a point of land.

We conceptualize that each assemblage is part of a geographically definable natural production system of interacting organisms that we term a "community." Non-interacting species within the same geographic area are not part of the functional community, by our terms. The "regular" species of the community comprise an "assemblage production unit" (APU). The "regular" species are those that are present in every season, i.e., they do not move in and out of the area in seasonal migration patterns (Tyler, 1971). The area of the APU is just large enough that the effects of the productivity processes (of the regulars) are dominant rather than the effects of mixing from adjacent areas. The APU's are analogous to fishery stocks (Gulland's usage) at the population level of concern.

The community and its component, the APU, is influenced by, or "driven" by, physical-chemical factors that are in turn often driven by forces remote to the assemblage, e.g. upwelling is driven by atmospheric dynamics. There are also biotic driving factors. We consider that the species that are regulars to the community have production processes that are driven by species that move through the area - the seasonals and perhaps the occasionals. We conceive of the seasonal species as driving factors on the regulars, since to model them as species we would have to model regions and processes outside of the region occupied by the regulars of the community.

Rather than conceiving an APU management scheme based on the equilibrium state (Schaefer's usage) or the average state (i.e. traditional yield per recruit modelling) we will try to deal with the transition state. In fact, the transition state may be the only reality for many systems of species. Perturbation, due either to within-species density dependence, or inter-species limit cycles, could induce wide, cyclic-form fluctuations. Also, a growing body of literature indicates that oceanographic trends often dominate fish productivity. Under this collection of influences an equilibrium yield would never even be approached.

Monitoring the transition states following controlled pulse fishing by the commercial dragger fleet may be a means of exploring and maintaining the viability of the APU's. Instead of watching a range of APU yields and component escapements during application of constant effort levels, one would monitor recovery of assemblage structure after fishing pulses of various magnitudes. These pulses could be applied simultaneously to a group of APU's. The most basic question to ask is do all species of the APU show recovery despite the magnitude of the pulse. The goal would be to find the limits of repetitive pulse fishing that would allow APU persistence.

SUB-PROJECT 4D: Interpretative application to the Benthic fisheries of a general theory of productivity and resource utilization

INVESTIGATORS: William J. Liss, Grant G. Thompson, Charles E. Warren

This research examined the effects of changes in environmental parameters, system composition, and response functions on key performances and capacities of a hypothetical fishery. This was done using the theoretical framework previously developed, which represents equilibrium community structures on sets of phase planes via isoclines deduced graphically from system response functions.

Among the environmental parameters considered were the system's energy input, the demand for fish in the economy, and the cost schedule facing the fishermen. In the area of system composition, the analysis examined how the existence of the following common components of fishery systems might affect key performances and capacities of the system:

1) Dynamic lower trophic levels. This enabled exploration of the effects of making rates of gain in the exploited population a function of the dynamics of the lower trophic levels.

2) A sport fishery. The existence of a sport fishery adds to the exploited population's rate of loss, acts as a competitor to the fishing effort component, and emphasizes the importance of non-pecuniary benefits from management.

3) A competing exploited population. While not contributing directly to the exploited population's rates of gain or loss, a competing exploited population affects both rates indirectly by altering the loss rate in the herbivore population and the gain rate in the fishing effort component.

Finally, variations in response functions were considered in both quantative and qualitative contexts, by changing the magnitudes of various coefficients and the forms of the equations used.

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