The Association between the Black Rockfish

(Sebastes melanops Girard) and Beds of

the Giant Kelp (Macrocystis integrifolia Bory)

in Barkley Sound, British Columbia

by

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to the required standard

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ABSTRACT

The association between the black rockfish, Sebastes melanops Girard and the giant kelp, Macrocystis integrifolia Bory, was examined in terms of habitat utilization. Distributional patterns of juveniles frequenting kelp beds were documented by three-dimensional positioning of observed fish with the kelp bed boundaries used as a frame of reference. Significantly higher numbers of smaller (30 - 100 mm) fish occurred inside the kelp bed than outside, both diurnally and nocturnally. A diel migration of larger (101 - 200 mm) fish occurred, showing significantly higher numbers of fish in the kelp bed nocturnally. Very few of the largest (201 - 250 mm) fish were observed in the bed and none of these exhibited this diel shift. Wider-scale sampling indicated an increasing cline in the size of fish when moving from inshore to the open sea.

Diet analysis does not indicate dependence by the fish on kelp bed diet items. Transporting experiments failed to demonstrate any significant homing ability within the size-class of fish studied. Artificial habitats employing plastic 'kelp' were constructed to test the assumption that the fish were responding to the amount of physical shelter provided by the kelp. Results show a highly significant numerical response by the fish population, to the changes in the amount of artificial shelter provided. It is concluded that the species utilizes the physical shelter of the kelp bed primarily as a refugium from nocturnal predators. The value of the kelp bed to the species lies in its enhancement of recruitment through increased survival of the 0 to I age-classes of fish.

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1. INTRODUCTION

The biota of the coastal waters of British columbia is characterized by a distinct seasonality of the abundance and diversity of species, particularly on those segments of coastline adjacent to the open Pacific Ocean. One of the most prominent floristic features of the summer months is the presence of stands of large phaeophyte algae, the upper portions of which form canopies floating on the surface waters. There are, primarily, two algae which form these conspicuous canopies in British Columbia; the giant kelp, <u>Macrocystis</u> <u>integrifolia</u> Bory, and the bull kelp, <u>Nereocystis</u> <u>luetkeana</u> (Mertens) Postels and Ruprecht. Beds of these large plants provide considerable structural heterogeneity in the otherwise almost unstructured water column. This increased heterogeneity gives rise to a proliferation of the species in the animal and plant communities in the vicinity of the beds.

The biology of kelp beds has received considerable attention in California. North (1972) provides an extensive bibliography of research on beds of <u>Macrocystis</u> <u>pyrifera</u> (Linneaus) C. Agardh. The works reviewed by North are primarily of a botanical nature, though ecological interactions of various animal species found in the beds are also included. Research into the biology of kelp beds in British Columbia has been limited. Scagel (1959) included B.C. studies in his review of the relationship of plants and animals in the marine environment. There has been little <u>published</u> material about research on B.C. kelp beds since 1960, although a considerable amount of effort has been expended in these habitats, including

both floristic and faunistic studies.

Many animals (invertebrate and vertebrate) found in kelp beds have a direct relationship with kelp plants. They live either in or on the plants, or the plants provide their trophic resource base. Species with indirect relationships are those which may be associated either with kelp plants themselves, or with the associated flora and fauna. The fish fauna of kelp beds may contain either type of species. The fishes of kelp beds have been examined both as a community (Limbaugh,1955; Davies,1958; Quast,1968; Ebeling et al.,1972) and as individual kelp bed species (Skogsberg,1939; Wales,1952; O'Connell,1953; Roedel,1953; Williams and Williams,1955; Phillips,1957; Follett,1960; Limbaugh,1961,1962; Turner and Ebert,1962; Gotshall et al.,1965). All of the above papers dealt with fishes in California kelp beds and, in general (except Limbaugh,1961), detail their interactions with the plants in a qualitative fashion only. The fishes of B.C. kelp beds have not received a great deal of attention; I know of no published material that deals specifically with these forms.

Sebastes melanops Girard is the most common neritic fish resident in the kelp beds of Barkley Sound,B.C. Juveniles of this species are found abundantly in beds of Macrocystis integrifolia and in lesser amounts in beds of Nereocystis luetkeana. Previously, I had observed that the abundance of fish was, roughly, inversely correlated with their size, and that some fish could be found consistently within the kelp bed. Larger fish, however, were not found in or near kelp beds, but instead, near the open coastline.

The present study was designed to examine the hypothesis that S. melanops is dependent upon kelp beds in some fashion and that this fish undergoes a transition in habitat association with age; from an inhabitant of kelp beds when young, to an inhabitant of moderate relief coastal areas when older. In the initial stages of the study I attempted to determine how the fish uses the kelp bed as a habitat. Several aspects of the ecology of the species were examined to categorize the links between the fish and the kelp bed. The later stages of the project were largely occupied with the testing of a subsequent hypothesis as to the primary nature of the association betweeen the two species.

2. METHODS AND MATERIALS

The study was conducted during the period June,1973 - September,1974 in Barkley Sound, near Bamfield,B.C. The field site was located in a small group of islets (Ross Islets) at position 48°52.45'N, 125°09.65'W; the kelp bed studied was situated in a small cove having a southwestern aspect (Figure 1).

2.1 Description of the study site

The cove containing the kelp bed studied was characterized in terms of several physical and biological parameters: area, topography, current velocities and kelp density.

(i) The area of the study site was calculated from a large scale map of the vicinity, as well as aerial and surface photographs taken at the same tidal heights. The total area of the site was taken as the average of these three measurements.

(ii) Topography of the bottom was determined by sounding with a metred, hand line. The values obtained were then incorporated into a bathymetric map.

(iii) Current magnitudes were extrapolated from daily wind and sea state data taken at Cape Beale lighthouse, approximately 12.8 km from the study site. In situ current measurements were taken at the study site over a short period of time. These data were then related to the Cape Beale data and a correlation plot constructed for the purposes of extrapolation throughout the year. The in situ measurements were obtained with a TSK Flow

Meter[1] over a fifty-day interval during May - June 1974.

(iv) Kelp density was estimated with a visual occlusion method employing SCUBA. A checkered, plywood panel 0.83 m² (9 ft²) was viewed from 2 m distance, normal to the panel, while the panel was held vertically, its base in contact with the substrate. Kelp density was taken as the mean percentage of the panel occluded by the kelp, when viewed from the four cardinal compass points. This procedure was repeated approximately once per week, at both random and specific locations in the kelp bed, during the periods of kelp presence.

2.2 Associated fish at the site

The fish assemblage of the area was partially known from previous work (Druehl, Green and Leaman, unpublished data) in this area and other similar sites. This work had included both netting and ichthyocide sampling. All species (other than S. melanops) were enumerated during the netting program of the current study to determine the total fish complement of the site.

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[1] Tsurumi-Seiki Kosakusho Co., Yokohama
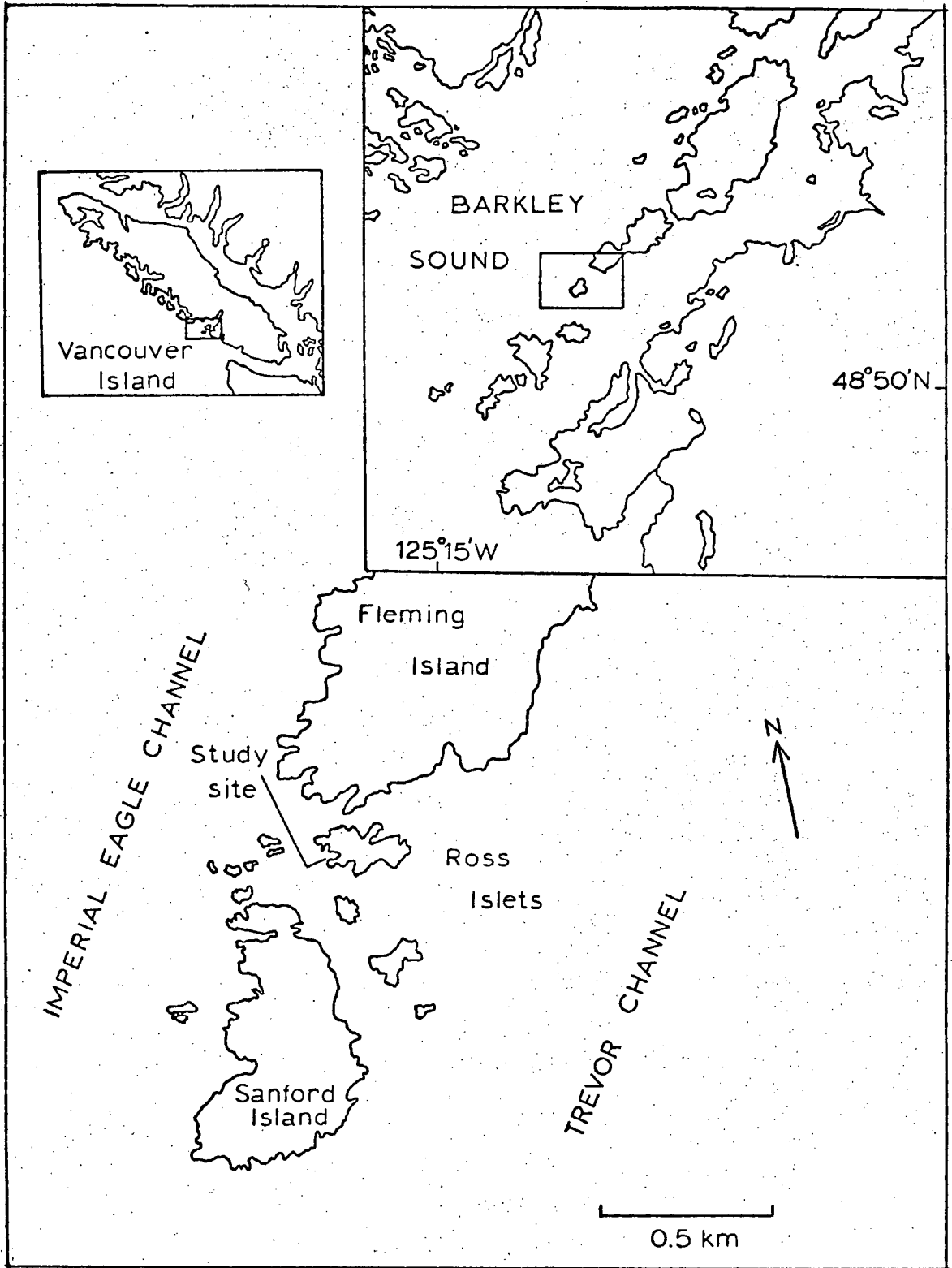
Figure 1

Location of the study area

2.3 Collecting

Fish [unless specified otherwise, 'fish' refers to Sebastes melanops] were collected for diet, population and movement studies with nylon monofilament gill nets of 1.27 (0.5 in), 2.54 (1.0 in), 3.81 (1.5 in), 5.08 (2.0 in) and 6.35 (2.5 in) cm (wet, stretched mesh) sizes. All nets were not employed simultaneously, rather, two nets, of 2.54 cm difference in mesh size, were set at any given time. Nets were set 1.0 - 1.5 hours before sunset and retrieved ≤0.5 hours after dawn in order to:

(i) maximize the number of living fish in the net, and

(ii) improve the probability of identifying the stomach contents of the fish.

Nets were set in a T-shaped or L-shaped pattern at various locations, in and out of the kelp bed.

Specimens of S. melanops were also obtained from other locations to complete an age-length regression. These additional fish were obtained using a sling spear and a Norwegian-type cod jig.

2.4 Tagging and growth

Fish recovered from the nets alive were anaesthetized, measured (TL), tagged, allowed to recover from the anaesthetic and released. The anaesthetic employed was MS-222 (tricaine methane sulfonate). Several different models of tags were employed for the population study, all of the nylon 'anchor' type (Dell,1968). All tags were inserted in the dorsal musculature of the fish, ventral to the base of the dorsal fin. An additional tag (Figure 2) was developed for short term

tracking studies. This tag was composed of a variable length of five mm (I.D.) glass tubing which was mated to the basic nylon anchor tag. The tube was then filled with powdered Na-fluorescein dye and the open end of the tube plugged with epoxy glue or silicone sealant. Fish were tagged and the epoxy or silicone plug removed immediately prior to release. It was possible to track the fish from the surface (if water clarity permitted), or from in the water, by the trail of dye which diffused from the tag as the fish swam. The length of time over which the tag was effective was a simple function of the amount of dye in the tag (and, hence, of tag size), e.g., a 55 mm tag lasted approximately five hours.

Data for population estimates were gathered both from net sampling and from observational sweeps through the study area, using SCUBA. Population estimates were generated through multiple censusing of the fish in the area for relative numbers of marked and unmarked fish, using the modified formula for a Schnabel capture-recapture estimate of Chapman (1954).

Growth of the fish was measured by growth of recaptured fish, and interpolation from an age-length regression. The regression was constructed from data taken from all size classes of fish. Fish were aged by both scale and otolith annuli counts.
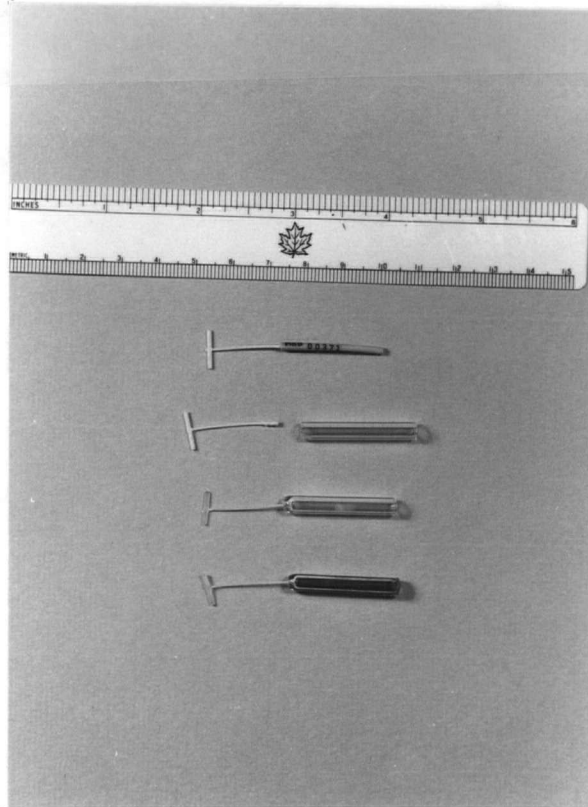
Figure 2

Construction details of the fluorescein tag

2.5 Diet

Fish recovered dead in the gill nets were frozen, upon return from the field and analyzed at a later time. Only the contents of the stomachs were analyzed because intestinal contents were, generally, unrecognizable or impossible to totally recover. Stomachs were removed from the animal, fullness estimated, and the contents emptied into a finger bowl for microscopic examination. The sagittal otoliths and a scale sample were also removed from all size classes of the fish recovered.

The analyses of the stomach contents were summarized on forms, an example of which is shown in Appendix I. Contents were scored by percentage occurrence and by percentage dominance. A dominant item was any item which represented $\geq 50\%$ of the total volume of the contents, estimated by eye. The dominant item selected on this basis yielded a general estimation of the major components of the fish's diet. Volume was the basic criterion employed because an analysis based on the frequency of occurrence of items alone confers equal statistical weight to all occurrences of any given item, without regard to the quantity of the item in the stomachs. A volume-based analysis has the additional advantage of incorporating some aspects of the energy contribution of diet items, although results regarding energy input through diet items must be interpreted cautiously if no data are available regarding caloric content and assimilation efficiency (Paine,1971). Specimens whose stomach contents exhibited no clearly dominant item, or whose contents were too digested to determine dominance, were assigned no dominance.

2.6 Distribution and abundance

The primary emphasis of the study was centred on the single kelp bed, but the overall regional distribution of Sebastes melanops was also investigated through jig and speargun captures, returns from a trolling cruise, reports from local fishermen and extrapolations from published data on the geographic and bathymetric distribution of the species. Jig and speargun samples were made on the southeast side of Trevor

Channel from Aguilar Point to Whittlestone Point; the trolling cruise covered the area at the mouth of Trevor Channel and that between Folger Island and Edward King Island (Figure 3).

The technique employed in establishing the distribution and abundance of S. melanops at the study site was to enumerate and size fish during underwater observational sweeps. The observational data encompassed physical parameters at the time of observation and information on the fish sighted. A typical observational summary sheet is illustrated in Appendix II. Sizes of fish were estimated and when necessary or possible, size was measured against background features, to which the fish could be adequately compared, using a pencil marked in centimetres. The accuracy of size estimation was checked by comparing the estimate with data on fish which were tagged or marked and observed on the same day.

The position of the fish in relation to the edge of the kelp bed was determined by comparison of sighting location with position along metred transit lines established on the bottom. There were three such lines of 35 mm metred, polypropylene rope, laid out 15 m normal to the edge of the kelp bed (Figure 4). The lines were anchored to bolts set into pre-packaged units of concrete which had been formed into rock crevices. These lines were only necessary during the initial observational dives until familiarity with the microtopography of the area was achieved, allowing accurate estimate of position. The observational sweeps were varied as to starting point, to minimize behavioural responses which could give rise to patterned positioning of the fish.

Observation dives attempted to monitor all aspects of the diel activities of the fish, in addition to seasonal features of their distribution and abundance.

Satellite Passage

Roquefeuil Bay

Dodger Channel

Aguilar Pt.

Cable Beach

Edward King Is.

TREVOR CHANNEL

Folger Is.

2nd Beach

Execution Rock

Whittlestone Pt.

N

Cape Beale

km
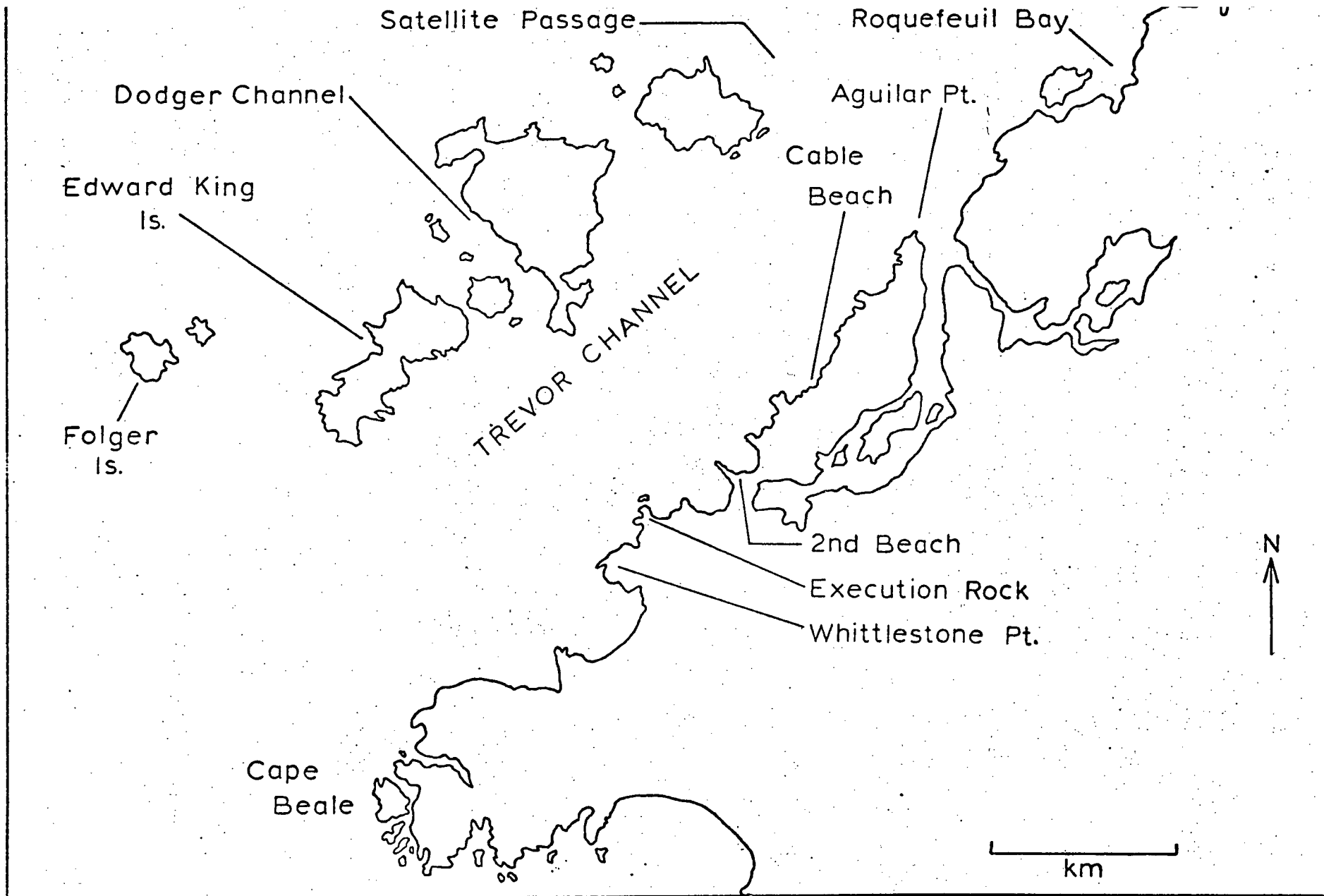
Figure 3

Sampling locations in Barkley Sound

Imperial Eagle Channel

Transit line

Frame II

Kelp boundary

Frame I

Sanford Island

Rock slope

N

Boundary of rock substrate

Trevor Channel
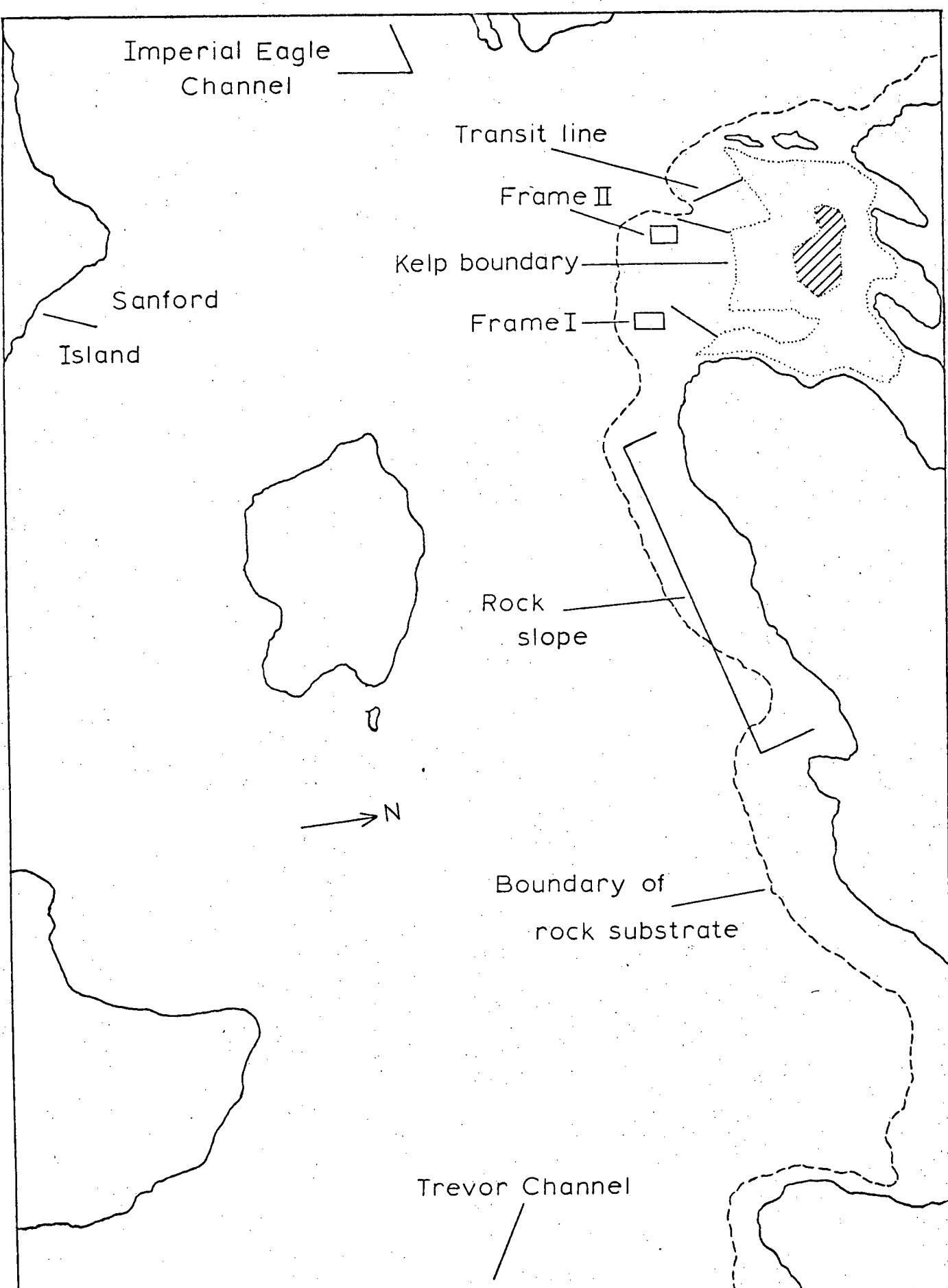
Figure 4

Study site and surrounding area

2.7 Laboratory experiments

Several laboratory experiments were conducted at the WCUMBS[1] Bamfield Marine Station, in an attempt to resolve conflicting field observations on nocturnal behaviour of the fish. The fish exhibited different distributional patterns under, apparently, similar nocturnal conditions. Observations suggested that light and current might be interacting to determine some aspects of the nocturnal distributional pattern. A series of experiments was conducted in which study fish were subjected to varying intensities of current and light, to determine if there was any interaction betweeen their phototactic and rheotactic responses.

Experiments were conducted in a 2700 litre aquarium inside a shaded area (illustrated in Appendix III), with fish being held in a similar aquarium prior to experiments. A single 40 watt microscope bulb controlled by a rheostat supplied the light. Actual light intensities were determined through interpolation from a plot of rheostat values versus lux produced, as measured with a photometer (Photovolt Corporation, Model 501-M). Experimental current regimes were produced with three submersible pumps (773 l/hr each) which were positicned at several lccations within the aquarium. The position of the fish and the orientation in the water column, assumed under each experimental condition, were noted. Behaviour between changes in levels of the factors was recorded.

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[1] Western Canadian Universities Marine Biological Society

2.8 Manipulative experiments

Two field experiments were conducted to determine the fidelity of the association between the fish and its habitat, and the nature of the relationship between the amount of physical shelter provided and the number of fish using it.

After these experiments, an artificial habitat, simulating the shelter aspect of the kelp bed, was constructed to examine the nature of the relationship between the fish and the shelter provided by the kelp.

(i) Previous work in Barkley Sound (Druehl, Green and Leaman, unpublished data) had shown that S. melanops (and other fish) were attracted to artificial 'beds' of kelp established in areas at least 70 m from the nearest kelp bed. These 'beds' consisted of elevated, rectangular frames covered with wire mesh. Plants, attached to bricks, were placed on the mesh in various densities. I repeated the essential features of this experiment without the metal frame, employing thirteen plants attached to clay bricks. These plants were taken from a kelp bed approximately 1000 m distant from the study site and were established at a location approximately 30 m from the nearest kelp. The edge of the existing bed at the study site was also extended 8 m, employing more plants from the same location as those used in the previous experiment. This second experiment was designed in an attempt to extend the contiguous distribution of the fish observed at the edge of the study kelp bed during daily observations.

A third experiment attempted to determine if there was any fidelity in the relationship of the fish and a given habitat

location or a given habitat type. Fish were captured and tagged at the study site and then transferred to several areas at varying distances from the site. In the instances where the fish were transported to another habitat containing Sebastes melanops, an equal number of similar sized fish were removed from this habitat, to ensure that the transported fish were not excluded from occupying this habitat by density-dependent factors. While the removal of these fish may have avoided a strictly numerical exclusion of the transported fish, it did not necessarily preclude, nor was it possible to control for, behavioural exclusion. The assumption must be made, therefore, that no antagonistic reactions existed between the two groups of conspecifics. The transported fish were tracked by net capture on the line of their transport to determine if they could return ('home') to the location from which they were taken; or whether they would remain in the new location to which they were transported. In addition, observations were made at the 'home' and the 'transport' sites to determine the fate of the transported fishes.

(ii) The capture of fish by size class over time was monitored and compared with changes in kelp density. The shelter provided by the kelp was estimated as kelp density, obtained by the method described in part 1. (iv) (p.7) of this section.

The artificial habitat (Figure 5) was constructed of 1.9 cm diameter iron reinforcing rod with corner brackets and rod holders brazed onto the frame. The dimensions of the habitat frame are given in the figure. The frame was partially

asssembled, transported to the study site and assembled under water (Figure 6). Shelter at the frame was provided by pieces of green 0.15 mm plastic cut into a shape to simulate kelp plants (Figure 7). The strips were cut into several lengths to enable them to reach the substrate from the supporting rods; the plastic was weighted at the bottom and attached to the supporting rods with clothes pins. The shelter provided by the plastic was taken to be the combined area of the strips. The amount of shelter provided by the plastic was changed periodically, by adding or removing pieces of plastic, and the numbers of fish associated with the frame was recorded during observation dives.

A second habitat frame was constructed and modified such that the pieces of plastic floated upward from the substrate (Figure 8), rather than hanging down as at Frame 1. Observations and manipulations at this frame were similar to those conducted at Frame 1.
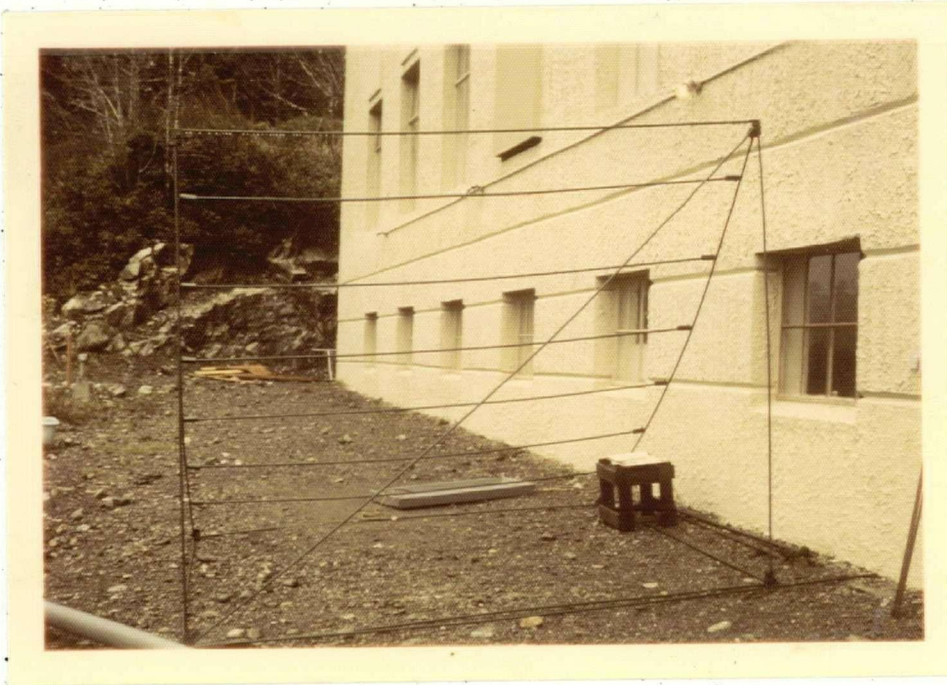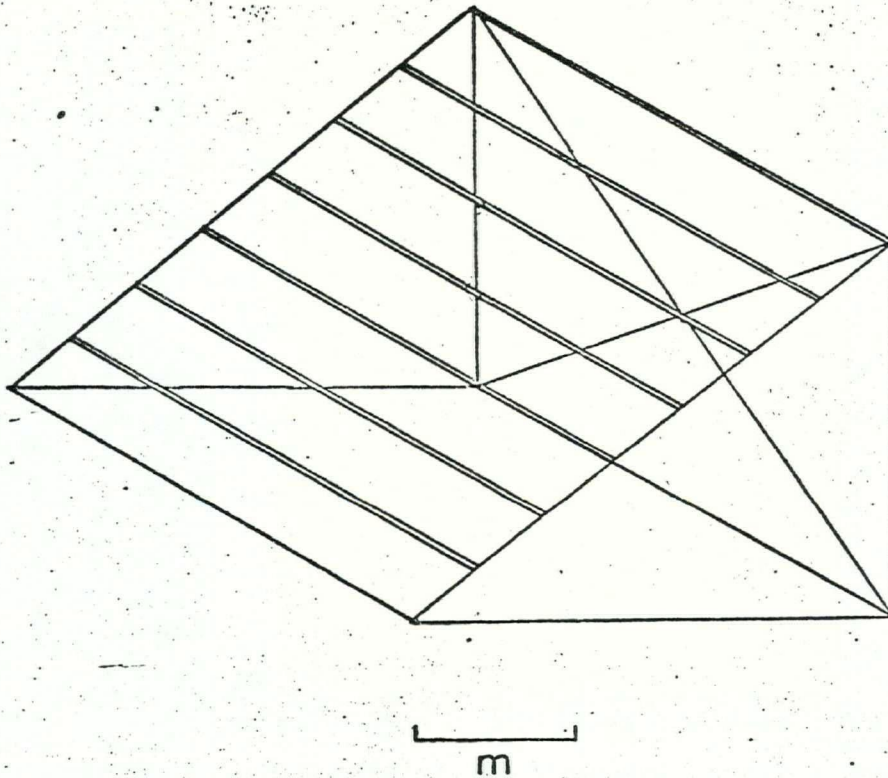
Figure 5

Photograph and dimensions of the habitat frame
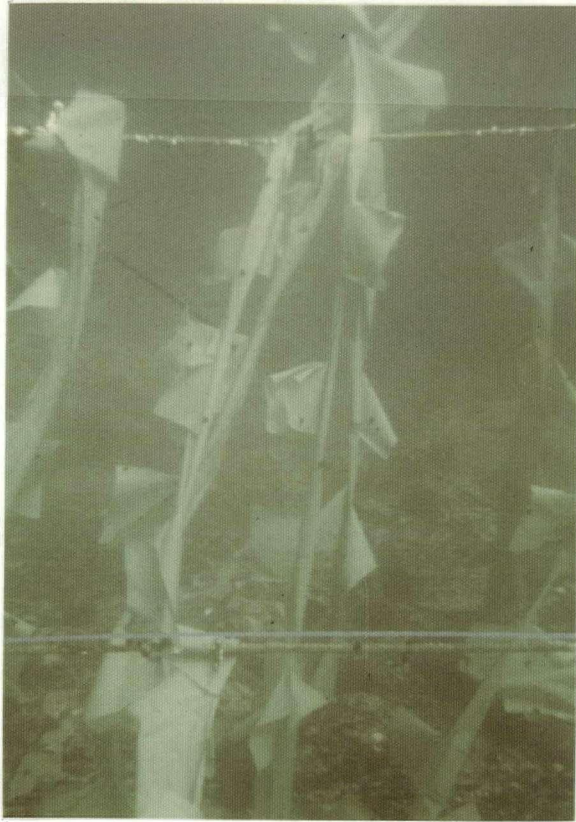
Figure 6

Underwater view of Frame I
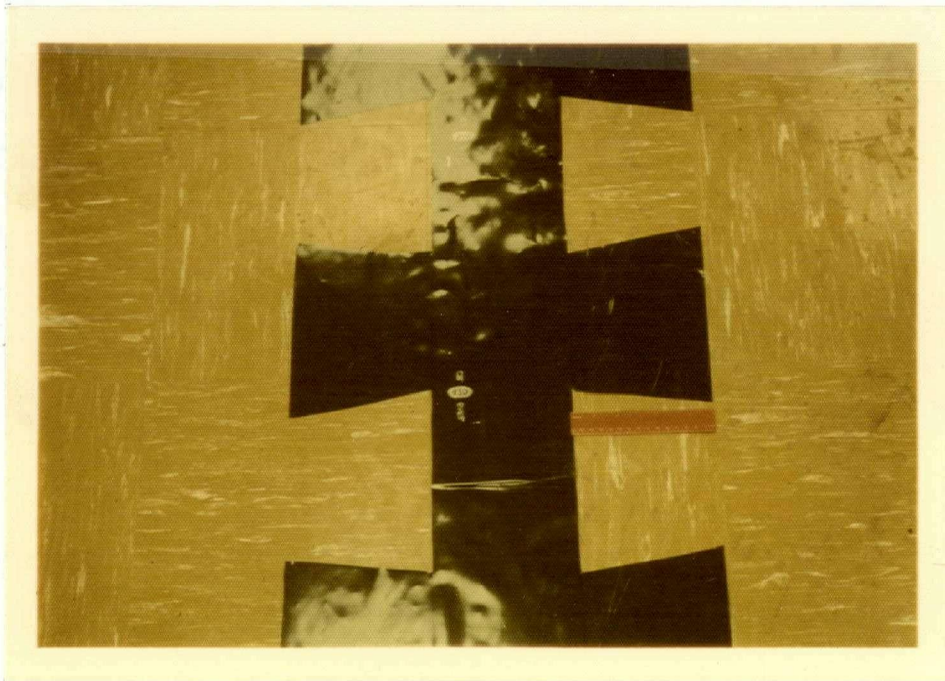
Figure 7

Plastic used in the shelter experiments

Figure 8

Underwater views of Frame II and the study kelp bed

3. RESULTS

3.1 Physical and biological characteristics of the site

The study cove comprised an area of appproximately 1000 m²
(995 m²), as calculated by measurements taken from an aerial
photograph, obtained through the Department of Lands, Forests
and Water Resources of the Province of British Columbia (BC
7261-052).   The kelp bed did not occupy the entire area of the
cove, rather, the surface canopy of the kelp was estimated from
a low - level aerial photograph (Figure 9) to be approximately
700 m² , or 70% of the area of the cove.

Figure 9
Low-level aerial photograph of the study kelp bed

Figure 10 is a bathymetric map of the site constructed employing the data obtained through hand soundings. The substrate is not uniform throughout the cove; there are several anomalies which affect the distributional patterns of the fish. The most prominent of these are the two trenches at the east and west sides of the cove. These depressions below the general level of the substrate have important ramifications on both the diurnal and nocturnal activities of the juvenile Sebastes melanops. A second anomaly at the site is the flat central portion of the cove, delineated by the crosshatched area in Figure 4 (p. 14). The significance of this central area is its substrate; the substrate of this area is sand with scattered, small (<5 cm diameter) rock, rather than the continuous, conglomerate rock of the rest of the cove. Since they require rock substrate for attachment, the plants are in very low abundance in this area. An examination of the low -level photograph illustrates this discontinuity.

The hydrographic conditions at the site were almost exclusively the result of conditions in Imperial Eagle Channel. Infrequent, large scale (>70 km/hr) winds from the southeast gave rise to waves striking the site from this direction. Predominant winds in the summer months were from the west, southwest and northwest and while southeast and east winds did occur during the summer, they were generally of too weak to generate waves impinging on the site from this direction. The result of the orientation of the site and the seasonal meteorological conditions is that the primary wave force was received onto the mouth of the cove from Imperial Eagle Channel.

The position and the orientation of the logs in the supralittoral region (Figure 11) of the cove illustrates the uniformity of this exposure.

The second major hydrographic influence in the region of the site was that of tidally generated currents passing through the two small channels, separating Sanford Island and Fleming Island, which link Trevor Channel with Imperial Eagle Channel. While tidal currents did not generate bottom currents in the immediate vicinity the kelp bed studied (Figure 12), their effect was considerable at the rock slope just to the east of the kelp bed. On extreme tides (4.5 m) tidal currents as rapid as 2.5 m/min were recorded at this location. The influence of these tidally generated currents on fish distribution will be presented in part 3.6 of this section.

The seasonality of the oceanographic conditions at the site was paralleled by a concomitant seasonality of kelp presence. Figure 13 details the change, over time, of the occlusion of the water column by kelp tissue. The degeneration of kelp tissue, beginning in August, is a result of several biological and oceanographic processes (e.g., degree of epiphytization, sea temperature, grazing pressure, etc.). While all of these factors influence the amount of tissue in the water column, the dramatic decrease in occlusion in August/September was closely correlated with the magnitude of south, southwest, and west winds or, more generally, the amount of stress to which the plants were subjected.

5 m

-0.5 m
-1.0 "
-1.5 "
-2.0 "
-2.5 "
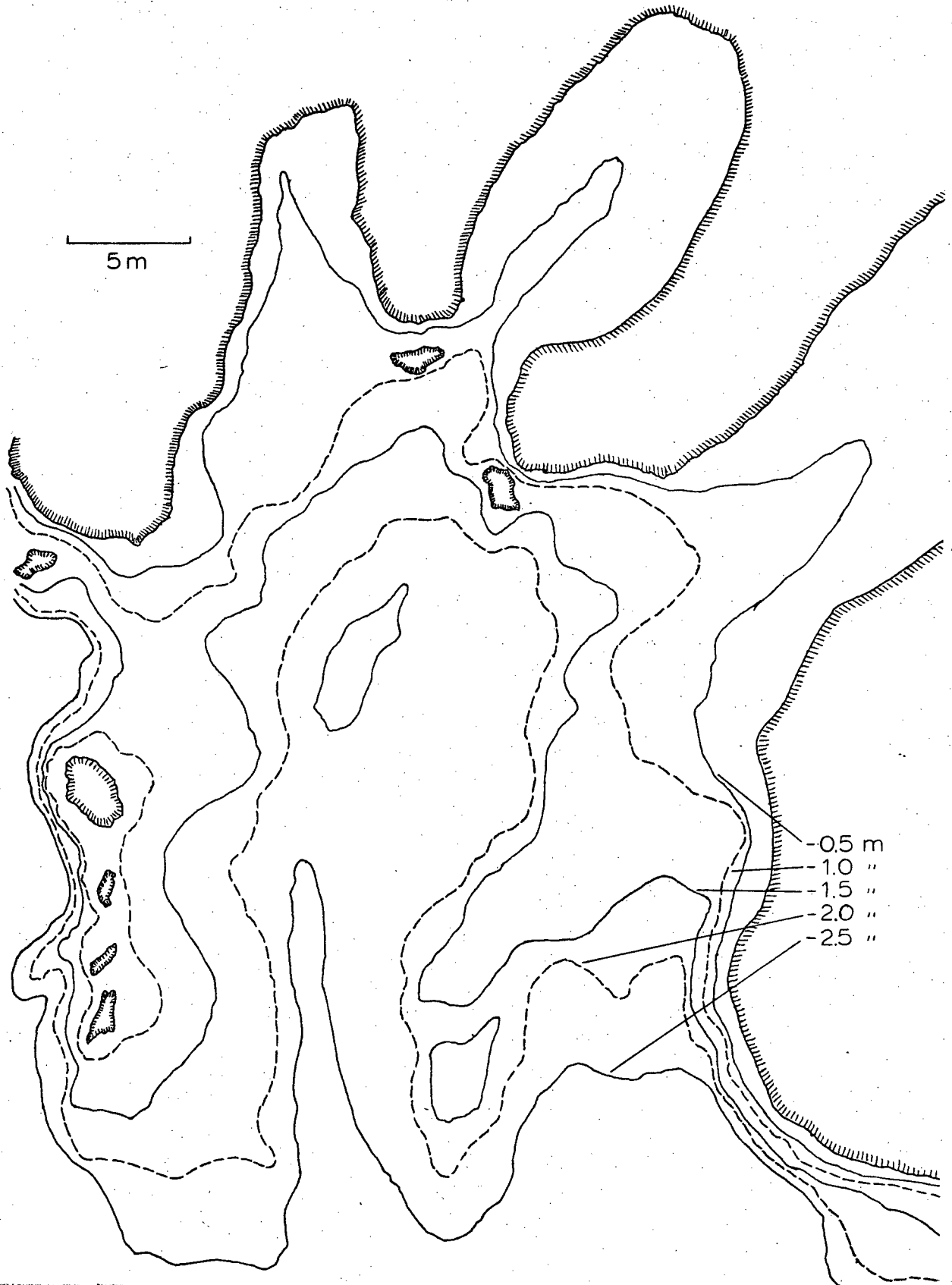
Figure 10

Bathymetric map of the study site

Figure 11

Aerial view of the study site. Note the orientation of the logs

on the beach
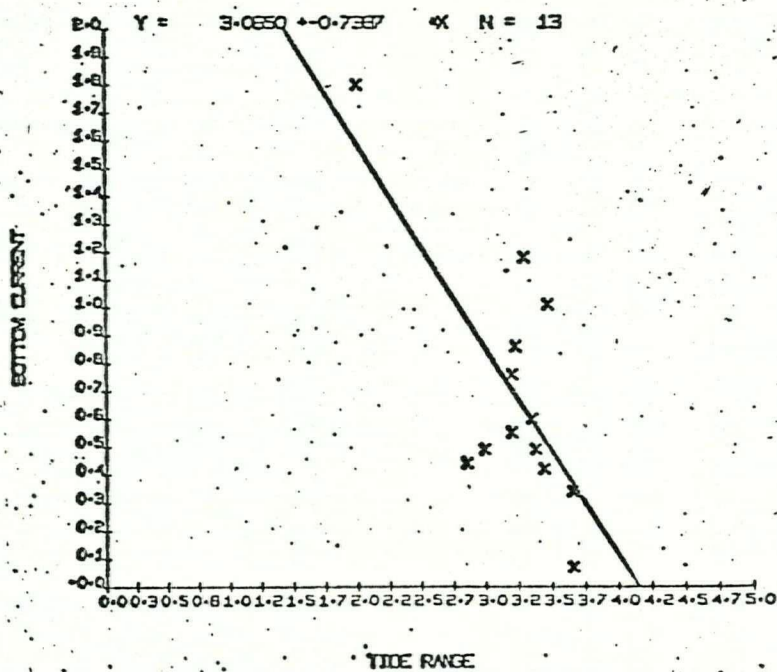
Figure 12

Regression of tide range on bottom current at the kelp bed

The fish assemblage at the study site, other than _Sebastes_
melanops, is presented in Table I. The sampling methods
employed differ in their effectiveness to sample any given
segment of a habitat, rotenone is most effective when sampling
those fishes associated with bottom features and gill nets are
most effective in obtaining larger water column fish. The
overlap between the two methods is, generally, a result of
either large specimens of epi-benthic fish being caught in gill
nets, or juveniles of water column forms being affected by the
rotenone.

OCCLUSION OF WATER COLUMN BY KELP 1973-74

TIME
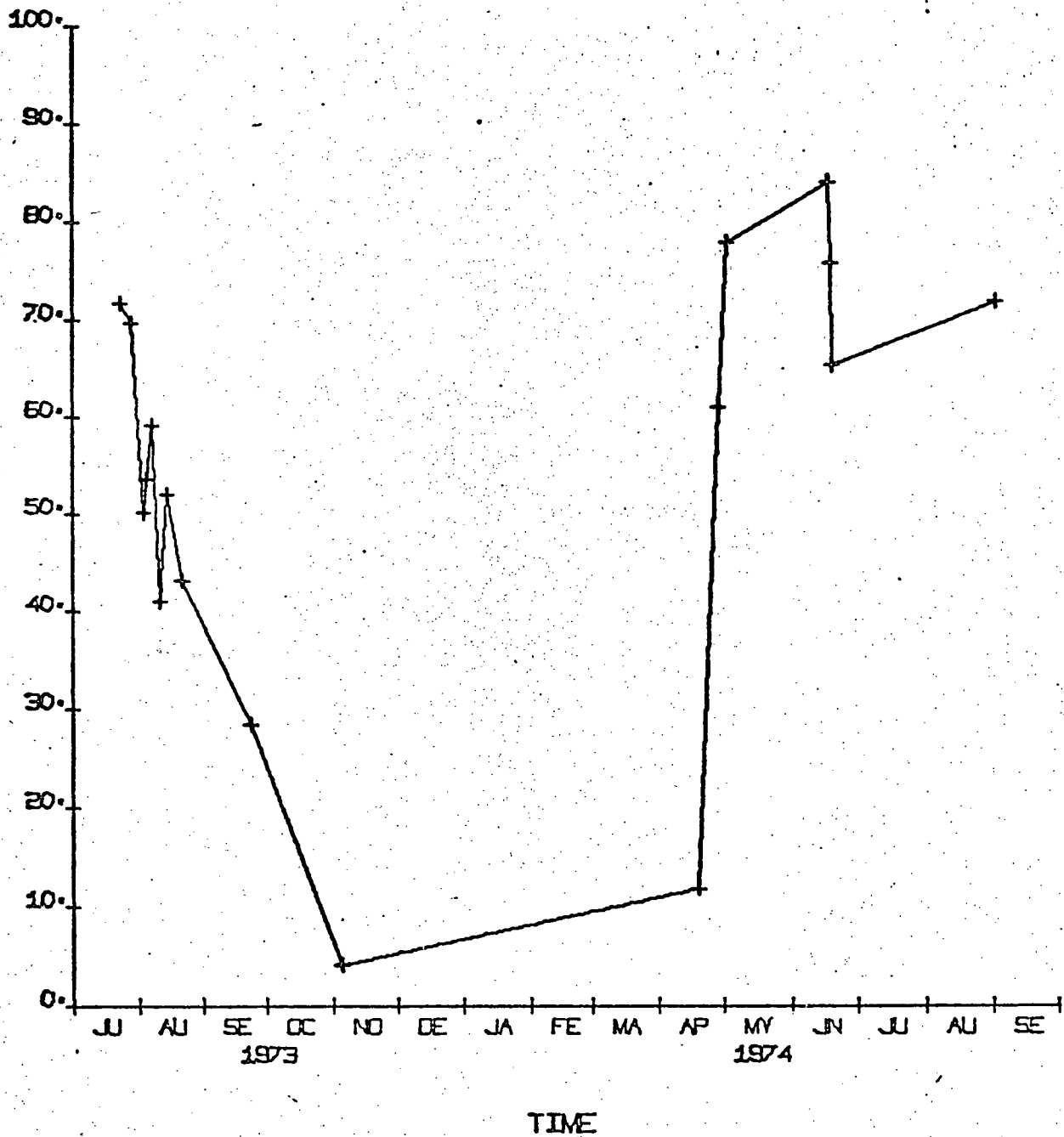
Figure 13

Seasonal change in average water column occlusion by kelp

tissue.   0.8 m above the substrate

TABLE I

Abundances of fishes, other than _Sebastes melanops_, at the study
site as determined through gillnet and chemical sampling.
Gillnet sampling, this study; rotenone sampling,1971

Species	Net	Rotenone
Engraulis mordax	96	
Hexagrammos decagrammus	29	
Sebastes caurinus	24	
Rhacochilus vacca	19	
Squalus acanthias	18	
Cymatogaster aggregata	11	24
Hemilepidotus hemilepidotus	10	13
Embiotoca lateralis	8	
Aulorhynchus flavidus	4	
Hexagrammos superciliosus	4	15
Merluccius productus	3	
Blepsias cirrhosus	2	2
Raja binoculata	1	
Clupea harengus	1	
Oncorhynchus kisutch	1	
Salmo gairdneri	1	
Porichthys notatus	1	
Sebastes paucispinis	1	
Ophiodon elongatus	1	
Scorpaenichthys marmoratus	1	
Artedius meanyi	1	
Oligocottus maculosus		97
Xiphister atropurpureus		55
Artedius lateralis		22
Pholis laeta		20
Xererpes fucorum		20
Anoplarchus purpurescens		15
Oligocottus snyderi		14
Apodichthys flavidus		10
Liparis florae		8
Artedius harringtoni		5
Gibbonsia montereyensis		5
Artedius fenestralis		3
Enophrys bison		1

3.2 Distribution of the species

The scope of the study was not sufficiently large to investigate the widespread distribution of the various life stages or size classes of S. melanops; however such information for adults has been obtained from an unpublished report on commercial trawl fishing along the Pacific coast (kindly supplied by Mr. Edwin Niska of the Oregon Fish Commission). Figure 14 is a map of the central Pacific coast of North America on which are indicated the positions, depths and yields of the adults of the species that were collected by Oregon - based trawlers. The bathymetric mode of abundance, as determined through this type of sampling, is in the 0 - 53 m depth range. The coastal regions, at the positions where these catches were made, are such that the depth range sampled is less than 10 km from the coastline.

A limited amount of sampling, other than at the study site, was done in Barkley Sound during the project. Figure 15 is a map of Barkley Sound on which are marked the numbers and average sizes of fish caught at several locations during this sampling program. An increasing cline in the average size of the fish is indicated when sampling from north to south in Trevor Channel. While the abundances of smaller size class juveniles (<150 mm) in Barkley Sound were not extensively investigated, observational samples in Macrocystis beds and in beds of the more exposed plant, Nereocystis luetkeana, show significantly higher numbers of S. melanops in beds of the less cumatophytic plant.
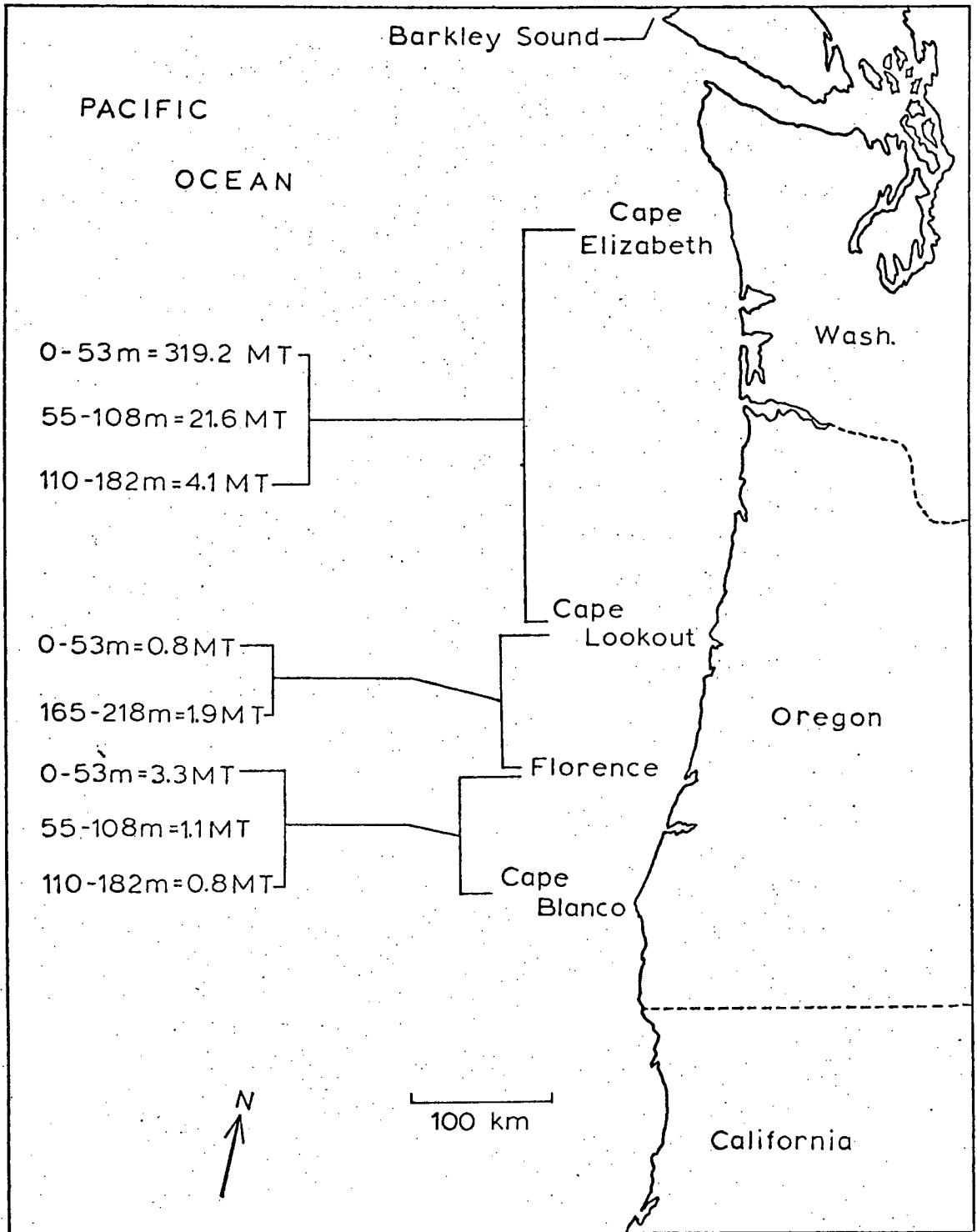
Figure 14

Abundances and depths of _Sebastes melanops_ capture by Oregon

trawlers. 1963 - 1971

Satellite Passage

N=15
$\bar{X}$=313m.m.

Edward King Is.

Folger Is.

TREVOR CHANNEL

N=23
$\bar{X}$=335m.m.

Execution Rock

N=5
$\bar{X}$=449m.m.

Cape Beale

N

km
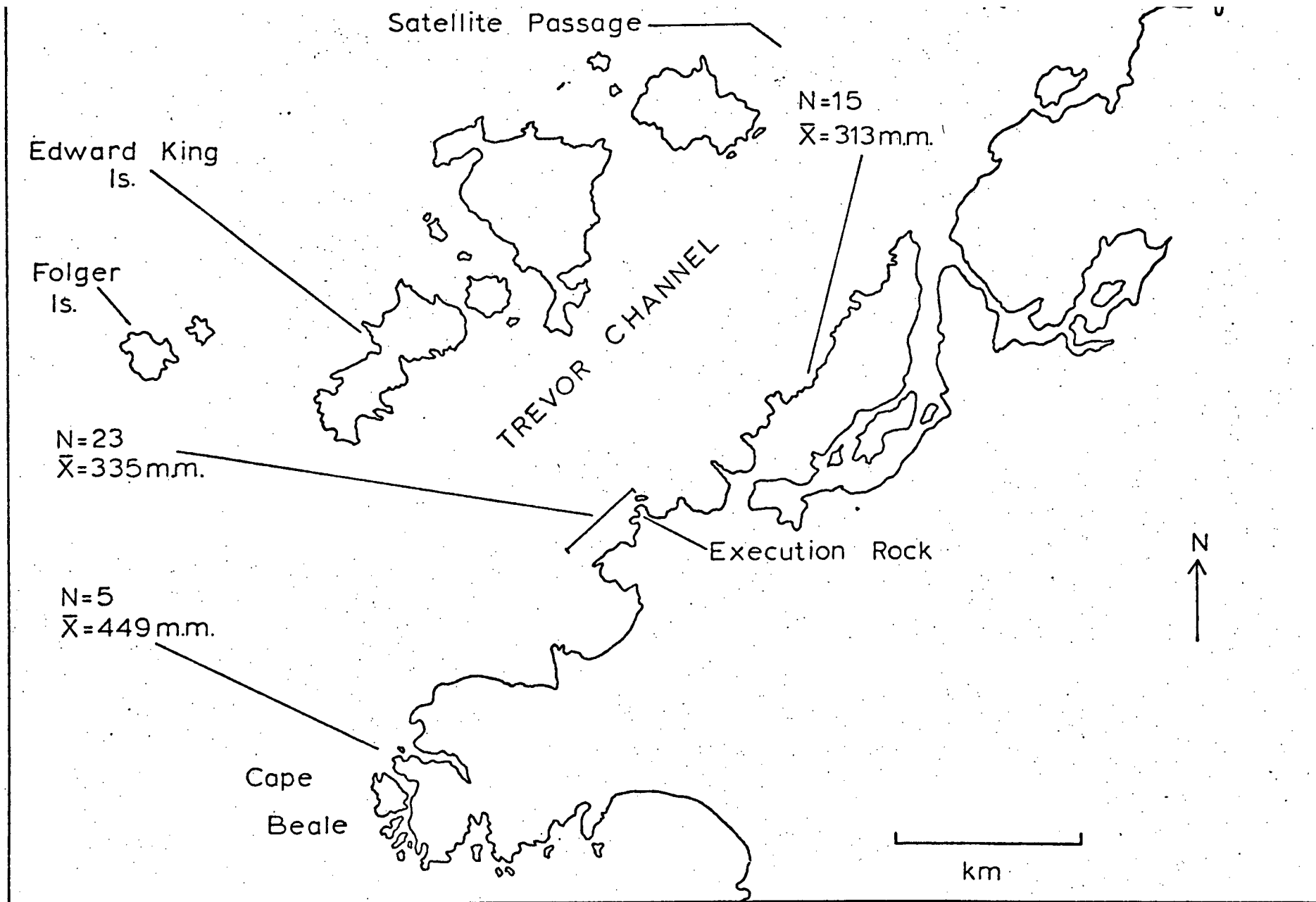
Figure 15

Sampling in Barkley Sound for *Sebastes melanops*

Plankton tows in Barkley Sound yielded numerous <u>Sebastes</u> spp. larvae (Figure 16), however, the appearance of 40 - 50 mm juveniles of <u>S. melanops</u> in mid-May indicates that none of the specimens collected was of this species. These 40 - 50 mm juveniles began to appear in the area of the kelp beds soon after the initiation of <u>Macrocystis</u> sporophyte growth. Significantly higher numbers of <u>Sebastes</u> spp. larvae were obtained in sheltered waters, both in surface and in subsurface hauls, than in open channels (e. g., 700 vs. 3, Trevor Channel vs. Ross Islets). The absence of any published description of the larva of <u>S. melanops</u>, as well as the large degree of intraspecific variation and interspecific similarity in larvae of the genus (S.J.Westrheim, personal communication) make the assignment of specific identity to any of the larvae questionable, at best.

No fish obtained at the study site were sexually mature and no gravid females were obtained in the course of sampling in the rest of Barkley Sound. All females caught which were sexually mature had ovaries at the stages 2 or 7 of Westrheim <u>et al</u>. (1968).
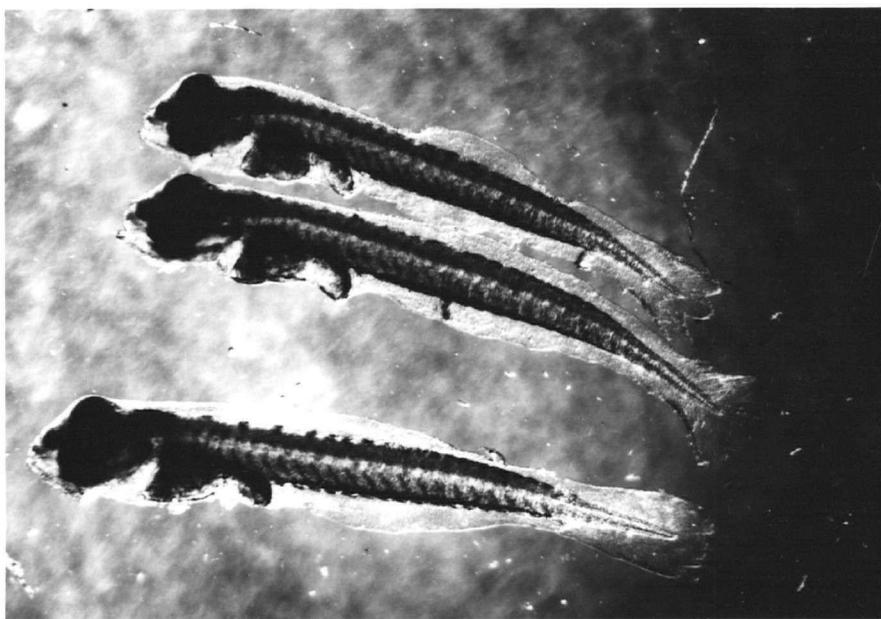
Figure 16

Sebastes spp. larvae obtained in plankton samples in Barkley

Sound.   January - April, 1974

3.3 Population dynamics of Sebastes melanops at the site

Collections of S. melanops, obtained by nettings over the
period of the study are presented by size classes in Figure 17.
The information presented in these figures was collected during
the course of the population sampling program, conducted to
obtain data on the dynamics of the species in the area.
Population estimates of the numbers of fish residing in the area
of the study site were derived separately from net captures of
tagged fish and from underwater observation of relative numbers
of marked and unmarked fish (Figure 18). 'Residence' of fish at
the site was assumed on the basis of both direct and indirect
evidence; the former, being recaptures of fish several times
over the course of the study, including overwintering
individuals, and the close similarity in population estimates
from season to season. Indirect evidence of residence includes
observations of tagged fish in the area of the site over long
periods of time, with no sightings in adjacent areas, and in
situ tracking of fish movements with fluorescein tags.
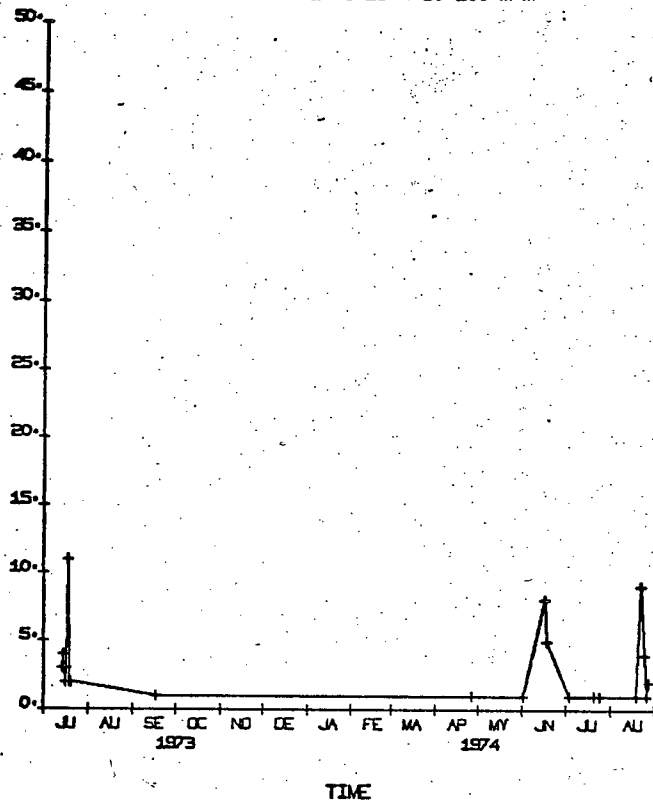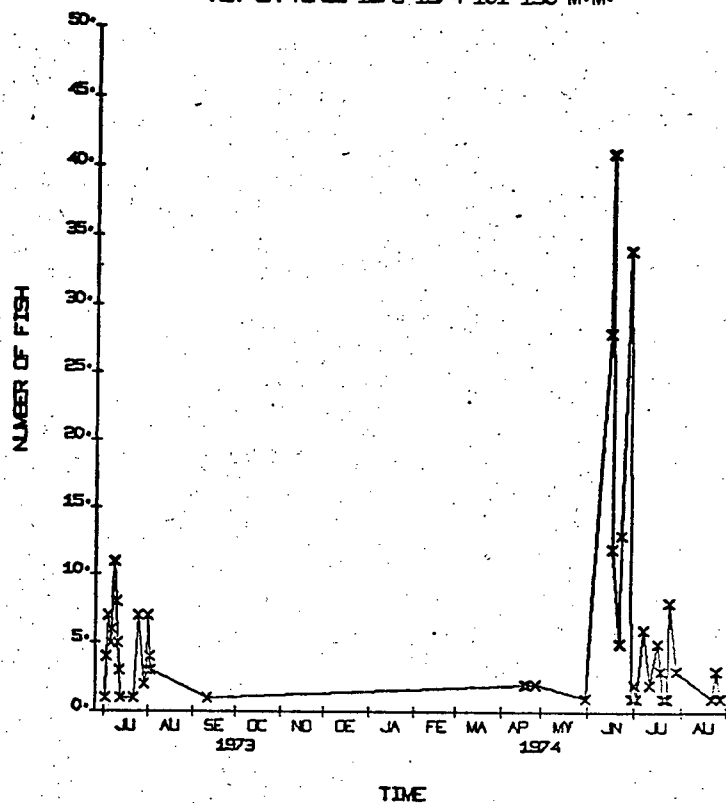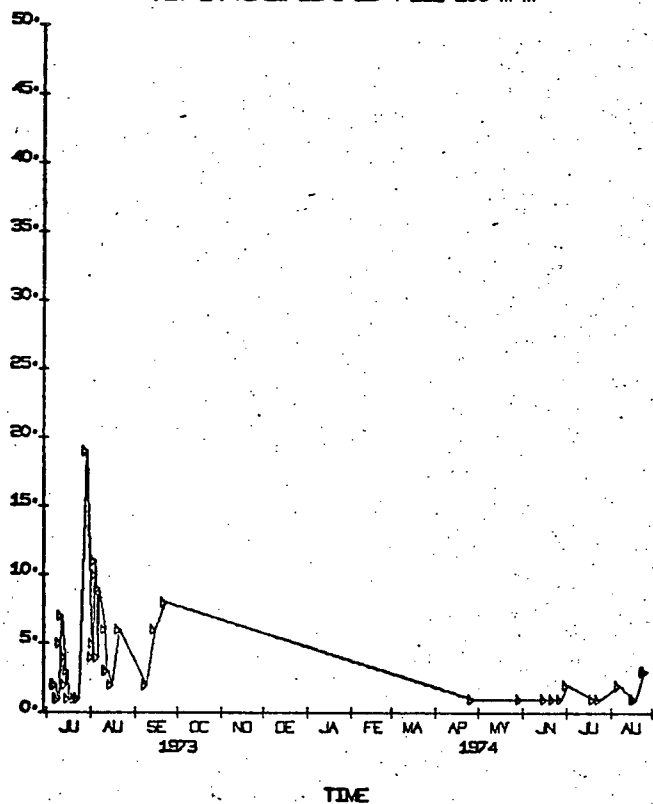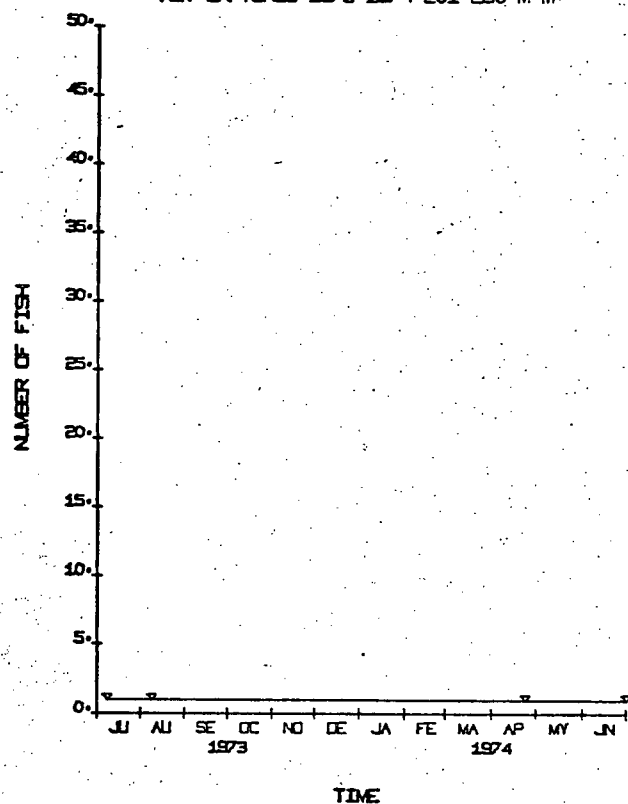
Figure 17

Net captures of Sebastes melanops at the kelp bed by size classes

CHAPMAN POP. ESTIMATES - OBSERVATIONS
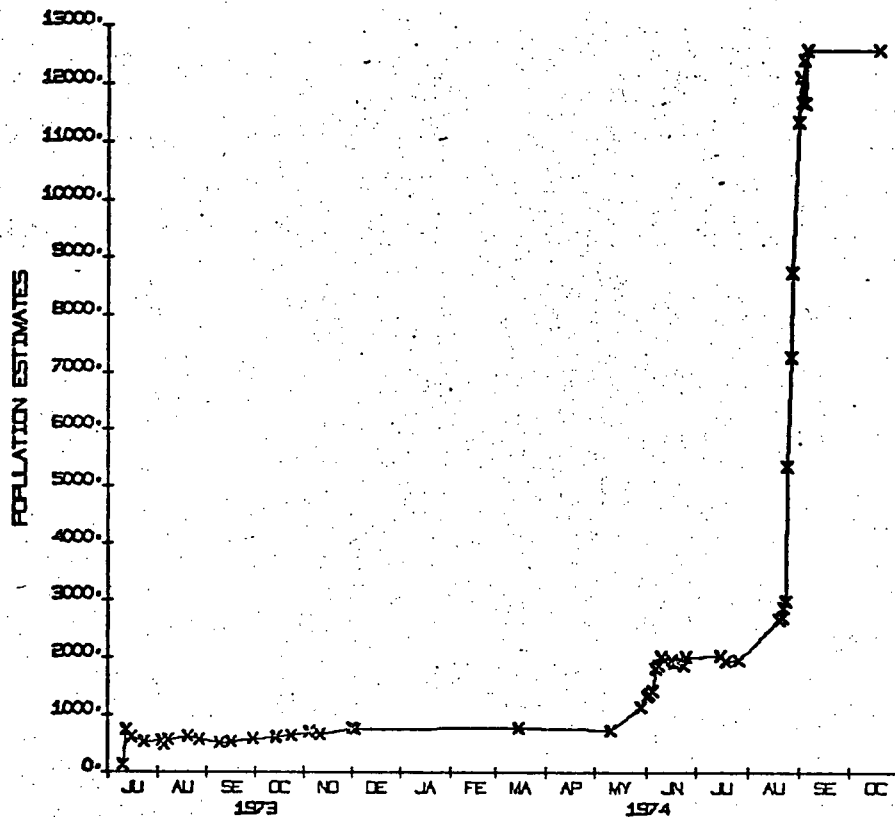
CHAPMAN POP. ESTIMATES - NETTINGS
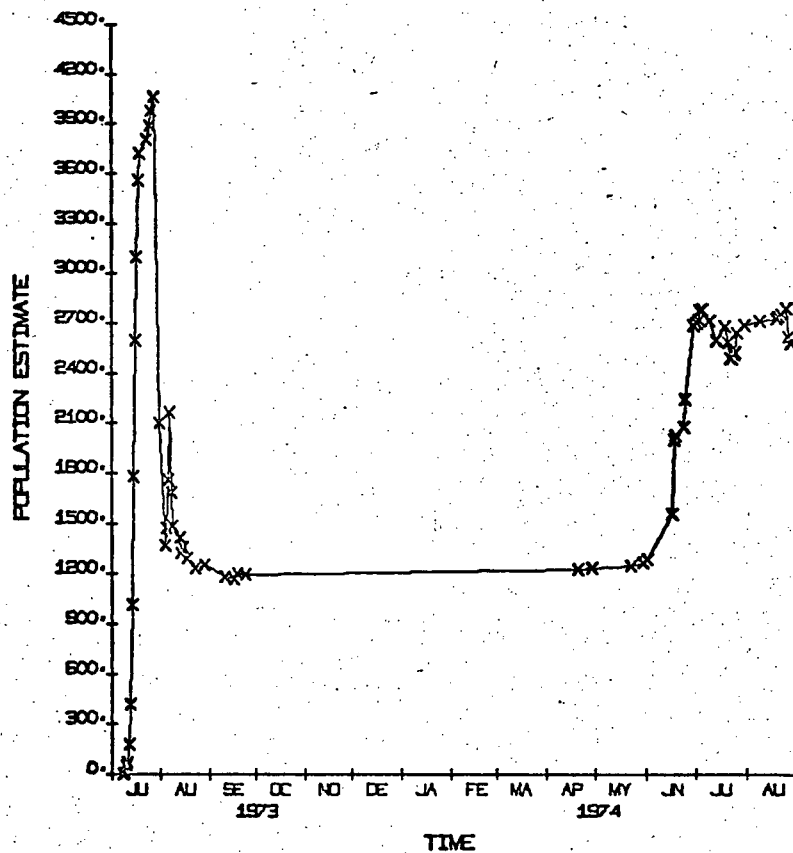
Figure 18

Population estimates of _Sebastes melanops_ based on recaptures

and observations of tagged fish

In addition to the population estimates generated with recapture data, changes in the lengths of these fish during the interval from initial tagging allowed calculation of their growth rates. Table II provides mean growth rates for two size classes of fish, as determined by the above method. Included in this table are the growth rates for these size classes as determined by regressions of age upon length, with age determination by both scale and otolith annuli estimation (Figure 19). A Chi-squared test for differences in the growth rates of the two size classes (as determined through recapture data) showed a significant decrease (p<.05) in growth rate for the 151 - 200 mm fish; the null hypothesis is that the rate was constant through the entire size range examined. There was also a significant difference between the growth rates of fish whose growth was interpolated from regression plots and those of 101 - 150 mm fish. The results presented in the table illustrate both the advantages of direct growth calculation and the lack of resolution of growth afforded with interpolation of age-length regressions. The age classes, corresponding to these size ranges, are also presented in this table.

AGE-LENGTH REGRESSION SCALES

Y =   -0.2549 + 0.1418E-01*X   N = 25

AGE IN YEARS

LENGTH IN MM.
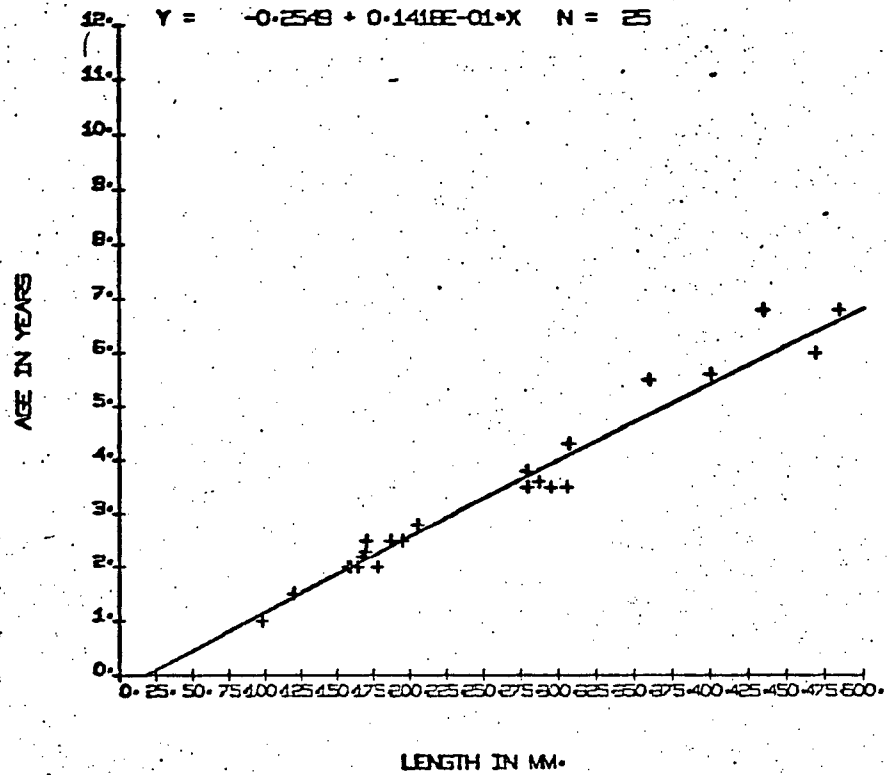
AGE-LENGTH REGRESSION OTOLITHS

Y =   -0.4806 + 0.1674E-01*X   N = 44

AGE IN YEARS

LENGTH IN MM.
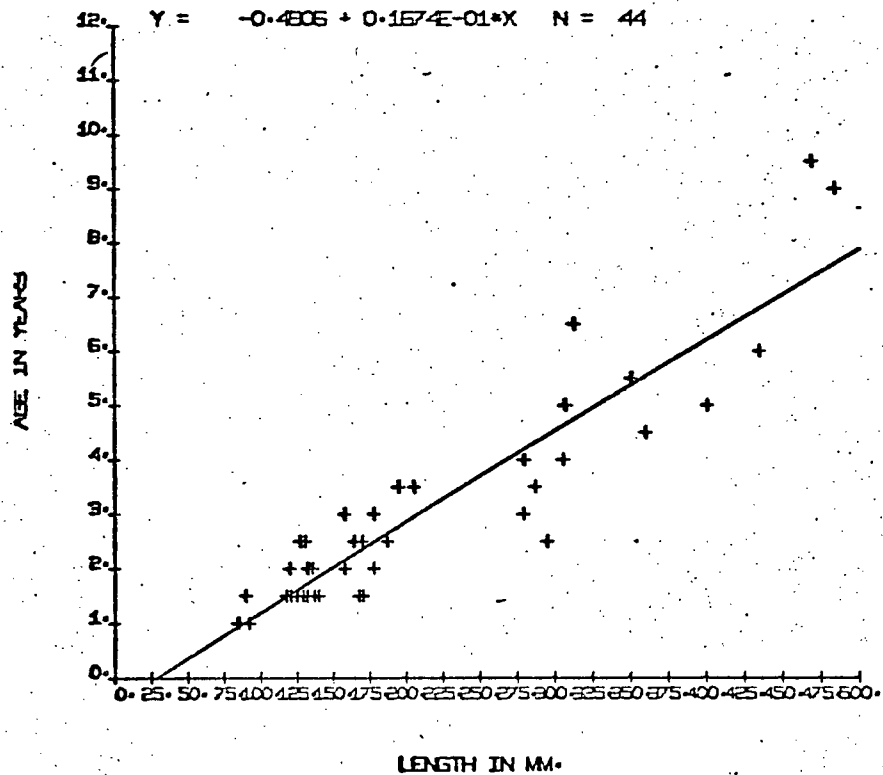
Figure 19

Age-length regressions for Sebastes melanops by scale and

otolith aging

TABLE II

Comparison of mean growth rates of _Sebastes melanops_ as determined by direct (recapture) and indirect (aging) measurements

Size-class	Age	Recaptures	Growth rate
1. 101-150 mm	I-II	9	104 mm/yr
2. 151-200 mm	II-III	10	58 mm/yr

Aging Method	No.	Size Range	Growth rate
3. Otolith aging	44 fish	84-484 mm	60 mm/yr
4. Scale aging	25 fish	98-515 mm	68 mm/yr

Growth rate difference	Chi-squared value
1. vs. 2.	12.76*
1. vs. 3.	11.94*
1. vs. 4.	7.73*
3. vs. 4.	0.49

* - significantly different (p<0.05)

3.4 Diet

Analysis of the stomach contents of net-caught specimens was performed in two ways:

- frequency of occurrence of diet items in the stomachs; and
- frequency of dominance (as previously defined) of any item in a given stomach.

These data are differentiated for all fish combined, and for the three size classes analyzed (Figure 20). The results of Chi-squared statistical tests for differential frequencies of dominance, between the two most common diet items for each size class are listed in Table III. The major habitat where each of these diet items is found is also included in this table. All of the size classes examined exhibited a relatively narrow total diet spectrum. The primary food input was restricted to two different diet items and was consistent for any specific time on an annual basis.

The seasonal change in the occurrence of the two primary diet items was examined as the number of fish of each size class whose stomach contained the item. Figure 21 represents the collation of this information for the period of the study.

DIET ITEMS - ALL FISH

Empty
Polychaetes
Mysids
Amphipods
Crabs
Crust. Remains
Mussels
Clupeids
Unident. Fish
Cumaceans
Eggs
Copepods
Euphausids
Zoea

PERCENT FREQUENCY

DIET ITEMS· 30-100 M·M·

Empty
Amphipods
Crust. Remains
Clupeids
Unident. Fish
Euphausids

PERCENT FREQUENCY

DIET ITEMS 101-150 M·M·

Empty
Mysids
Amphipods
Crabs
Crust. Remains
Mussels
Clupeids
Unident. Fish
Copepods
Zoea

PERCENT FREQUENCY

DIET ITEMS 151-200 M·M·

Empty
Polychaetes
Mysids
Amphipods
Crabs
Mussels
Clupeids
Unident. Fish
Zoea

PERCENT FREQUENCY

Figure 20

Frequency of diet item occurrence in Sebastes melanops. Open

bars = occurrence, hatched bars = dominance

SEASONALITY OF DIET OCCURRENCE

+ clupeids

x mysids

PERCENTAGE FREQUENCY

TIME

JN   JU   AU
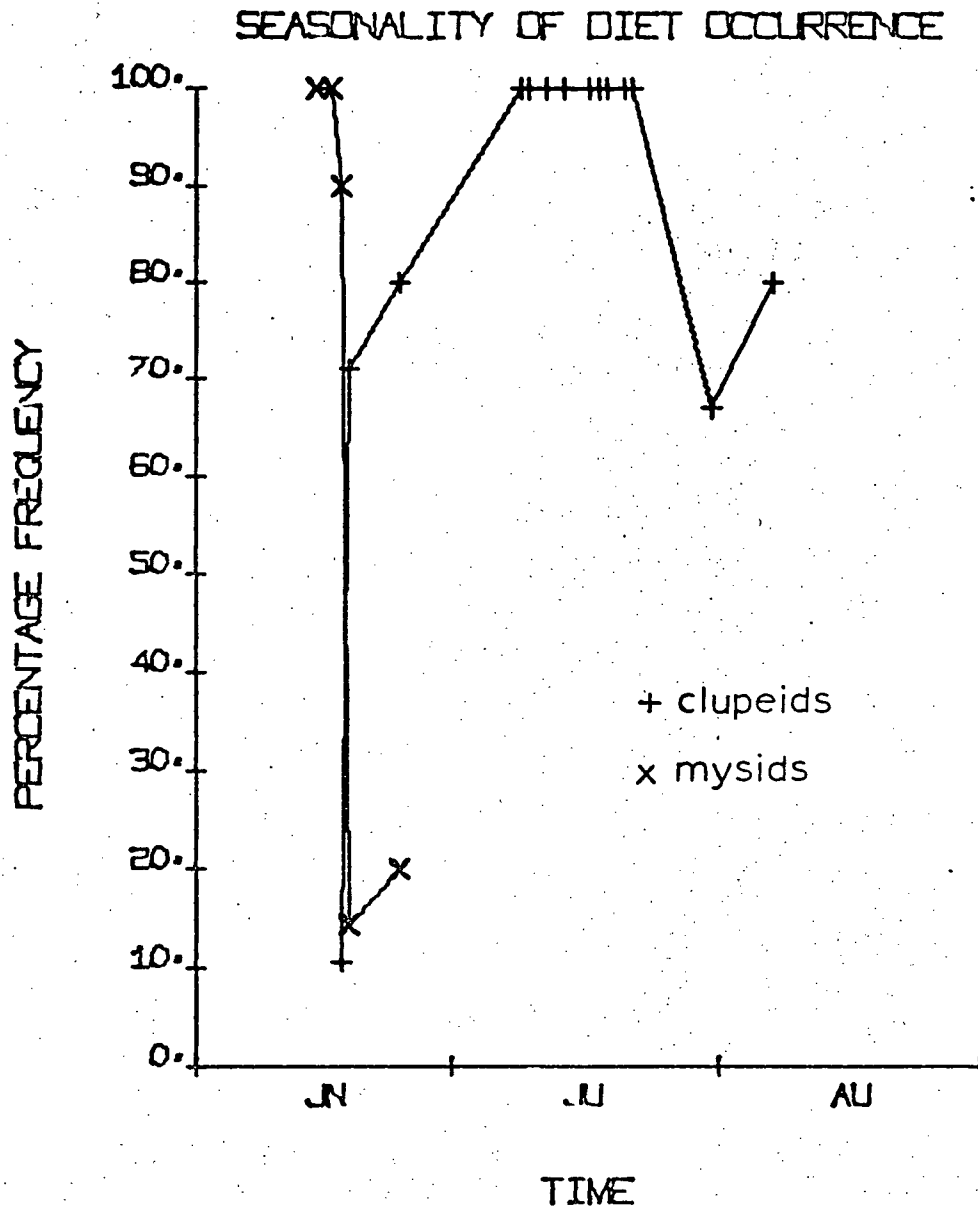
Figure 21

Seasonal change in the occurrence of mysids and clupeids in the
diet of <u>Sebastes melanops</u>.

TABLE III

Major food items of each size class of Sebastes melanops, as determined through gut analysis, with a statistical comparison of the percentage frequencies of dominance of these items

Size Class	Stomachs Examined	Major Food Items	Type	Freq. of Dominance
30-100 mm	10	clupeids	P	66.7%*
		unid. fish	P	33.7%
		euphausids	−	−
101-150 mm	79	mysids	P	51.7%*
		clupeids	P	36.2%
151-200 mm	39	clupeids	P	73.7%*
		mysids	P	10.5%
		amphipods	B	−

* - significantly greater (p<.05)

P - pelagic/water column form

B - benthic form

3.5 Localized distribution and abundance

(i) Seasonal: Fish were not present throughout the year at the location of the study kelp bed, rather, fish were present only when the kelp plants were present. Figure 22 is a composite of previously presented figures which illustrates the close correlation between the abundance of net caught fish and

the presence of kelp. Nettings during the period from October,1973 to April,1974 did not yield any fish from those locations netted during the rest of the study (Figure 22). Fish in the size range 201 - 250 mm were uncommon at the kelp bed throughout the study. In addition to the study kelp bed, a second area of consistent fish occurrence was monitored for the duration of the study. This location was a sloping area, immediately to the southeast of the study site, composed of uneven, large (1.0 - 3.0 m diameter) boulders extending 2.4 -9.1 m in depth and meeting the same sand flat which fronted the kelp bed area (Figure 23). Seasonal abundances of fish at this area showed an approximate inverse correlation with the presence of fish at the kelp bed (Figure 24). This correlation was more apparent for 30 - 100 mm fish than for 101 - 100 mm fish.

(ii) Daily: Considerable variation was evident in the numbers of fish seen on any given day or series of days. This variation existed within larger scale changes in fish abundance at any location and was present at both high and low levels thereof. Experimental work conducted during the project must be considered in light of this variation. A more detailed treatment of variation in abundance is included in section 3.7 (p.57).
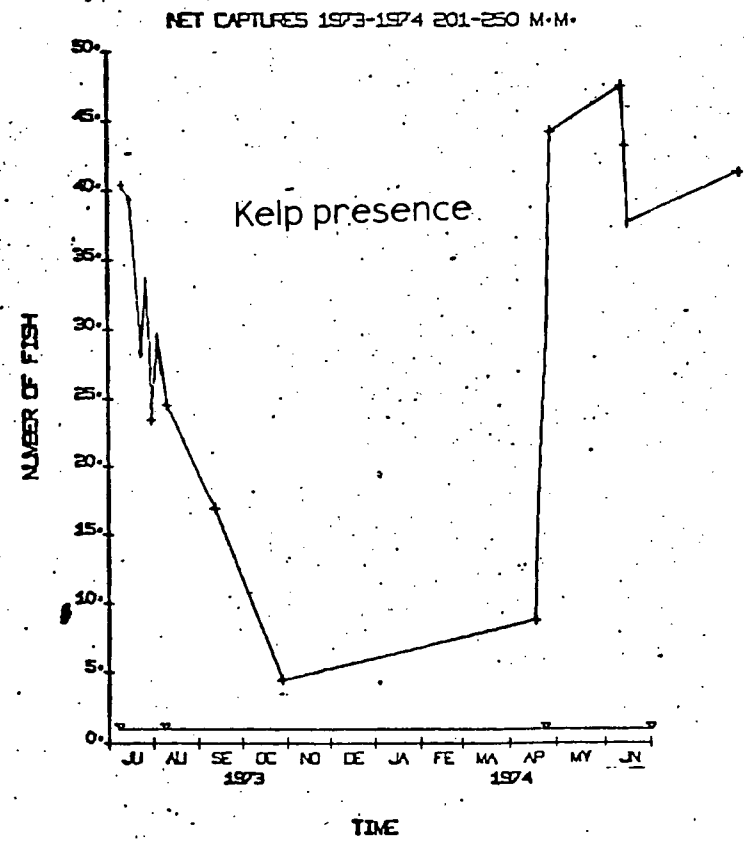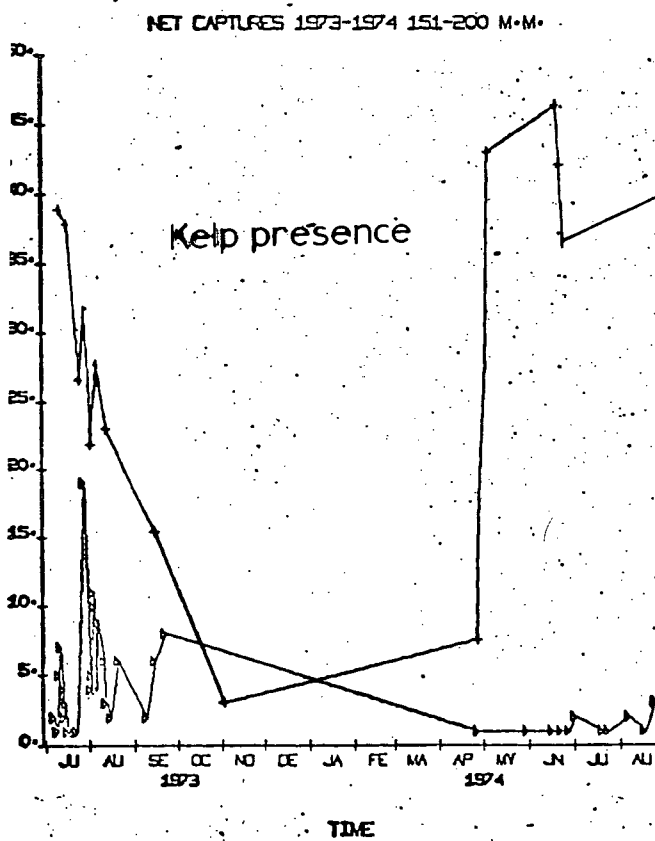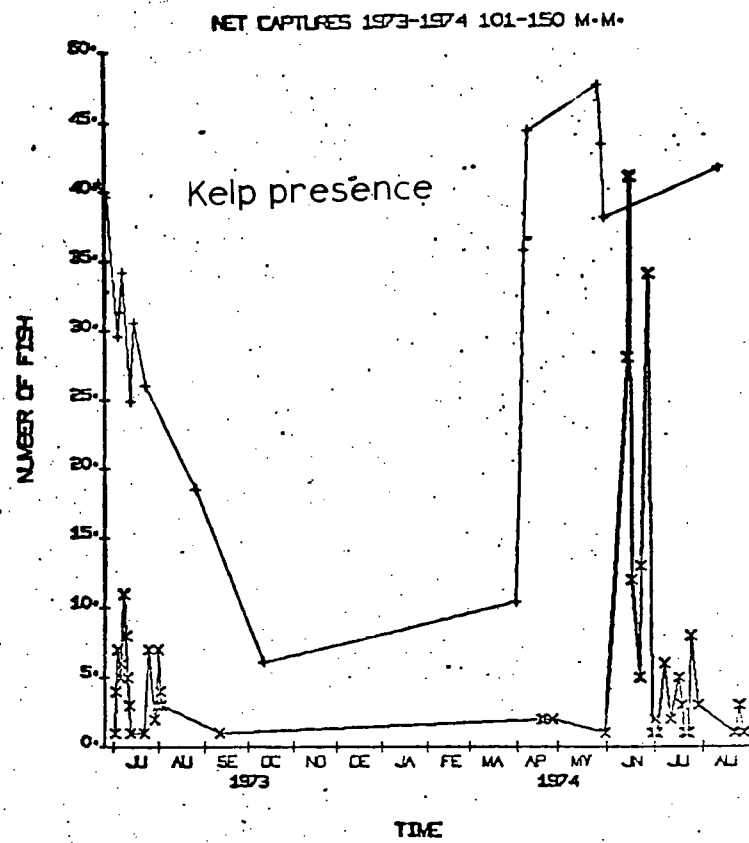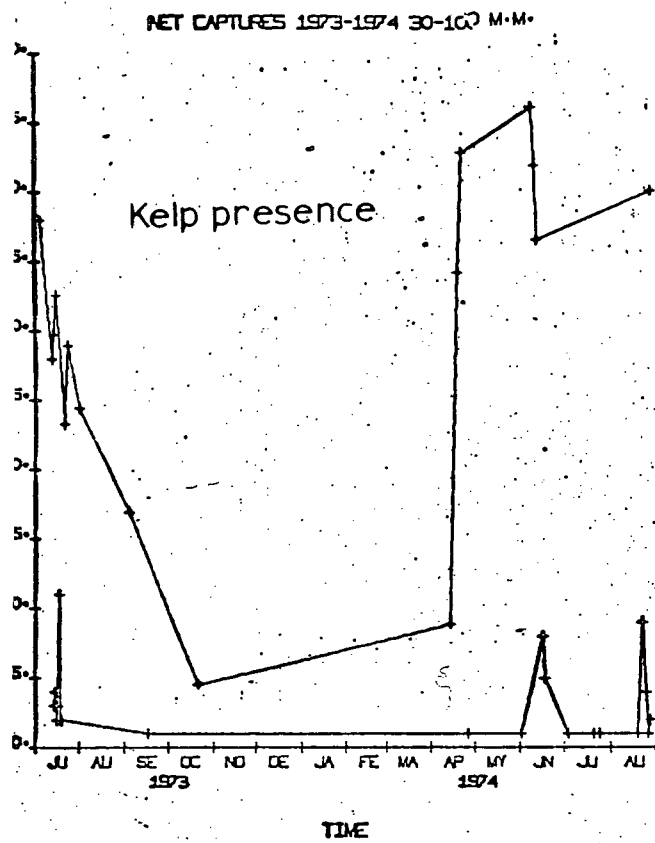
Figure 22

Coincidence of kelp presence and fish capture
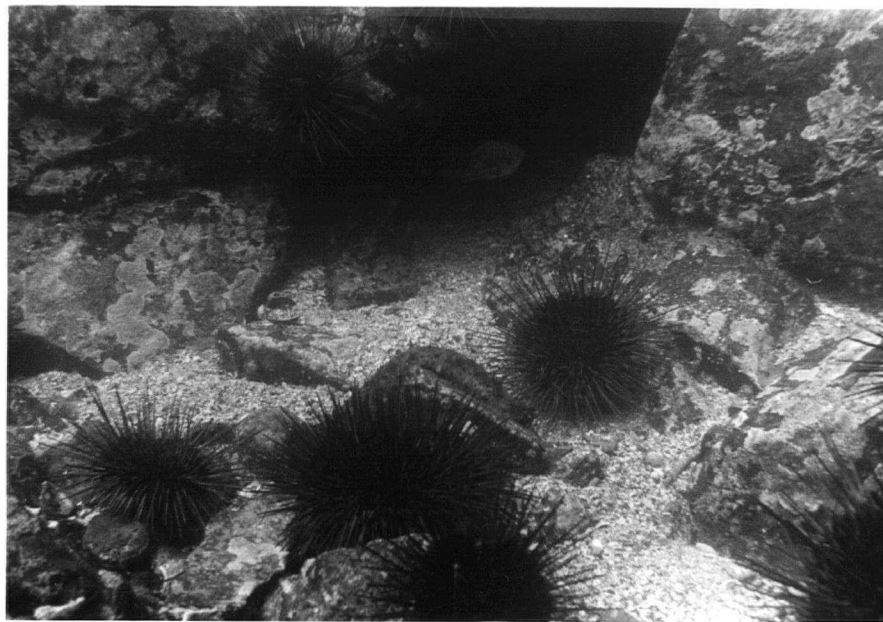
Figure 23

Physical nature of the rock slope area
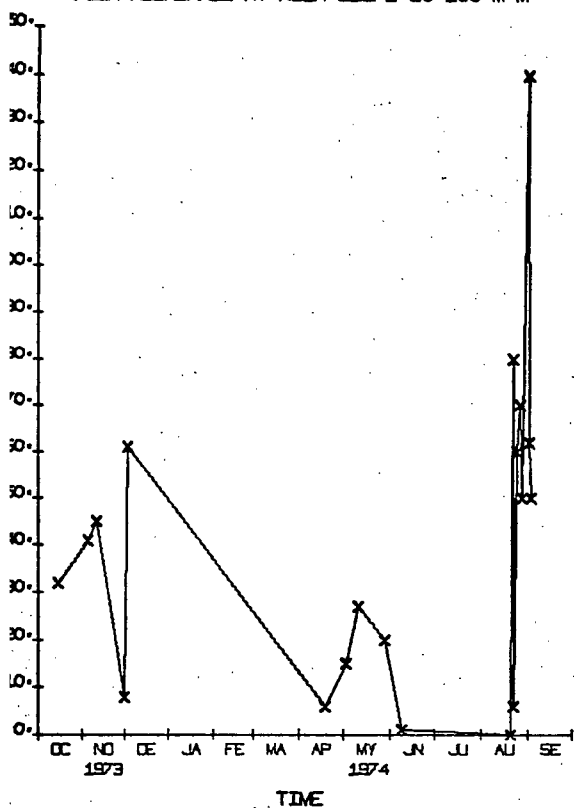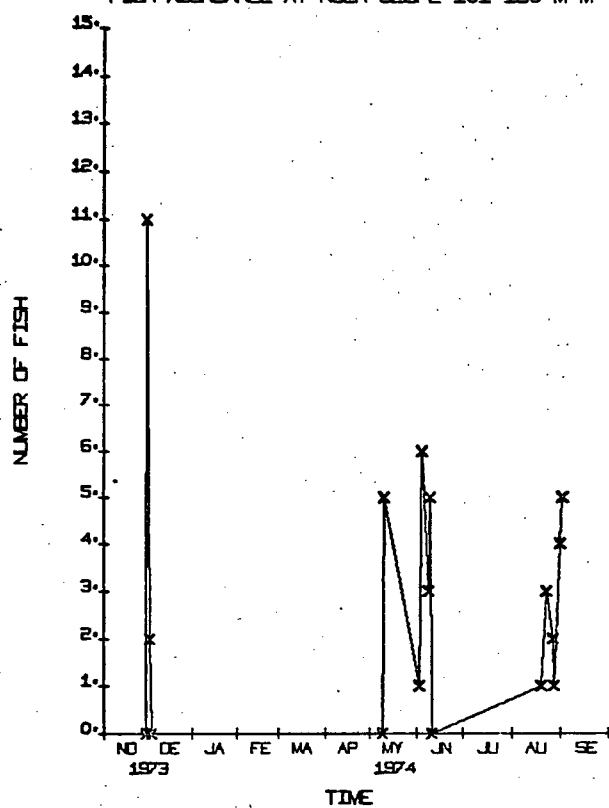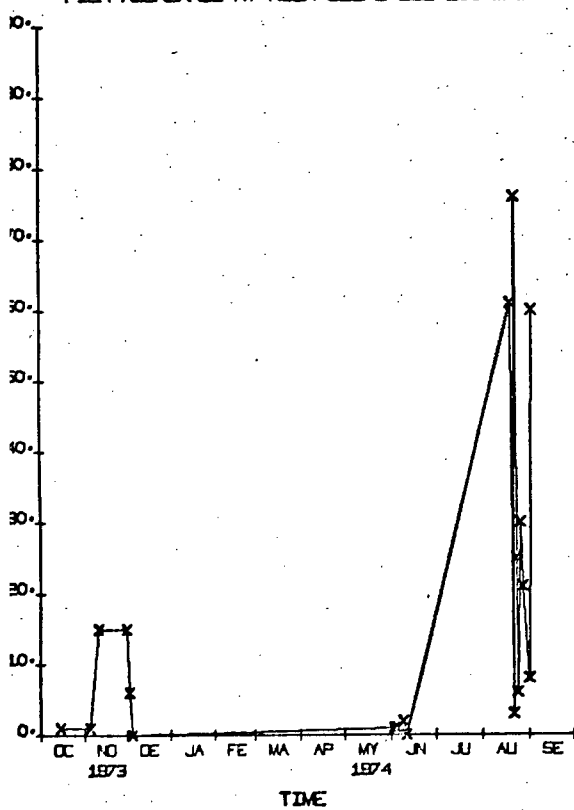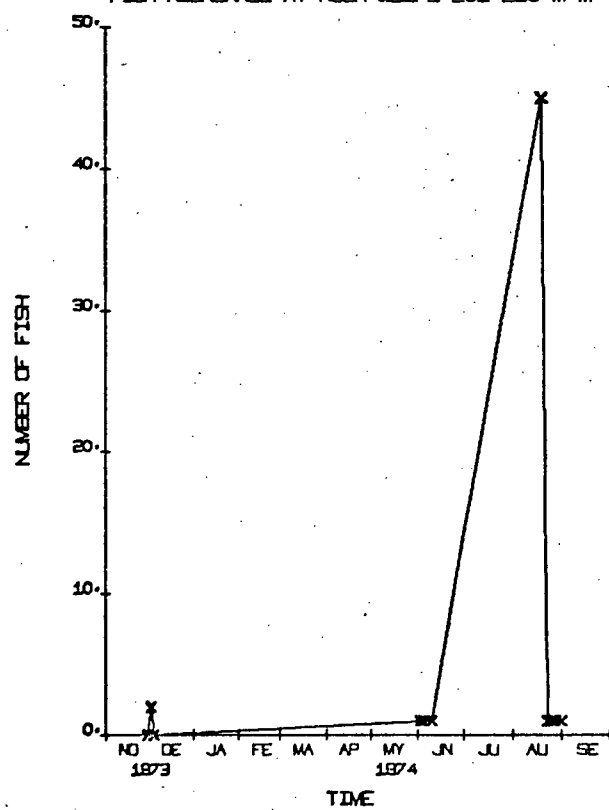
Figure 24

Observed abundances of fish at the rock slope

(iii) Diel: S. melanops juveniles undertake diel migrations throughout the immediate vicinity of the kelp bed. The extent of these migrations varies, often extensively, between different size classes of fish but the initiation, duration and completion remain relatively consistent. The lengths of the migrations are closely related to the size of the fish involved. Size-class distribution graphs for 1973 and 1974 (Figures 25 to 27) establish cumulative totals of in situ nocturnal and diurnal positions of the fishes, using the kelp bed as a frame of reference. Negative and positive numerals on the abscissa correspond to positions (in metres) shoreward and seaward from the outside of the bed, respectively. Statistical analyses (Table IV) of the positional abundances of the size classes of the fish show significantly greater numbers of fish inside the bed than outside. In 1973 this situation existed both diurnally and nocturnally. In 1974 the distribution of the fish showed an alteration of habitat utilization by the larger size classes; in this year, 30 - 100 mm fish showed a consistent association with the kelp bed, both nocturnally and diurnally. Fishes of sizes 101 - 150 mm and 151 - 200 mm displayed a diel transition such that significantly higher numbers of fish were present outside the bed diurnally. Conversely, the nocturnal distribution patterns were the same as in 1973. Observations indicate that the inward migration of fish takes place before sunset and, in a similar fashion, the outward migration occurs after sunrise. No differential timing of the migration was noted between the two size classes.
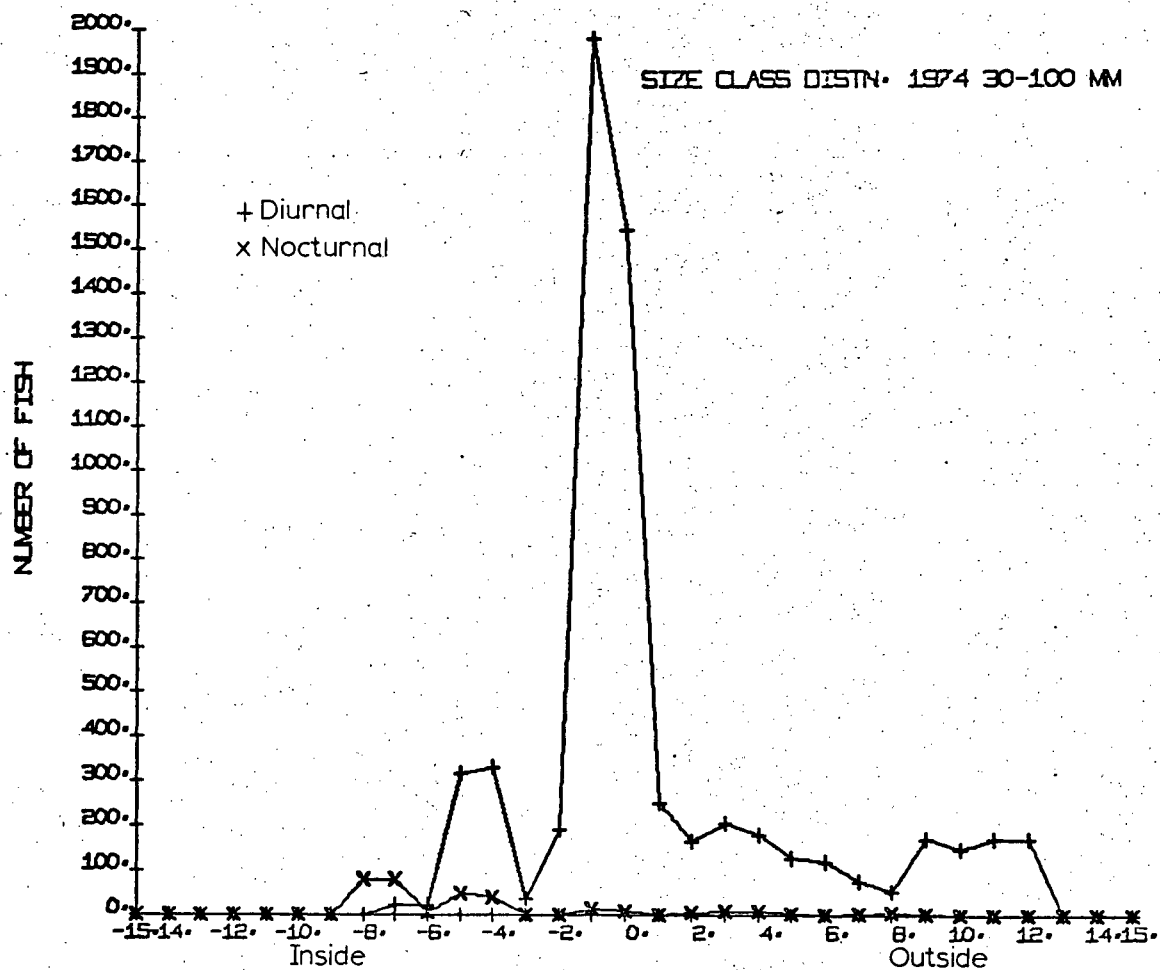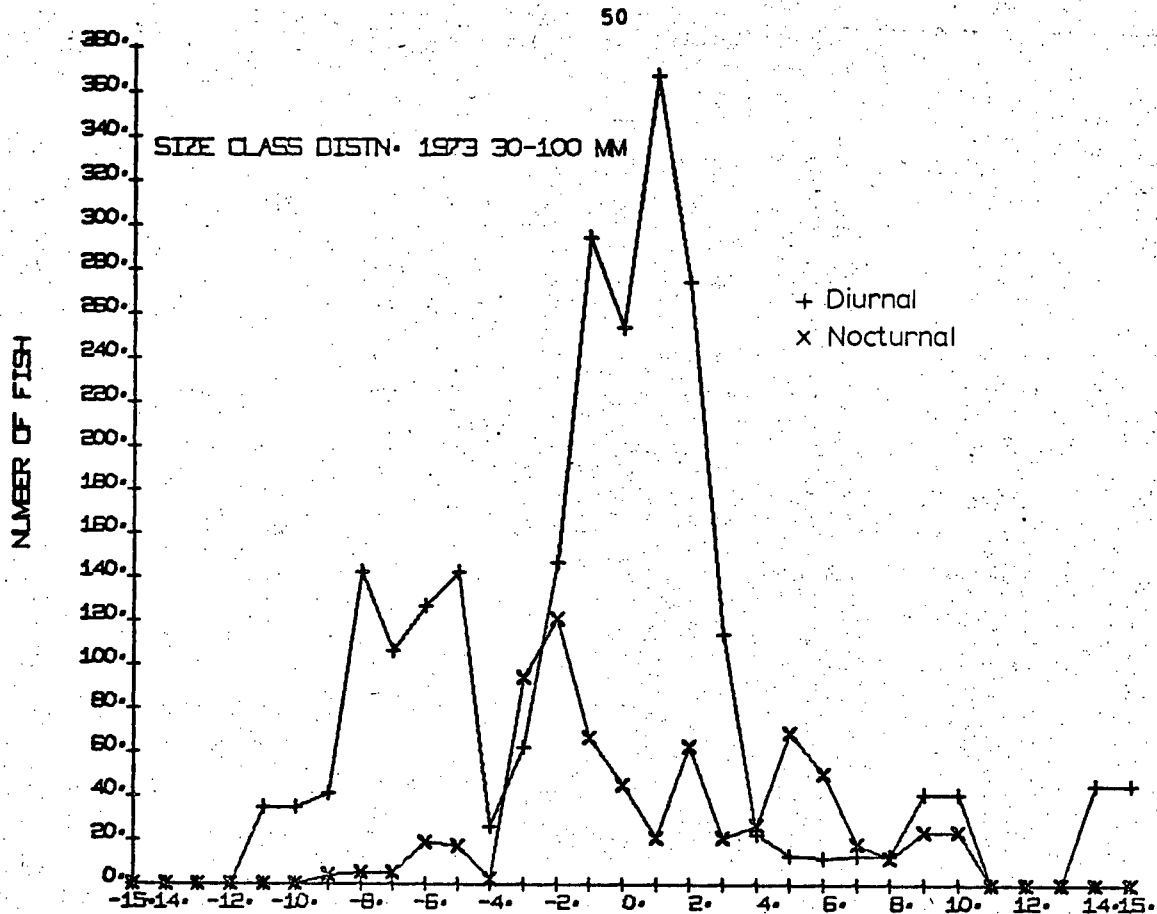
Figure 25

Cumulative nocturnal and diurnal observations of fish position.

30 - 100 mm fish
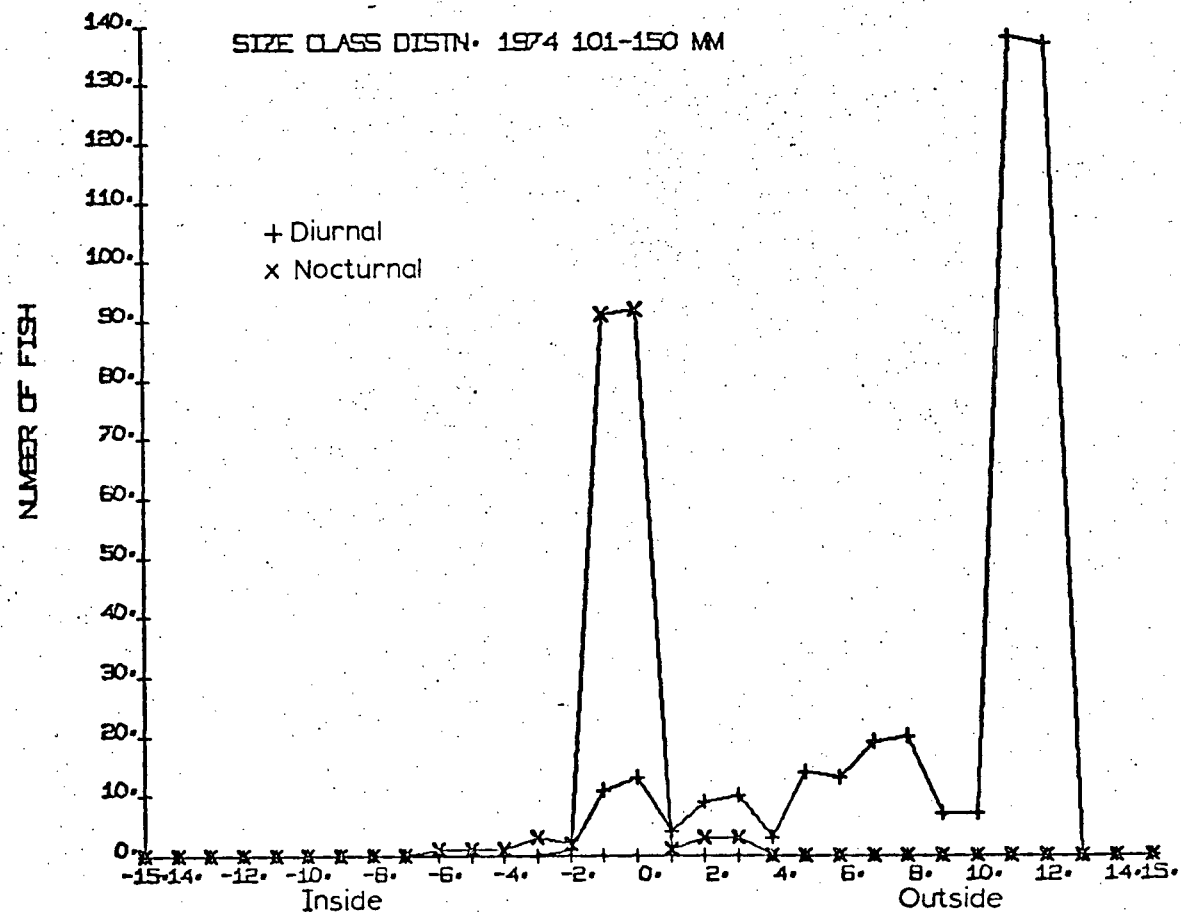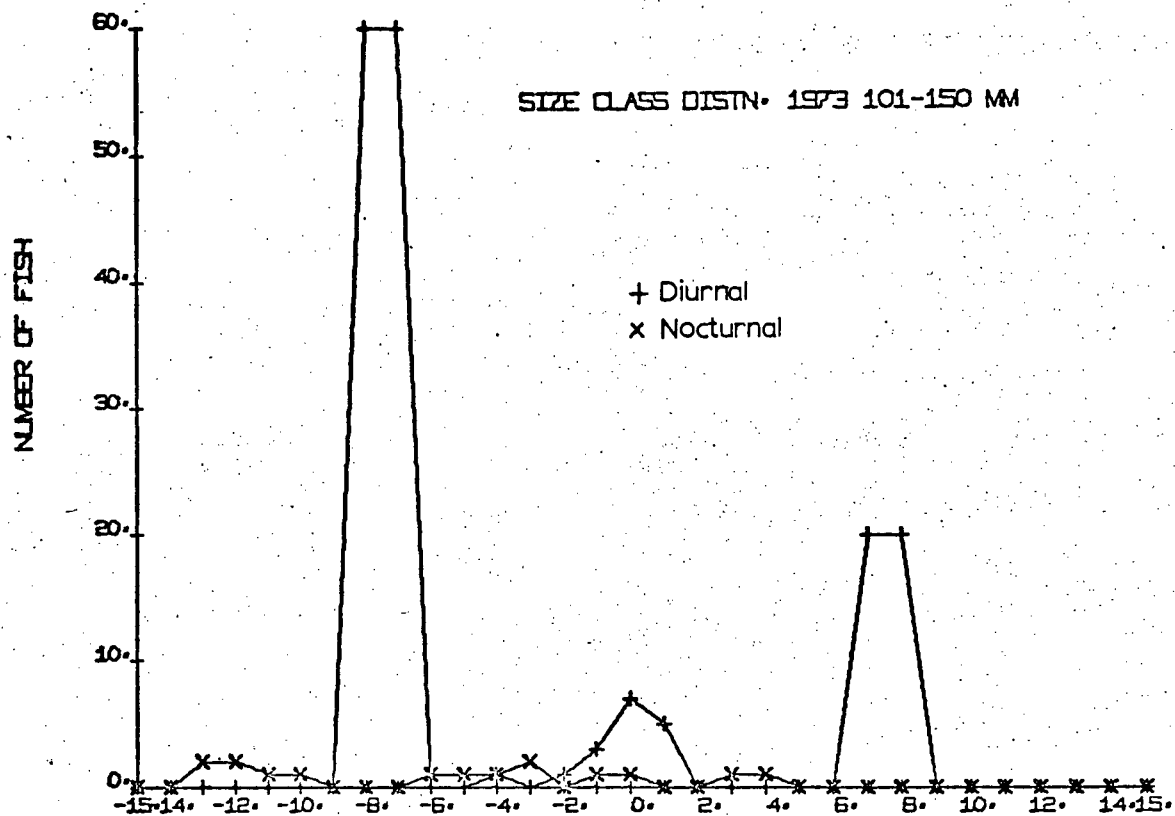
Figure 26

Cumulative nocturnal and diurnal observations of fish position.

101 - 150 mm fish
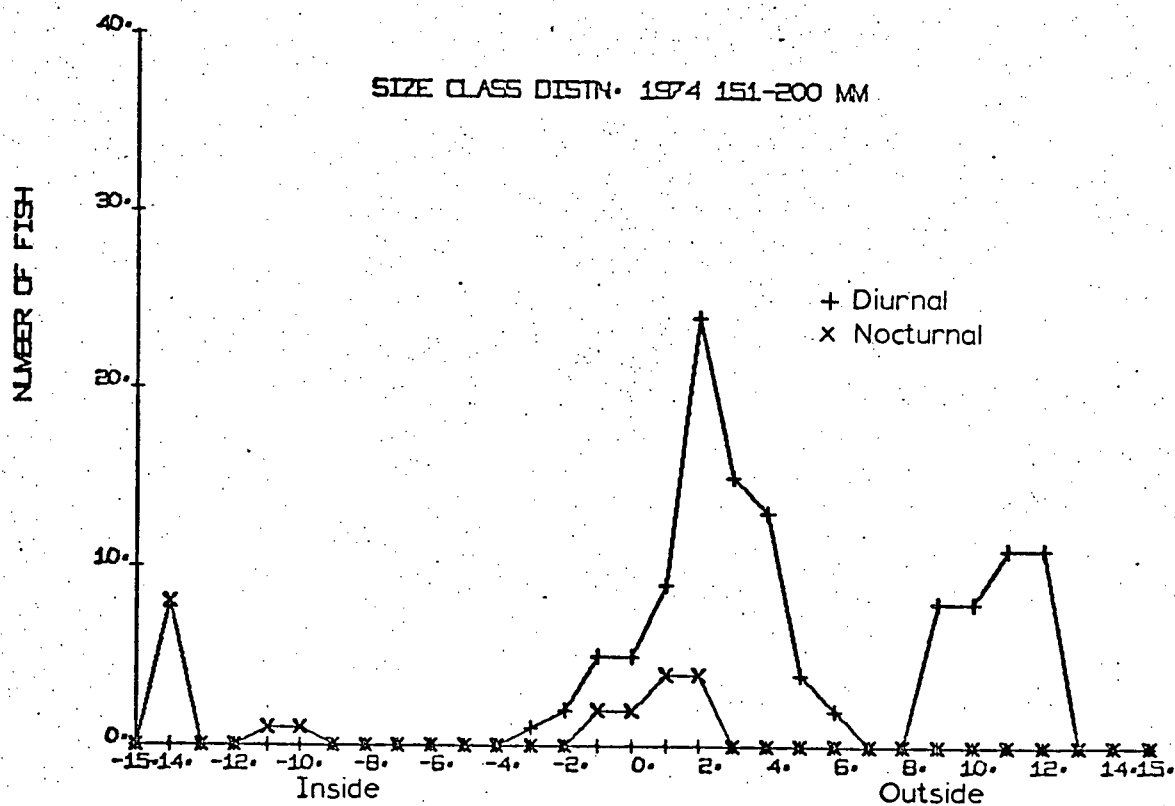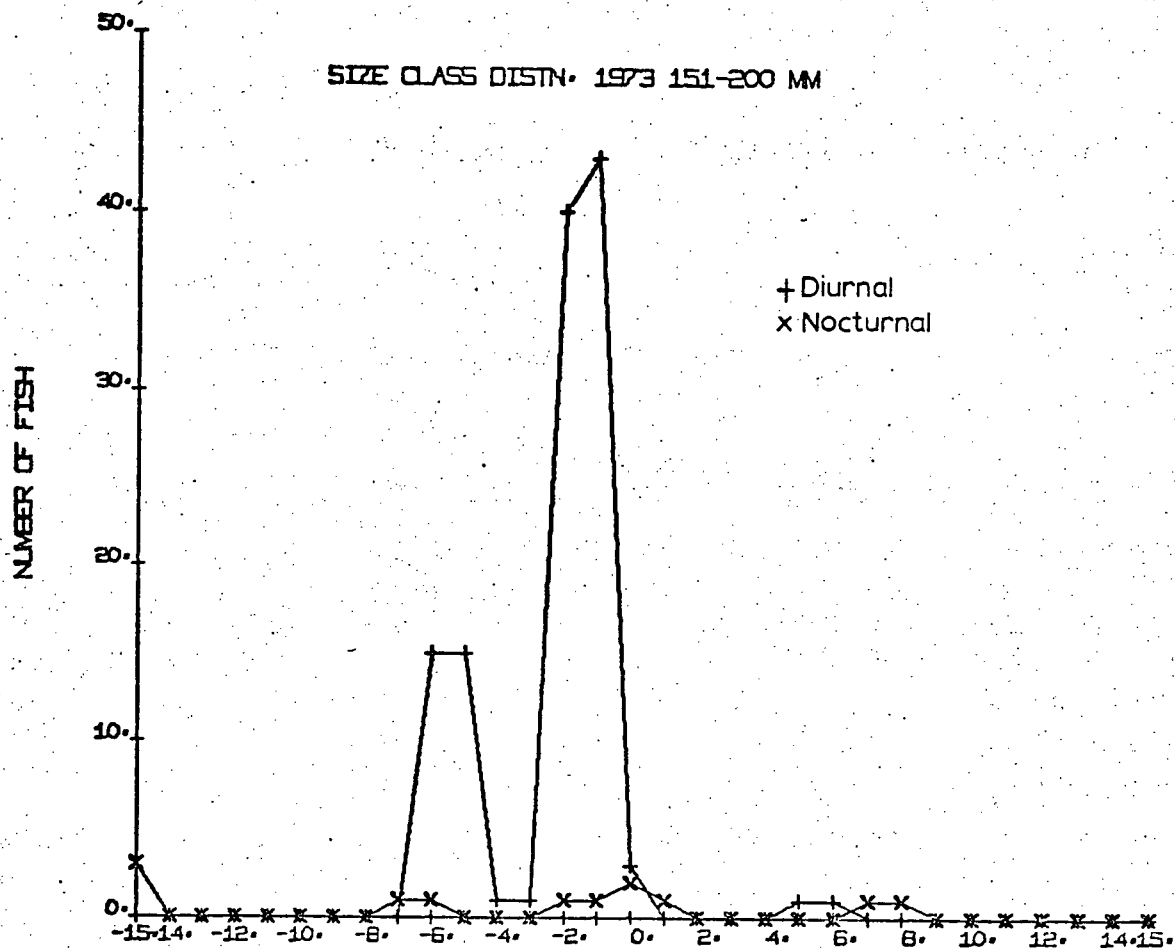
Figure 27

Cumulative nocturnal and diurnal observations of fish postion.

151 - 200 mm fish

TABLE IV

Statistical comparison of diel positions of the cumulative
totals of fish observed

	Day	Night	
Size	**I/O**	**I/O**	**Diel shift**
1973			
30-100 mm	1412*/1003	379/329	–
		(+1m) 400*/308	No
101-150 mm	132*/45	14*/2	No
151-200 mm	118*/2	9/3	–
		(+1 m) 10*/2	No
1974			
30-100 mm	4449*/1844	280*/37	No
101-150 mm	25/381*	191*/7	Yes
151-200 mm	13/105*	14/8	–
		(+1 m) 18*/4	Yes

(+1 m) – data includes those fish at +1.0 m
            as being inside the bed.
* – significantly greater (p<.05)
I – inside the kelp bed
O – outside the kelp bed

3.6 Environmental correlates of distribution

The diurnal distribution of 30 - 100 mm fish was consistent, in that higher numbers of fish were consistently found inside, rather than outside the bed. The observations of fish inside the bed were further analyzed to determine if any smaller scale migrations may have occurred and to determine if the water column was being exploited in any differential fashion by the various size classes of fish. Figure 28 illustrates the distribution of all fish under conditions of 2.0, 2.5, 3.5, 4.0 and 8.0 metres visibility. Data on the times, tidal heights and meteorological conditions on each occasion supplying visibility-distribution data, are presented in Table V. Efforts were made to observe the distribution patterns under approximately equivalent conditions. There was no significant difference in the average height of the fish in the water column, nor was there any difference among the size classes - either within each sampling occasion or among different ones.
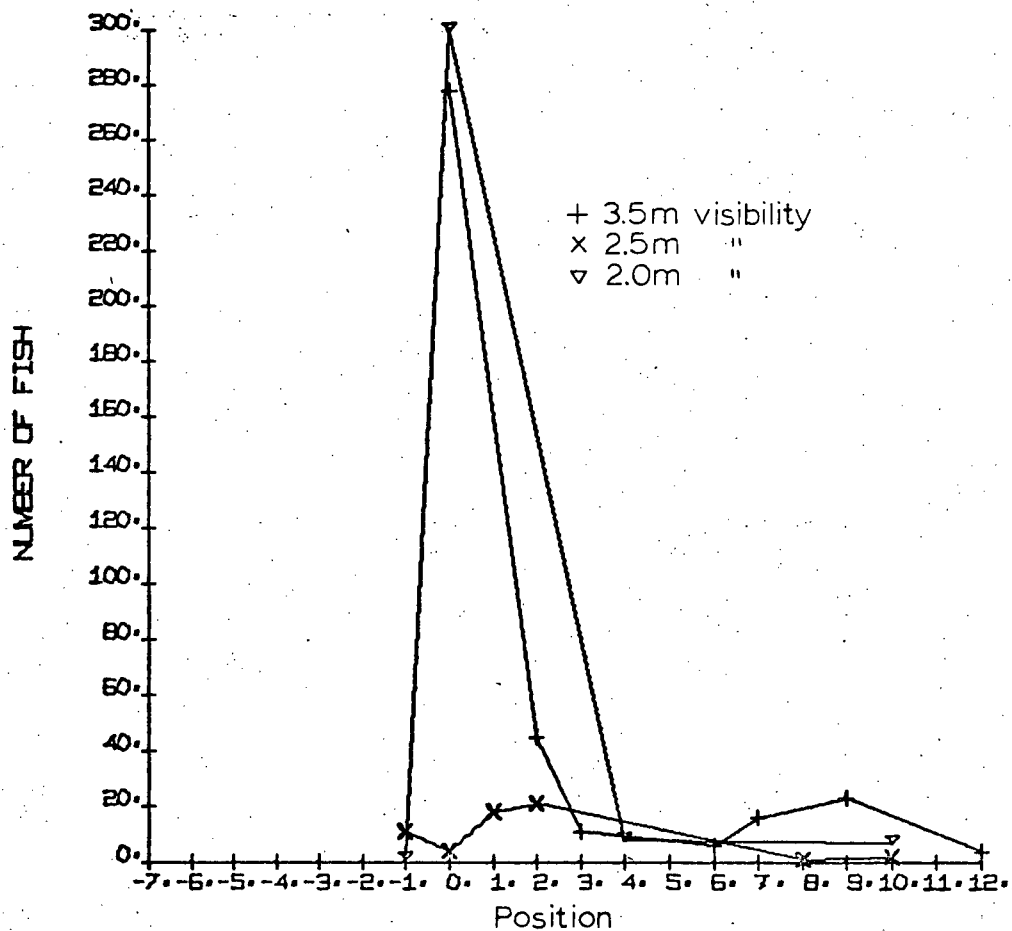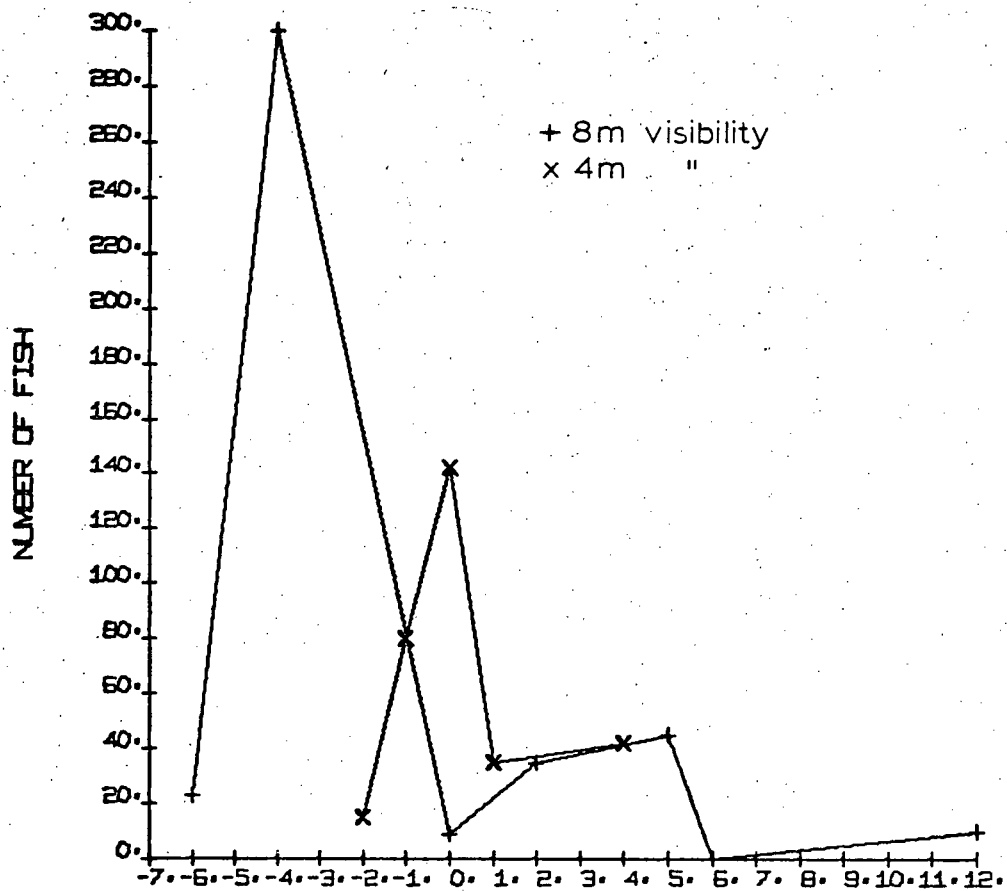
Figure 28

Changes in fish position with water clarity

TABLE V

Environmental conditions on each date supplying data for
visibility-distribution analysis

Date	Meteorology	Visibility	Tide	Time
27/VII/74	Clear,sunny	8.0 m	1.80 m	15:00
25/VIII/74	"	4.0 m	2.25 m	16:00
28/VIII/74	"	3.5 m	2.13 m	13:50
10/VI/74	"	2.5 m	2.04 m	15:00
1/IX/74	"	2.0 m	2.01 m	16:30

A second set of environmental correlates with fish
distributional patterns was that of nocturnal illumination and
current magnitude. This influence was shown primarily at the
rock slope, since tidal range had little effect on currents at
the study kelp bed (Figure 12). Fish appeared to exhibit
contradictory phototactic responses under apparently similar
illumination; on moonless nights, fish could be found, on
different nights, to be either down in rock crevices or up in
the water column. Further observation suggested that the
magnitude of the current in the area may have been influencing
the fish's response to light. Table VI presents the results of
laboratory experiments examining the influence of rheotaxis upon
phototaxis. The presence of both phototaxis and rheotaxis was
first established and was subsequently followed by the
introduction of a current into the phototactic experiment to
determine if any behavioural modification was induced from the
observed 'normal' response. Results indicate an overriding

effect of current on the 'normal' positive phototaxis, such that current of sufficient intensity will negate the phototaxis exhibited by the fish. The photonegative response indicated in the table refers to movement by the fish away from the light, which is associated with their movement toward the current.

TABLE VI

Initial conditions, manipulations and results of experiments examining the phototaxis of Sebastes melanops and the reversal of this response generated by current changes

Phototaxis					
Date	No. Fish	Initial Light	Initial Current	Change in Light	Response
21/I	2	441.27 lux	773 l/hr	-269.00 lux	+photo
22/I	2	441.27 "	773 "	-269.00 "	+photo
1/II	2	441.27 "	773 "	-269.00 "	+photo
2/II	2	0.11 "	773 "	+4.09 "	+photo
11/II	4	441.27 "	773 "	-269.00 "	+photo
18/II	4	172.16 "	773 "	-172.05 "	+photo
14/III	4	212.94 "	773 "	-176.35 "	+photo
Influence of Rheotaxis					
Date	No. Fish	Initial Light	Initial Response	Change in Current	Response
7/I	2	0.05 lux	+photo	+2319 l/hr	+rheo/-photo
3/II	2	441.27 "	+photo	+1546 "	+rheo/-photo
11/II	4	441.27 "	+photo	+773 "	+rheo/-photo
11/II	4	0.56 "	+photo	+773 "	+rheo/-photo
18/II	4	172.16 "	+photo	+773 "	+rheo/-photo
18/II	4	172.16 "	+photo	+773 "	+rheo/-photo

+photo - photopositive response
+rheo - rheopositive response

3.7 Fidelity and quantification of association

(i) The experiment involving the establishment of a small group of plants 30 m distant from the kelp bed was successful to

the extent that the juvenile S. melanops were observed among the plants diurnally, where none had been noted in the area previously, however no fish were observed nocturnally.

The extension of one segment of the bed margin by 8 m served to extend the contiguous distribution of fish normally associated with the bed. No differences in behaviour or abundance of fish were noted, concerning either those fish at the 'new' bed margin, or those at the artificially established bed, in relation to those observed within the natural bed.

Tracking of fish with fluorescein tags indicated that the association of the fish and the kelp bed was relatively intimate. A typical tracking record is illustrated in Figure 29. Some of the tracked fish displayed wide ranging forays (+15 m) but, generally, maintained a close enough association with the bed such that they could return to it when rapid advances toward them were made. Figure 30 illustrates numbers of fish and dates of the transport of tagged fish from the study site. Transplants were performed to test the fidelity of the association between the fish and the kelp bed as a habitat. These experiments examined the fish's ability to return ('home') to a site of initial capture. A statistical analysis of the results of subsequent sampling for homing (Table VII) does not support the concept of significant homing ability to the site of initial capture, by these size classes of fish.

Kelp boundary

05:51

05:54

06:01

05:36

Release
05:35

06:00

31/5/74
125m.m.
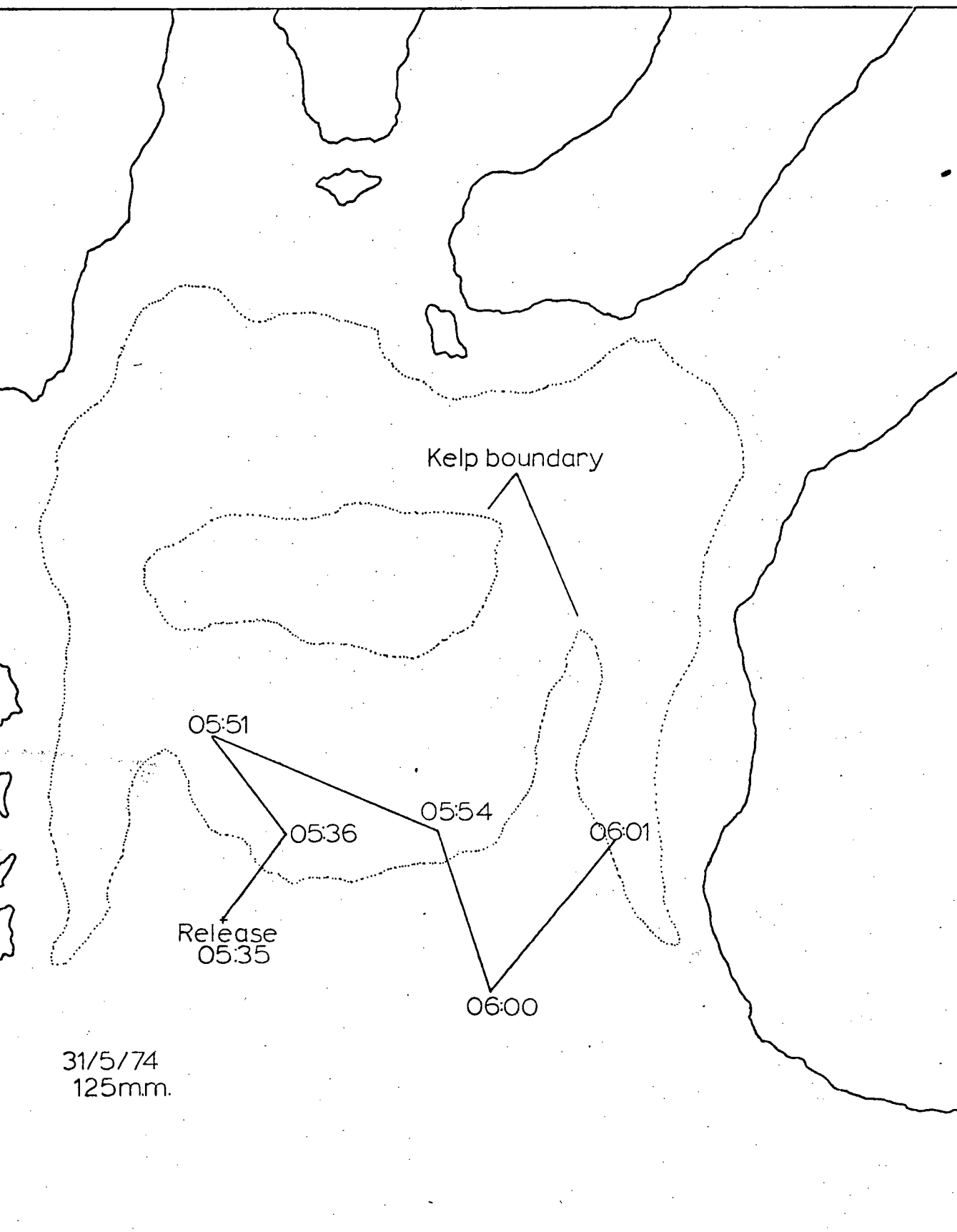
Figure 29

Tracking record of fish tagged with fluorescein tag
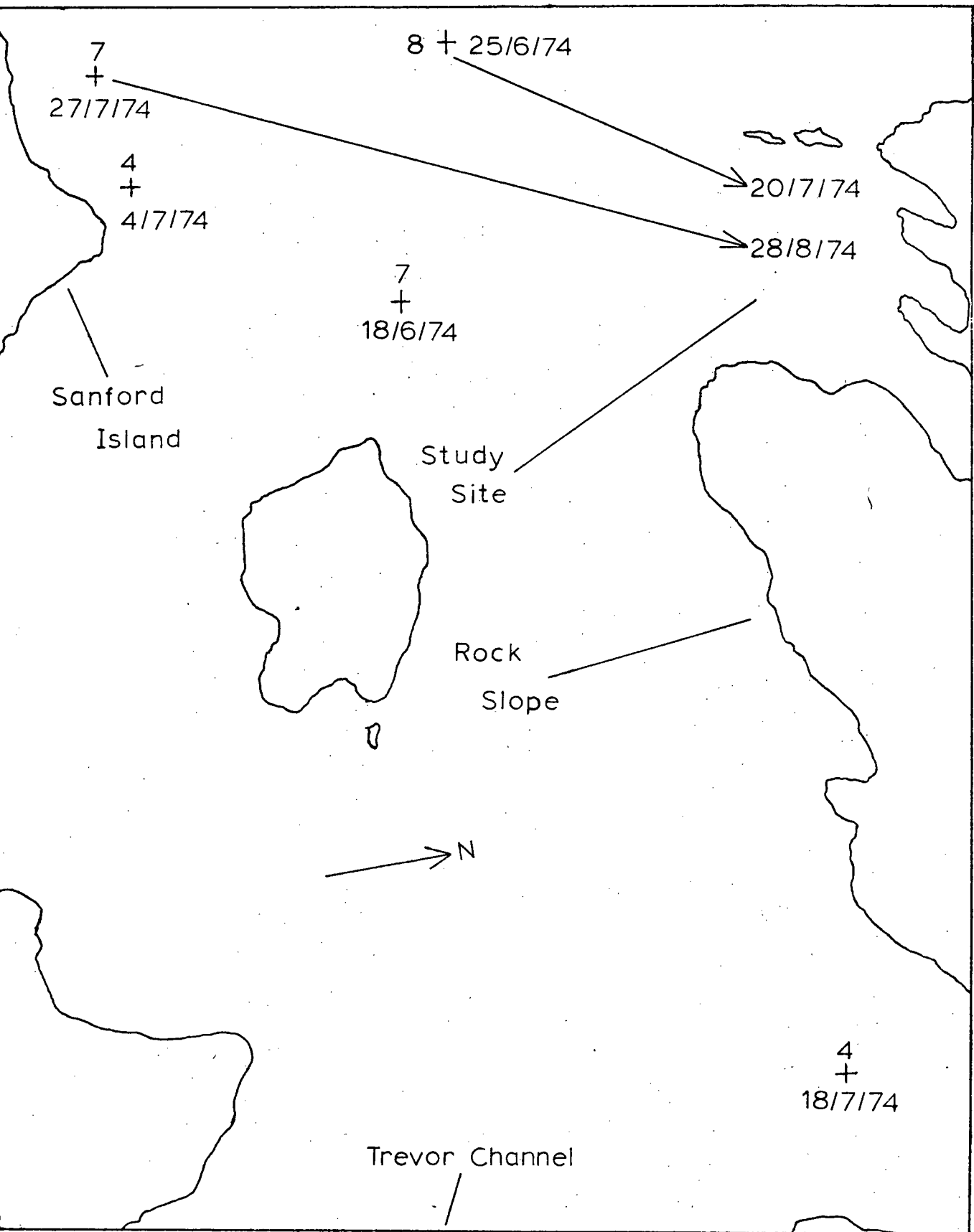
Figure 30

Transporting of fish and returns during fidelity experiments.

TABLE VII

Numbers, sizes and habitats to which _Sebastes melanops_ were
transported, together with the numbers and sizes of fish
exhibiting homing behaviour

Date	No. of Fish	Size Range	Transport Habitat	No. Returned
18/VI/74	7	118-123 mm	open water	0
25/VI/74	8	123-144 mm	open water	1-144 mm
4/VII/74	4	134-191 mm	kelp bed	0
18/VII/74	4	120-151 mm	rock bottom	0
25/VII/74	7	110-160 mm	kelp bed	1-149 mm

(ii) In general, the experimental work involving the habitat frames centred on the upright Frame I. This was because the fish were not attracted to Frame II as well as to Frame I; abundance of fish at the former was uniformly an order of magnitude less than at the latter. The results presented, therefore, refer only to Frame I data. Table VIII details information on the levels of shelter provided at the frame and the numbers of fish observed during each interval of that level (Figure 31).
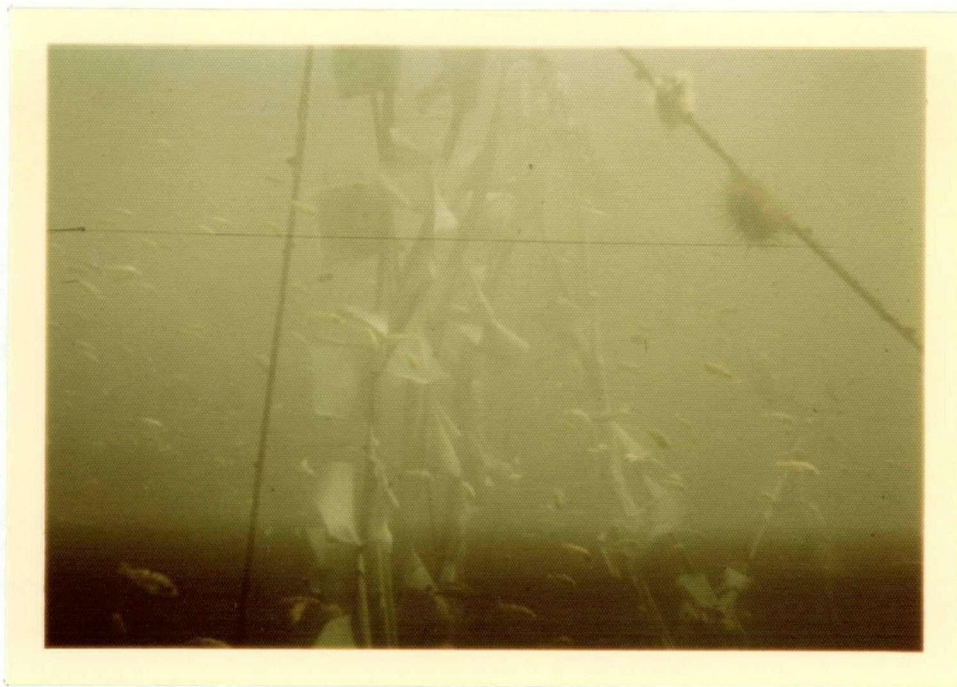
Figure 31

Fish at Frame I at 14.2 m² and 33.2 m² levels of shelter

TABLE VIII

Levels of shelter and fish associated with Frame I, together
with an analysis of the variance in these numbers in relation to
changes in the shelter provided

Date	Level of Shelter	Fish at Frame	Fish at kelp bed	Proportion of fish at Frame
11/V	23.7 m²	3	8	0.27
20/VII	"	125	373	0.25
20/VIII	"	3	13	0.19
22/VIII	"	156	138	0.53
24/VIII	33.2 m²	125	213	0.37
25/VIII	"	80	336	0.19
27/VIII	"	175	196	0.47
28/VIII	"	181	373	0.33
1/IX	"	7	523	0.01
2/IX	"	55	169	0.25
3/IX	14.2 m²	10	120	0.07
4/IX	"	20	292	0.06
5/IX	"	85	283	0.23

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	'F' Statistic
Among	2	0.61	0.30	16.67**
Within	10	0.22	0.018	
Total	12	0.83		

The numbers of fish at the frame are presented as the proportions of the total number of fish seen on the observation day. The transformation of the raw data into this standardized form was necessary to compensate for the large inherent variability in the numbers of fish observed on any given day. A transformation of this nature bears the justifiable assumption that both the kelp bed and the habitat frame draw upon the same 'universe' of fish to populate their environs. The results of a single classification analysis of variance (ANOVA) for the three levels of shelter are also included in the table. The 'F' statistic resulting from the ANOVA (16.67) indicates that the variance in the numbers of fish observed under each shelter treatment is significantly accounted for by the changes in the treatment, rather than by factors outside the experimental design.

4. DISCUSSION

4.1 General distribution

The use of kelp beds by the fish should be examined in relation to its total geographic and bathymetric range. The geographic distribution of Sebastes melanops was not delimited by its describer (Girard 1856). The first major range statement being made by Jordan and Evermann (1898:1783), who described the distribution as extending from "...Monterey to Kadiak [=Kodiak], most abundant northward; very abundant at Sitka ...at San Francisco, much less common than S. mystinus; about Humboldt Bay much more common being the most abundant food fish.". The known distributional limits have been extended only slightly since that time. Miller and Lea (1972:96) describe the range as extending from "...Paradise Cove [California] to Amchitka, Alaska...". A similar situation exists regarding the depth range. Early papers infer that the species is a shallow water form; the increasing depth range reported in succeeding years reflects an increased sampling efficiency and effort rather than the the abundance of the species at the depths involved. The current delimitation of depth is probably an accurate estimation of the true bathymetric range of the species, since sufficient effort has been expended in deeper waters but has produced no specimens of S. melanops. The reported (Miller and Lea,1972) depth range (3 - 92 m), when correlated with the microgeographic range of the fish, leads to a description of fish's distribution (as an adult) as being closely associated with the coastal waters. A manuscript compilation of the results of catch surveys (Niska, 1973) on S. melanops shows a mode of abundance

of adults from 0 - 50 m deep in areas from 1 - 10 km from the coastal region. An earlier publication by Alverson, Pruter and Ronholt (1964) indicated a much deeper mode of abundance (92 - 181 m) than the Oregon report. Several features of the earlier study should be considered when assessing the distributional patterns of the adults: firstly, the sampling effort was considerably higher in the 92 - 181 m depth range; secondly, abundances were gauged by the frequency of occurrence in total trawls; and, finally, trawling was done primarily during the winter months. An increased sampling effort might have indicated greater abundances in shallower water. The use of a frequency of occurrence measure masks abundances. With regard to this point, the highest frequency of occurrence and the greatest yield of the species (by weight) did not occur at the same depth range; the maximum yield occurred at shallower depths. The seasonal nature of the fish's movements may indicate that the reports do not represent distinct differences in the modes of abundance. Alverson (1960) has postulated, on the basis of catch data, that S. alutus Jordan and Gilbert undergoes a seasonal migration, moving into deeper water during the winter. In view of the large numbers of demersal fish which undergo such a seasonal migration, it is probable that S. melanops follows suit, this may account for the apparently distinct distributions in the two reports.

The fishing areas (Figure 14) are generally low to moderate relief exposed segments of coastline or closely adjacent to them. Commercial catches of the fish reflect relatively low abundance of the adults in most areas (when compared to S.

alutus and _S. pinniger_ Jordan and Gilbert, or the other fish most abundant in the same hauls with _S. melanops_) accessible to commercial fishing. Dunn and Hitz (1969) reported a spent female specimen of _S. melanops_ 385 km southeast of the Alaskan peninsula, over water 2000 m deep, but in the absence of similar offshore records of the species, this must be regarded as anomalous.

The inshore coastal distribution of the species has received more attention than that of the nearshore, because it is a component of the sport fishery catches in California, Oregon and, to some extent, Washington and British Columbia. While _S. melanops_ rarely exceeded 5% of the total inshore catch, it ranked 12th by numbers and 8th by weight for all species of sportfish landed between Oregon and Port Arguello, California from 1957 - 1961 (Frey, 1971:75). Sport fish catches lend corroborative evidence to the inshore nature of the species; Frey describes it as being "...primarily a shallow reef species...". Delacey, Miller and Borton (1972) record the largest collections of _S. melanops_, taken by the University of Washington, as coming from the inner reaches of Puget Sound (Colvos Passage).

Adult distribution, therefore, does not appear to be strongly associated with the occurrence of kelp beds, although populations may be within several kilometres of them. Published reports and comments by commercial fishermen, as well as personal sampling, establish the inshore adult populations as being in moderate relief areas, close to the coastline or shore, often with considerable exposure to wave action.

The larva of the species has never been described. Ahlstrom (1965), LeBrasseur (1970) and Waldron (1972) have described the broad coastal distribution of 'Sebastes species' for the California - Baja, northeast Pacific and Oregon - B.C. areas, respectively. Their results definitely show that the larval distribution has a strong coastal or inshore (<914 m in depth) component. The highest abundances of Sebastes species larvae, excepting seamount stations, were found within 10 kilometres of the coastline.

Published accounts of the distribution and abundance of juveniles are few, if any; I have been unable to locate any reference which treats the distributional aspects of the younger life stages of the species in anything except qualitative form.

Hubbs and Schultz (1933) described a form related to S. melanops based upon 5 specimens obtained in a salmon trap, in 1926, at the mouth of the Columbia River. They designated the new species as Sebastodes [=Sebastes] columbianus and differentiated it from Sebastodes melanops on the basis of eye diameter, colour, and body configuration. The meristic counts published overlapped with those of S. melanops. The specimens employed in the description of S. columbianus were all over 400 mm TL, yet the authors stated in their diagnosis of the species that "...young not occurring in tide pools of reefs.", whereas the young of S. melanops were described as "...developing in tide pools."(Hubbs and Schultz,1933:21). The point of significance is that, in Barkley Sound waters, the young of S. melanops are rarely, if ever, found in tide pools. The form described by Hubbs and Schultz was reduced to subspecific status

by Alverson and Welander (1952) for Washington and B.C. waters. Phillips (1957), however, does not designate any subspecific forms of S. melanops, nor do any of the California works following his paper, e.g., Hitz (1965) or Miller and Lea (1972). Specimens of British Columbia forms have been uniformly described as Sebastes melanops, and I follow this practice for the Barkley Sound forms.

4.2 Barkley Sound distribution

The first record of the species in Barkley Sound was reported by Evermann and Goldsborough (1907) who described a specimen taken by the United States Fisheries Commission steamer Albatross on September 23,1888. This record is questionable because the station records of the Albatross do not indicate that it was in Barkley Sound on this date.

My sampling within Barkley Sound indicates a macro-distributional pattern correlated with the size of the fish. No data are available which allow determination of any similar patterns within the coastal range of the adults susceptible to commercial fishing. Commercial fishermen of the Bamfield region attest that, while the adults are occasionally caught in the inner parts of Barkley Sound (Satellite Passage, Dodger Channel) the largest specimens of the species are caught past the mouth of the Sound. These reports corroborate the results of the sampling of this study; however, they should be interpreted with caution for two reasons. Fishing vessels of the Bamfield region are salmon trollers and are, basically, upper water column samplers; and fishermen describe the fish as 'black bass' and at

least two species caught at the mouth of Barkley Sound are commonly denoted as such (S. melanops and S. mystinus Jordan and Gilbert). The latter species is, generally, found only at the mouth of the Sound during the summer months, and appears to accompany the northward intrusion of warmer water during this period.

In summary, the adults of the species appear to be concentrated at the mouth of Barkley Sound, rather than being distributed more uniformly, or in a different biased fashion, throughout the area. Such a distribution, if maintained annually, establishes the centre of reproductive effort as being along the coastline, or slightly farther away, if the fish undergo a seasonal migration. Insufficient data exist to confirm this, since no gravid females were taken during the study and there are no published accounts of either gravid female capture or their occurrence/distribution.

Results of sampling in the present study show a definite increasing cline in the size of fish captured, when sampling from the head to the mouth of the Sound (Figure 19). This cline is corroborated by observational data. These data also establish higher abundances of O, I and II age-classes in the inside of the Sound, than at the mouth. A plausible life history of the species must account for this distribution.

The plankton tows taken in Trevor Channel and in the Deer Group islands in 1973-1974 showed significantly higher numbers of Sebastes spp. larvae in sheltered waters of islands and bays than in open channels. Hourston (1958,1959), working in Barkley Sound, found a similar distribution of juvenile herring in

regard to these two types of hydrographic situations, and postulated that such a distribution was achieved through dispersal from the spawning grounds (primarily on the northwest side of the Sound) and gradual accumulation of the juveniles in these sheltered areas. He concluded that such dispersal was neither passive, with the currents, nor was an active searching on the part of the juveniles for such environments. Hourston believed, on the basis of several tests of distributional correlates, that the aggregations of juveniles were the result of primarily random movement by the fish; movement which diminished when a suitable environment was found. The attractiveness of the sheltered areas was thought to be related to the decrease in physical stress which the herring experienced while there. He also demonstrated an increased abundance of the fish in the most sheltered areas of the bays and inlets; around, "...docks, log booms, kelp patches and rock piles." (Hourston,1959:303).

The concentrations of Sebastes spp. larvae found in my study generally mirror that reported for juvenile herring. The fine-scale distribution of the larvae may or may not have reflected the same pattern, but with regard to the kelp patches, it was impossible to determine this because the new year's growth of kelp sporophytes was insufficient to establish visible kelp patches. Although the abundance of larvae was greater in many areas which later contained kelp beds, there was at least one large bay (Roquefeuil Bay,Figure 3) which supports both large kelp beds and S. melanops populations during the summer, within which very few Sebastes spp. larvae were taken. The

distribution of S. melanops larvae can only be extrapolated from that of observed specimens of Sebastes spp. The size of the juveniles of S. melanops appearing in the kelp beds in mid-May indicates that the time of spawning for this species agrees with the February Puget Sound spawning records (Delacy et al.,1964), rather than with the April Vancouver Island reports (Westrheim et al.,1968).

The segregation between the observed abundances of adults and those of larvae may be explained by physical oceanographic factors. Doe (1952) found high surface transport out of Barkley Sound on the west side of the Sound during the spring. This surface transport was primarily a result of freshet conditions in the Toquart and Somass rivers. A corresponding inward flow of water took place on the east side of the Sound and in deeper water on the west side, during this period. It is plausible that S. melanops larvae, if extruded at the coastline, could be passively carried into the Sound with these currents.

Observational samples show S. melanops juveniles, especially 30 - 100 mm fish, to be more abundant in beds of Macrocystis integrifolia than in beds of the more exposed Nereocystis luetkeana. Higher numbers of fish were found in M. integrifolia beds in sheltered waters (Ross Islets, Roquefeuil Bay) than in beds of the same plant in more exposed locations (2nd Beach, Cape Beale). These observations, when coupled with the clinal variation in size of sampled fish, lead to the conclusion that the observed distribution of fish is related to the degree of exposure of the habitat or, more generally, the wave stress imposed upon the fish. This

conclusion may not reflect the only cause and effect mechanism at work but it is definitely a major component in the determination of the distributional pattern of this size group of juveniles.

4.3 Sebastes melanops in Macrocystis beds

The presence of the species in beds of Macrocystis integrifolia is limited to the juveniles in that none of the fish from the kelp beds were found to be sexually mature. The smallest fish in the kelp bed were 40 - 50 mm young-of-the-year. These fish would be designated as the 0 - I age-class and would include those fish up to 100 mm. The population of the fish at the site included three or, infrequently, four age-classes (Table II). The abundance of the fish at the site was reasonably constant on an annual basis for the ages II to IV fish. Major fluctuations in the population were a result of yearly recruitment by the 0 - I age fish (Figure 18). The recruitment and growth of these fish to a size which was capable of being tagged is reflected in the sudden increase in estimates of population in August, 1974. The recruitment of these individuals was obvious in observations beginning in June of the year but it was not possible to tag them until early August, due both to the small fish (<80 mm) being unsusceptible to net capture and unable to support a tag.

The close agreement between population estimates computed in late fall, when the kelp bed was degenerating and in the late spring, when the new year's sporophyte growth began, infers an approximately constant population overwintering at the site.

These estimates may indicate a probable low value of natural mortality over winter, as well as a minimum residency of tagged individuals of at least one year. The similarity of these estimates may also indicate that mortality, followed by immigration was occurring; however, this would necessitate differential mortality of untagged fish in order to maintain similar estimates, and I think this situation unlikely.

The initial increase in the population estimate (by both methods) in early 1974 is a result of the previous year's juveniles becoming accessible to the tagging program. The large increase in the population estimate in August,1974 is not mirrored in 1973 because very few O - I juveniles were tagged in 1973 and, the recruitment of this age class of fish was higher in 1974. A third possible factor responsible for this increase was the addition of the two habitat frames at the site in this year. The degree to which these may have increased the resident population is unknown, however an influence is inferred by the facts that the increase in the population was almost exclusively through this size class and that these were the fish which were attracted to the habitats.

A degree of learning by the fish is indicated by the consistently lower estimates generated using observational data over those using recapture data. A higher proportion of tagged vs. untagged fish were observed than were represented in the net captures. This is most probably accounted for by net avoidance on the part of tagged fish and concomitant decrease in recaptures. Observational data collection did not necessitate capture and handling and the sampling technique was not biased

toward untagged individuals. In light of these considerations, I feel that the estimates generated using the observational data are the more accurate of the two. In addition, the availability of the tagged fish to observation, as opposed to recapture, is responsible for the lower degree of fluctuation in the observation estimates.

4.4 Diet

An examination of the diet of those fishes present at the site leads to the conclusion that the population in this area directs the majority of its foraging activity to the water column, rather than to the benthos. The clupeiform fish and mysids which form the dominant portion of the diet are water column inhabitants. Neither of these items were found to be in higher abundance inside the kelp bed than outside. Clupeiform fish, of the size found in the stomach contents, were never observed inside the bed, albeit they maintained an intimate spatial relationship with it at times. In the few instances when S. melanops were actually observed feeding on clupeids, the situations were very similar. A school of Clupea harengus pallasi Valenciennes would pass close to the bed and an individual S. melanops would dash out and capture one of the small herring. On every occasion, the individual capturing the herring had pieces of the uningested herring torn from its mouth by conspecifics.

Some alternation in the use of trophic resources on a seasonal basis, similar to those described by Gotshall et al. (1965) is evidenced in Figure 21. While some overlap

exists, there is a segregation between the periods of maximum occurrences of mysids and clupeids in the stomachs of the fish. It is known that the young-of-the-year herring appear near kelp beds in late May (Hourston,1958,1959; Marliave, personal communication). Mysid blooms have been noted in 1974 and 1975 to occur in early May. These times of occurrences correspond generally to the times cf occurrences of these diet items in the fish's stomachs. I do not have quantitative data on the abundances of these two primary prey items in the environment and it is not possible to construct any index of trophic selection such as those similar to Ivlev's (1961) 'E' index, e. g., Frame (1974) or Gerald (1966). The anlysis of the diet data differs from previous diet analyses performed under a similar data handicap. I have tried to eliminate the subjectivity of the methods of Tester (1932) and Hynes (1950) as well as avoid a sole reliance on the occurrence of diet items (Quast,1968). The dominance data employed are conservative estimates of the contributions of various diet items rather than optimistic ones such as results from an analysis based on occurrence of items alone. A more detailed analysis, such as that of Carr and Adams (1973) was not possible, while a less detailed one (Fritz,1974) did not yield sufficient information. The analysis in my study attempts to improve on the basic occurrence/volume presentation (Heubach et al.,1963; Gotshall et al.,1965).

No experiments on the feeding behaviour of Sebastes melanops were conducted. It must remain unknown, on the basis of currently available information, whether the abundances of

items in the diet represent preference or specialization (Bryan and Larkin,1972; Landenberger,1968; Wood,1968) or a passive response to differential abundances of prey items in the environment (Gerald,1966; Murdoch,1968). 'Switching' (after Murdoch,1968; Holling,1965; Tinbergen,1960) by S. melanops would result in a similar record of diet item occurrence if such a seasonal alteration of mysids and clupeid fish had occurred; however the studies of Murdoch (1968) and Landenberger (1968) indicate that even sophisticated experimental design will not prove the existence of such switching. Strong preferences by predators tend to negate differential abundances of prey items in the laboratory and preference testing is generally inconclusive when the predator is faced with multiple prey items. In addition, Holling (1959) found that predators would occasionally select non-preferred diet items even when the preferred item was abundant. Increasing the levels of the preferred item even further yielded an increasing utilization of the alternate diet items.

While the size, appearance, habits and taste of the prey may act to govern their abundance in the diet (Allen,1941), Gerald (1966) found good correlation between forage ratios of diet items and their abundance and/or availability in the field. The latter indicates a purely passive feeding response on the part of the predator, when faced with differential abundances of diet items. I use 'passive' in the sense that the alternate prey is eaten merely because it, "...offers a sufficiently higher rate of reward..." (Croze,1970:79), rather than actually connotating greater preference, in the sense of Murdoch (1968).

Although it is impossible to determine the degree of selectivity, if any, which the fish exhibit toward their total diet spectrum, an analysis of the relative contribution of the various diet items can be made. The statistical analysis of the volume - based dominance data infers a general reliance by the species on clupeids and mysids for the vast majority of its energy input during its presence in the kelp bed. The presence of mysids as the dominant item for 101 - 150 mm fish, while the other two size classes exhibit clupeid dominance, warrants comment. Firstly, the sample size for the 30 - 100 mm fish is very small for a positive indication of major diet input. Secondly, those herring eaten by the smallest fish were larval or juvenile forms and thus, probably not attractive to the larger fish as a diet item. For the duration of their presence in the kelp bed, fish of the largest size class examined (151 - 200 mm) exhibit overwhelming reliance on clupeid fish. While the fish have been shown to utilize clupeids and mysids to a greater degree than other diet items during their period of residence in the kelp bed, no evidence is available which describes their primary diet input during the winter months, when they adopt an alternate habitat. The seasonality of their summer food sources (Hourston,1959) requires an alternate winter diet. The metabolic rate of the fish and hence their feeding rate, is necessarily smaller in the winter months; evidence for this is both direct (temperature control of metabolic rate) and indirect (annual checks in scale circulus formation). The identity of the winter diet is unknown but in consideration of the habitat associations of their summer forage items, I would

assume that S. melanops utilizes pelagic species as its primary energy source during the winter as well. Previous work in Barkley Sound (Druehl, Green and Leaman, unpublished data) has shown that S. melanops in other locations utilizes sandlance (Ammodytes hexapterus Pallas) as a food source late in the summer. Later work in Nereocystis luetkeana beds (Leaman, in preparation) has shown that shoals of 80 - 100 mm sandlance appear in these beds in late August - early September and present a demonstrably exploitable resource.

4.5 Activities in the kelp bed

The utilization of the kelp bed as a habitat by the fish was strongly seasonal as a direct result of the seasonality of the bed itself (Figure 13). The onset of sporophyte growth in May - April was not immediately accompanied by the appearance of Sebastes melanops in the bed. The time lag between growth initiation and the appearance of fish is a function of the degree of water column occlusion by the growing plants. Fish did not occur until after the percentage-occlusion had exceeded 75%. The apparent disparity between the appearance of the fish at this occlusion value and the maintenance of fish at lower values later in the summer is related to the morphometry of the plant throughout its growing season and the technique of measurement of occlusion. The plant grows from a basal holdfast and proliferates to the surface through a graduated and continuous series of fronds. The progress of the growth of these fronds through the water column, albeit via intercalary meristematic tissue, is analagous to the growth of a terrestrial

shoot. The water column is not occluded gradually as a whole but progressively from the bottom to the surface. The fish were not present in the bed until the plants were approximately one-half of the distance to the surface. The occlusion measurements were made only 0.8 m above the substrate and were not necessarily representative of the entire water column exploited by the fish, which is primarily a mid-water-column form. The maintenance of fish in the kelp bed in August - September, when the occlusion values fell below 60%, again reflects the plant's morphometry and the measurement technique. Lower laminae of the fronds degenerate in late summer resulting in the decreased occlusion values. Upper and mid-water laminae of the plants remain viable during this period (Figure 32) and continue to provide an occluded water column. The fish appear to be unaffected by the changes in the lower portions of the plants. This situation contrasts with the response of birds to changes in the vertical structure of terrestrial forests (Hagar,1960; Martin,1960), wherein bird communities change both qualitatively and quantitatively with changes in the successional status of the forest. It also contrasts with the species changes associated with differences in forest foliage profile (MacArthur and MacArthur,1961).

Figure 32

Surface canopy of the plants in late August,1974

Daily observations of fishes in the kelp bed were characterized by a large variation in the numbers of fish seen, similar to observations in California kelp beds (Quast,1968; Turner et al.,1969). This variation in sightings related primarily to the smallest size class of fish due to their greater abundance. Several features may have acted singly, or in concert, to mask the actual abundance of fish. The foremost of these features was the clarity of the water; water in which visibility is decreased through phytoplankton blooms, terrestrial run-off or particulate detritus, severely hampers observation. I consistently made only one set of observational sweeps through the kelp bed to minimize the possibility of duplicate enumeration. Observations made during periods of

lowered visibility were more susceptible to duplicate sightings because of the possibility of undetected movement of the fish to unenumerated areas. Observations made during or after storms often yielded few sightings because the fish were sheltering in crevices, both in and around the kelp bed. The additional time required to make a more thorough search of these refugia resulted in a decrease in the total time/area observations. Similarly, the illumination in the bed (distinct from water clarity) affected my perception of the fish in the water column. The variation in sightings is thought to be primarily a function of factors affecting observations, rather than a reflection of actual variation in the numbers of fish present. This does not negate the fact that such variation in numbers undoubtedly occurs on a daily basis. The actual variation in the numbers of fish inside the bed may be an expression of the abundance of the larger size classes of fish, since they are known to undergo more extensive migrations than the smaller fish.

The local distribution of the fish and their diel activities have parallels in both other kelp bed studies and in limnological work. Limbaugh (1955) found a similar pattern of greater abundance of fish at the edge of California kelp beds. He did not, apparently, make any observations of the clines in the abundance of fishes with position in the kelp bed, other than noting that the juveniles of some species appeared to be more abundant in the inshore rocky zone than inside the kelp bed. The larger size of the plants in California and the greater depth in which they grow introduces an added habitat complexity which is not mirrored in British Columbia kelp beds.

Limbaugh was able to distinguish whether species were primarily bottom, mid-kelp or canopy fishes. The shallowness of my study site precluded any depth distinction of this nature. _Sebastes_ _melanops_ appeared to exploit the entire water column, save for the surface layer above the thermocline (at approximately -1.0 m). Quast (1968) also distinguished utilization of segments of the kelp bed by various species, although he did not detail the smaller scale movements of individual species. Neither of these studies quantified the pattern of abundance of kelp bed forms within the bed, nor did they encompass diel observations. Their qualitative comments about various species included an assessment of the 'dependency' of the species on the kelp bed biotype but their assessment of 'dependency' was primarily based upon the the degree of crypsis in the colouration of the fish. Fish showing no cryptic colouration were assumed to be non-dependent on the kelp bed. _S. melanops_ would fall into this category. The lack of diel observations in the aforementioned studies hamper the comparison between _S. melanops_ and the probable California analogues, _S. serranoides_ Eigenmann and Eigenmann, _Paralabrax clathratus_ Girard and _S. saxicola_ (Gilbert). These species appear to occupy the same type of habitat as _S. melanops_ but diet analysis (Quast,1968) indicated that they forage more on benthic invertebrates than _S. melanops_ does. High values of clupeoid fish occurrence in the stomach contents of the California fishes was thought to be a function of the sampling technique ('chumming'), rather than an expression of the normal feeding behaviour of the fish.

The diel activities of _S. melanops_ are thought to be a

result of the feeding benefits derived from an extended diurnal range and the survival benefits associated with the utilization of a nocturnal refugium from predators, such as *Ophiodon elongatus* Girard, *S. paucispinsis* (Ayres), *Squalus acanthias* Linnaeus and *Salmo gairdneri* Richardson. Diel changes in gut content and sampling for diet items within the kelp bed do not indicate that the kelp bed is utilized as a food resource base by *Sebastes melanops*. More recent work in California kelp beds (Bray, personal communication) has investigated the diel activities of *Oxyjulius californica* Gunther, *Phanerodon furcatus* Girard and *Brachyistius frenatus* Gill in terms of foraging and habitat preferences. Activities of these species were determined from laboratory swimming experiments, limited field observations and the diel fluctuation of gut contents. All species were diurnal feeders; *O. californica* sheltered by burrowing in sand at night. No information was available on the migrations of these fish. Bray has also investigated the diel activities of *Chromis punctipinnis* (Cooper) and *Hyperprosopon argenteum* Gibbons. The former species feeds by day in the kelp bed and hides in holes at night. The latter species schools inshore during the day and migrates out to the kelp beds to feed at night. The activities of *H. argenteum* are the converse of those of *Sebastes melanops*.

The activities of *S. melanops* in Barkley Sound appear to be analogous to those of some species in California kelp beds but it is difficult to accurately compare them because the information on the southern species is either of a qualitative nature only, or it is unfinished or unpublished.

Work on coral reef fishes by Hobson (1973) elucidated their diel feeding migrations, characterized by movement away from the reef at night to feed and schooling near the reef diurnally, in response to predation pressure. This type of migration, although temporally opposite, is similar to that of S. melanops, except for the schooling behaviour. The tropical counterparts are certain sciaenids and pomadasyids. Baumann and Kitchell (1974) described diel feeding migrations between diurnal limnetic feeding areas and the nocturnal littoral area in juvenile Lepomis macrochirus Rafinesque, which correspond to the movements of the larger size classes of S. melanops but not to the smallest. In addition, the migration by L. macrochirus was primarily by the smallest juveniles (the larger fish remaining in the littoral area) and was thought to be solely related to feeding; no mention of refuge seeking is made.

With regard to the activities of Sebastes melanops, the diel migration of 101 - 200 mm fish, which occurred in 1974, was not noted in 1973. I believe that these migrations are density - associated phenomena. The abundance of the smaller (30 - 100 mm) juveniles was very much higher (approximately five times) in 1974 than in the previous year (Figure 18) and since this size-class was the most intimately associated with the kelp bed, the competition for trophic resources in the immediate vicinity of the kelp bed would have been concomitantly higher in that year. The larger fish, being relatively less vulnerable to predation, were able to avoid this increased competition by exploiting more distant trophic resources which were unavailable to the O - I juveniles.

The behaviour of S. melanops has biological correlates in terms of feeding and shelter. There are also environmental correlates of these activities. Increased water clarity results in a movement of the smallest size-class of fish deeper into the kelp bed. This response appears to be a graded response above a certain threshold level (Figure 28). Distribution of 30 - 100 mm fish is centered about the edge of the bed when visibility is less than 3.5 m. Movement into the kelp bed is initiated under conditions of increased water clarity. The juveniles are not cryptically coloured to a great degree and the increased water clarity would increase their vulnerability to predation by visual predators, hence the inward movement with its concomitant increase in shelter and security. The larger size classes of fish do not appear to participate in this retreat, reflecting their size-associated decreased vulnerability. Size-dependent susceptibility to predation has been detailed for a wide variety of organisms, both aquatic and terrestrial (F.E.Smith,1954; R.L.Smith,1966; Pianka,1974) and the behaviour of S. melanops juveniles is only one of several mechanisms which organisms employ to escape predation on juvenile forms (crypsis, shelter-seeking, mimicry, morphological adaptations, etc.).

The alteration of the distribution of the fish through its rheotactic response is another environmentally correlated facet of the behaviour of this species. The significance of this behaviour is open to speculation. The species is apparently exchanging a degree of security, which it gains through its association with the kelp bed or rock slope, for a benefit derived from its hovering postion in the tidal currents.

Several explanations may be presented for this behaviour. Given the fact that the species is primarily a water column forager, it may simply be optimizing its foraging opportunuties; the response may be the expression of a faculty necessary in the adult stage of its life to maintain its position in exposed habitats; or, the currents generated may exceed the 'crtical velocity' (Pavlov et al.,1972) at the substrate level, forcing the animal up into the water column. The existing information is not sufficient to indicate the value to the fish that such behaviour imparts, but the assumption must be made that it does not evidently act to the fish's detriment.

4.6 The nature of the association

In the analysis of the association of Sebastes melanops and beds of Macrocystis, the data gathered indicated that the fish was using the bed as a physical refugium, probably from nocturnal predation. The diel distribution patterns clearly indicated the proportionate increase in the nocturnal utilization, especially when considering the larger size classes. Results of experimental plant manipulation showed that the distribution of the plant has a definite effect on the distribution of the juvenile fish, both in terms of extending an existing distribution and attracting fish to a new location. The transporting experiments did not show a significant homing ability on the part of S. melanops juveniles, when displaced from their point of capture in the study kelp bed. A homing ability may be present in the adults, after the fashion of S. flavidus (Carlson and Haight,1972) but this ability has not been

demonstrated for the juveniles of any species of _Sebastes_.

The lack of returns of transported fish indicated that the juveniles were either unable to home (or had not yet developed the ability) or, that there was no feature of a kelp bed that was sufficiently important to the species to warrant the development, over evolutionary time-scale, of an ability to return to a given bed. The habitat frame experiments were conducted to elucidate what general feature of any kelp bed supported the obvious association between the two species. They were designed to provide only the shelter component of the kelp bed and to do so in an abiotic fashion, which would test whether this component was of significant importance in attracting fish. The highly significant response of the juveniles to the changes in the shelter provided (Table VIII) clearly indicates that the physical shelter provided by the plastic (and by analogy, the kelp) represents a component of the habitat which may potentially determine the numbers of fish present within the environs of a given bed. The importance of the shelter component of a habitat in attracting fish populations has been indicated previously by the provision of artifical substrates (Fujimura and Kami,1958; Kami,1962; Carlisle, Turner and Ebert,1964; Ogawa,1966,1967,1968; Ogawa and Onoda,1966). None of these studies attempted to quantify the numbers of attracted fish with the amount of shelter provided at a given size of reef, rather, they examined various sizes of reefs. Ogawa amd Aoyama (1966) did find that the provision of plastic strips inhanced the attractiveness of any artificial reef but they neither quantified this enhancement, nor manipulated the number

of plastic strips.

Senta (1965) related the results of studies conducted in Japan on the association of fishes and floating clumps of seaweed. The fishes found in and around these clumps were primarily pelagic, oceanic forms and Senta regarded the fishes as using them mainly as refugia from predation. He found no relation between the size of the clumps and the number of fish present but he did find that the degree of structural heterogeneity of the clumps was a major factor in attracting fish. In addition, he found that fish exhibited varying degrees of association with the seaweed. Small _Sebastes_ _inermis_ Valenciennes leave these seaweed clumps and move into the nearshore seaweed beds when they reach 50 - 60 mm. The response of _S. melanops_ to plastic 'kelp' parallels the response of pelagic fish noted in this study. Quast (1968) stated that the fish utilized the kelp as orientation points in the water column to establish their contact with the bottom. I do not believe this is the case with _S. melanops_ because visibility is not related to the position of the fish in the water column. The fish appears to be using the physical presence in the water column as shelter rather thas an an orientation point with the substrate.

Hunter and Mitchell (1968) found a disproportionately large number of fish surrounding their three-dimensional raft when comparing its size to two-dimensional rafts of similar size. They inferred that the size of the three-dimensional raft might not be as important as in a similar two-dimensional one although they employed only one size of three-dimensional raft. My

studies with three-dimensinal shelter suggest that, while a three-dimensional object is more attractive, a similar relationship between size and abundance of fish exists with three-dimensional objects, as does with two-dimensional ones.

The results of my studies using artificial seaweed do not illustrate that the amount of shelter provided by the kelp plants is the sole cause and effect relationship governing the abundance of juvenile _S_. _melanops_ present; however, they do provide proof that this component of the habitat is one to which the fish show a very strong _in situ_ numerical response.

4.7 Significance of the kelp bed to the fish

The information presented in this thesis, together with published material, indicate that the association between _S_. _melanops_ and _M_. _integrifolia_ in Barkley Sound is almost exclusively concerned with non-sexually mature juveniles. Diet analysis does not imply a reliance by the fish on a food resource base which is strongly associated with kelp beds. A strictly biotic association between these two species is not evidenced by this study. I believe that the significance of the kelp bed to _S_. _melanops_ is that of a physical refugium from predators. While feeding in the kelp bed undoubtedly occurs, observations of feeding and inference from diel migrations indicate that adjacent environments contribute the majority of the food resource base.

The association is more constant for smaller size class fish and the dimunition of it with increasing size infers that the smaller fish are more dependent on the kelp bed than larger

ones. The distribution of the adults of the species and the increasing cline in the sizes of fish observed in Barkley Sound, lead me to believe that the vulnerability of the young to predation results in a dependence of the species on kelp beds, and probably other sub-littoral refugia, for the initial survival of the yearly recruitment to the population. The appearance of recently transformed juveniles in the early stages of the yearly sporophyte growth illustrates both the coordination of spawning with kelp bed development and the provision to the fish of some advantageous feature about the kelp bed. Experimental results show that the juvenile fish will respond to the provision of physical shelter in a manner similar to their response to natural kelp beds. The results lead to the conclusion that the shelter of the kelp bed is of primary importance to the juvenile Sebastes melanops.

5. CONCLUSIONS

(i) The life history of Sebastes melanops encompasses a change in habitat association with the size and age of the fish. Adults are associated with the coastal zone while the juveniles associate with inshore features, particularly kelp beds. Young are spawned in late January - early February and appear in the kelp beds in mid - May. Juveniles spend up to four years in these inshore areas. An increasing cline in the size of fish from the inshore to the coastal zone is present in Barkley Sound.

(ii) Higher abundances of juvenile S. melanops are found in Macrocystis integrifolia beds than in beds of the more cumatophytic Nereocystis luetkeana. In addition, the abundance of juveniles in Macrocystis beds is inversely correlated with the degree of hydrodynamic exposure of the bed.

(iii) In the kelp bed studied, three, or occasionally four, age classes of juveniles are found in the beds, none of which are sexually mature. The absolute abundances of II, III and IV age-class fish are, generally, consistent over time. Fish recruited to a kelp bed often overwinter in the same area during the absence of kelp.

(iv) Smaller-sized juveniles (30 - 100 mm) are more intimately associated with the kelp bed than either of the other two size classes. The latter fish occasionally make diel feeding migrations from the kelp bed, returning to the bed before nightfall. These migrations are thought to be a response to the greater feeding competition resulting from higher densities of population recruits in some years.

(v) The kelp bed represents neither a feeding nor a reproductive sanctuary for the fish. Adjacent environments supply the primary food resource base. Fish may be 'resident' around a particular kelp bed during their inshore phase, but experiments indicate no fidelity to that bed should displacement occur. Distributional pattern of fish around the kelp bed has both biotic and abiotic correlates. Abundance of fish is both qualitatively and quantitatively correlated with kelp abundance. Fish adopt an alternate habitat during periods of kelp absence. At some size, in excess of 200 mm, inshore forms undergo a gradual migration to the coastal zone.

(vi) The kelp bed presents several ecological benefits to the fish, the main one of these being the physical shelter of the plants and their occlusion of the water column. The provision and manipulation of artificial seaweed shelter induces a numerical response in the fish population, similar to its response to the shelter provided by the kelp plants.

(vii) The kelp bed represents an important physical refugium to the fish. Its primary value is in the enhancement of the survival of the C - I age class juveniles.

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7. Appendix I

Macrocystis Study

Fish Food Analysis

Species *Sebastes melanops*   Date 25/6/74   Method 1½" gill   Time 20.00-05.30

# of items and dominant item by volume.

Fullness of gut (F,½,¼,T,o)	½F	O	¼	O	½	O	O	F									
algae																	
coelenterates																	
polychaetas																	
mysids						/											
isopods																	
amphipods																	
shrimp																	
crabs																	
crustacean remains																	
lamellibranchs																	
gastropods																	
bryozoans																	
holothurioides																	
fish (Clupeiform)	ch/	ch/	/	/													
fish (Perciform)																	
fish (Unidentified)																	
urchins																	
others																	
Calanoid copepods								/									
Brachyura megalops								/									
Cumaceans																	

126 132 127 122 118 122 124 115 54
↑

Notes and Comments: 122 - red peduncle.

_____

_____

Signature: _____

4-0
3-½
2-F

Diet analysis summary sheet
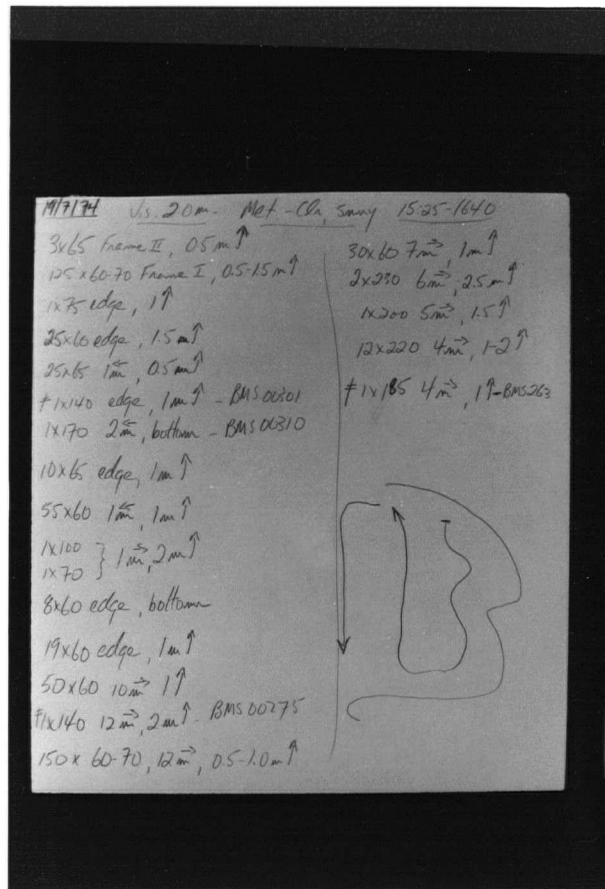
7.1 Appendix II

Example of an observational record

7.2 Appendix III

Experimental aquarium