SELECTED ASPECTS OF THE BIOLOGY OF THE RADIATED SHANNY, *ULVARIA SUBBIFURCATA* (STORER) 1839 (PISCES: STICHAEIDAE)

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by

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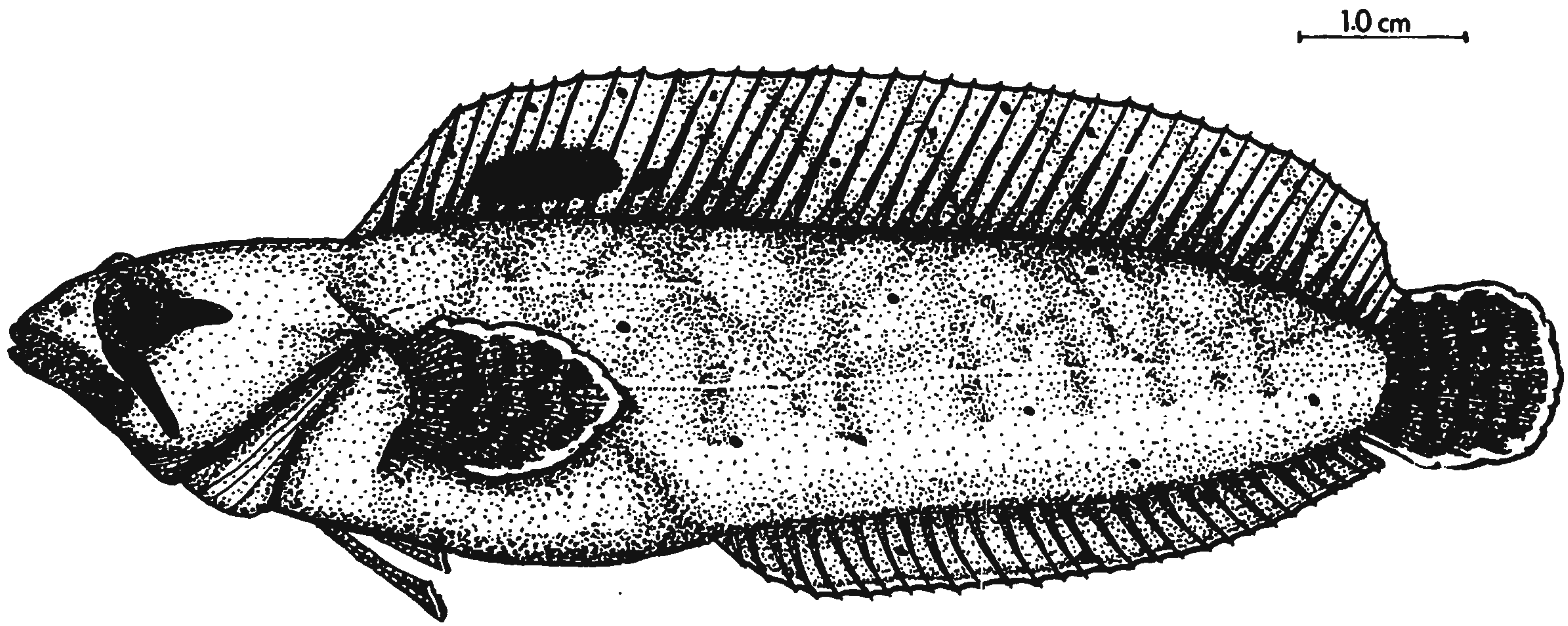

Ulvaria _subbifurcata_ (Storer) 1839

ABSTRACT

Collections of Ulvaria subbifurcata were made by diving at several locations on the Avalon Peninsula.

The diet of fish less than 55 mm total length comprised mainly copepods; larger fish, nereids. Polynoids and amphipods were eaten by fish of all sizes. These major food items were eaten during all seasons.

Tagging studies showed that U. subbifurcata has restricted movements and will home to the capture site. Larger (> 6 cm total length) fish are nocturnal; smaller fish diurnal. Activity decreased in fish of all sizes during the winter.

Spawning occurred in May at 4 C with fish first spawning at age three to five years. No secondary sex characters were noted. During each breeding season females spawned once, producing a demersal egg mass (mean - 2706 eggs). Males spawned up to four times and subsequently tended the egg mass (or masses). Incubation lasted 35 - 40 days. At hatching (6 - 9 C) larvae (mean - 6.58 mm total length) were positively phototropic. Young-of-the-year settled on bottom by August.

Age determination by scales was validated by the Petersen method. Few fish exceeded an age of seven years. Theoretical L_∞ calculated by a Walford line was 130 mm.

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ACKNOWLEDGEMENTS

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Finally I acknowledge the help given by my wife Joan throughout the study.

INTRODUCTION

The radiated shanny, Ulvaria subbifurcata is a common inhabitant of the littoral and sublittoral zones along the coast of eastern North America from the northern tip of insular Newfoundland to the Nantucket Shoals off Massachusetts (Leim and Scott, 1966).

Despite its abundance, the biology of this species is poorly known and, except for a recent study of agonistic behaviour in juvenile Stichaeus punctatus (Farwell, 1970) no studies have been done on the life history of any of the western north Atlantic members of the family Stichaeidae, to which it belongs.

The present study was therefore undertaken to provide information on the life history of this little known species. The thesis is organized in four sections each dealing with a separate aspect of the biology of U. subbifurcata: Food and Feeding; Activity and Movements; Reproduction; and Age and Growth.

Data were obtained from October 1968 to March 1971 from Bellevue, Trinity Bay and various other locations on the Avalon Peninsula of Newfoundland.

DESCRIPTION OF THE STUDY AREA

Monthly collections, tagging experiments, and observation dives were conducted at Bellevue, Trinity Bay (Fig. 1) in a shallow cove (maximum depth 2 m) at the mouth of the estuary known as Broad Lake. This cove was named Collection Cove (Fig. 2). From enlargements of aerial photographs and measurements taken in the cove a map was drawn showing the gross features of the bottom (Fig. 3).

The cove changes from sandy bottom in the east to rocky (rubble-boulder 10 - 100 cm diameter) in the west with a bar of rocks (the remnants of a fishing stage) protruding into the centre. A ridge of bedrock marks the western extremity of the cove. Shannies abound in the rocky areas of the cove especially along the western "ridge" as well as outside the cove along the side of the gut.

Because of its location strong currents run along the cove with back eddies occurring when the tide is ebbing and flooding. These currents keep the cove ice-free in the winter. The cove is relatively protected from the wind and only with a northwest or north by northwest wind is there any heavy wave action.

Figure 1. The Avalon Peninsula, showing diving sites where *U. subbifurcata* was collected and observed.

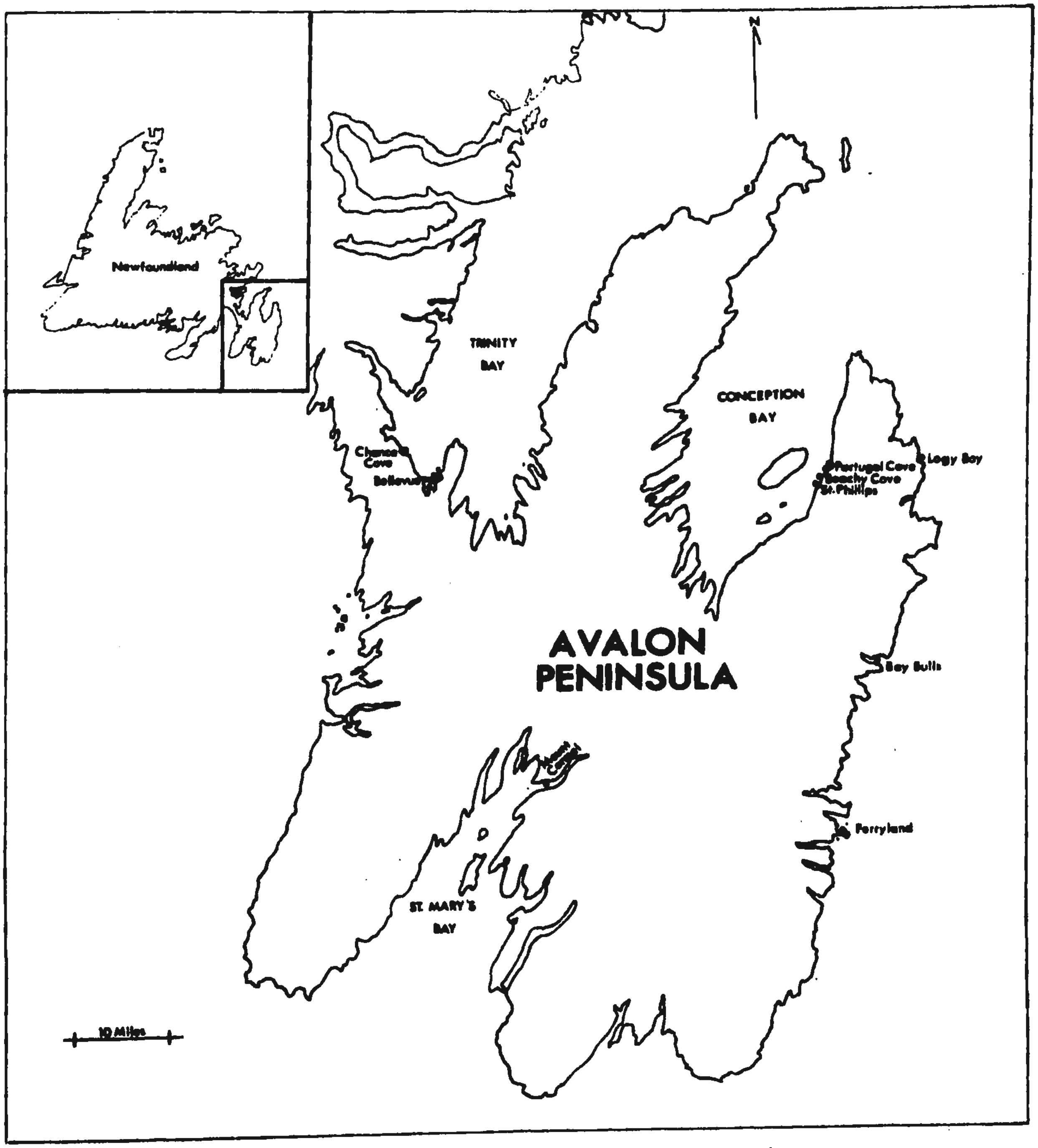
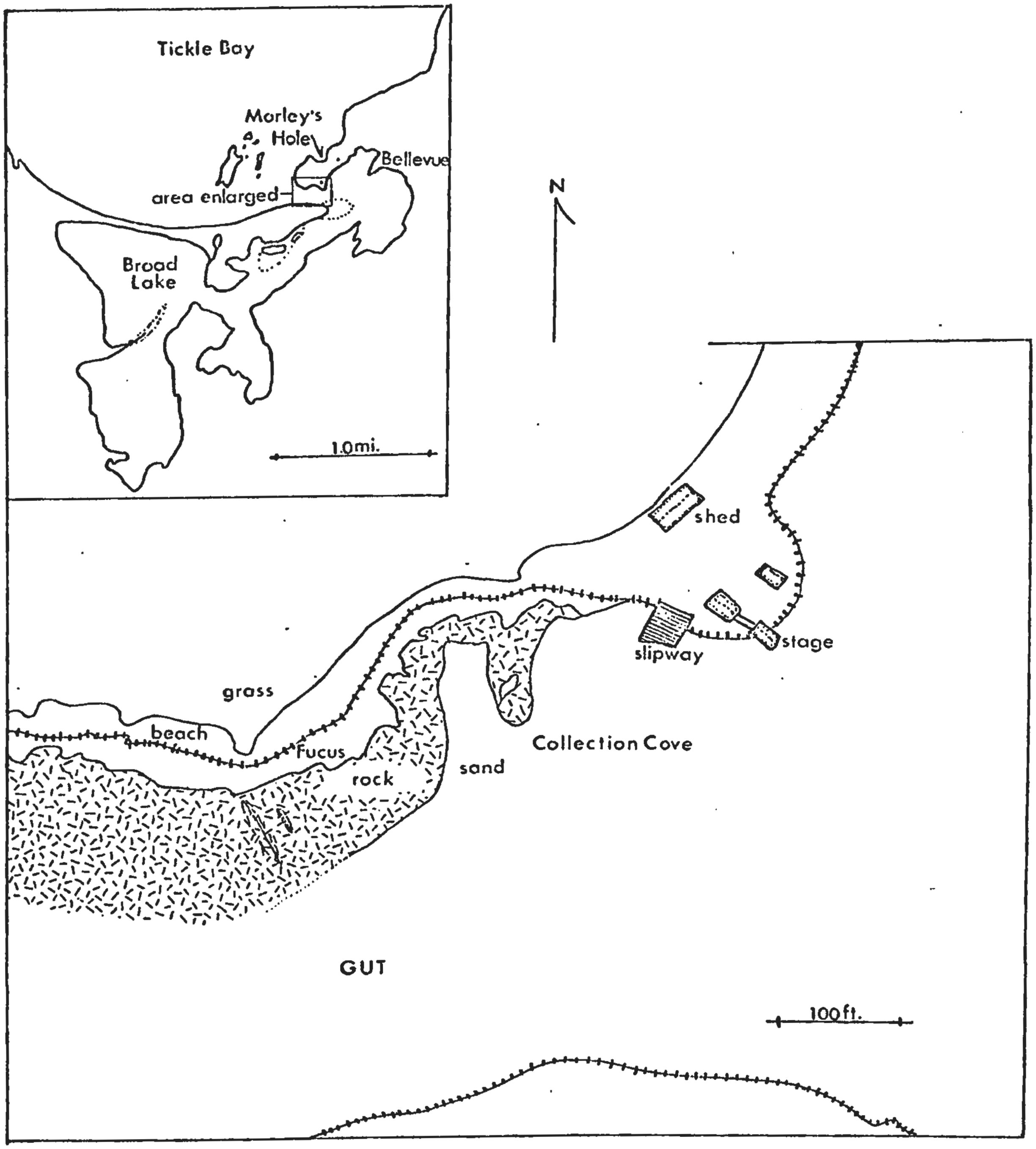

N
Newfoundland
TRINITY
BAY
CONCEPTION
BAY
Chance
Cove
Portugal Cove
Logy Bay
St. Phillips
AVALON
PENINSULA
Bay Bulls
Ferryland
ST. MARY'S
BAY
10 Miles

Figure 2. Collection Cove, Bellevue, Trinity Bay
(looking west from fishing stage).

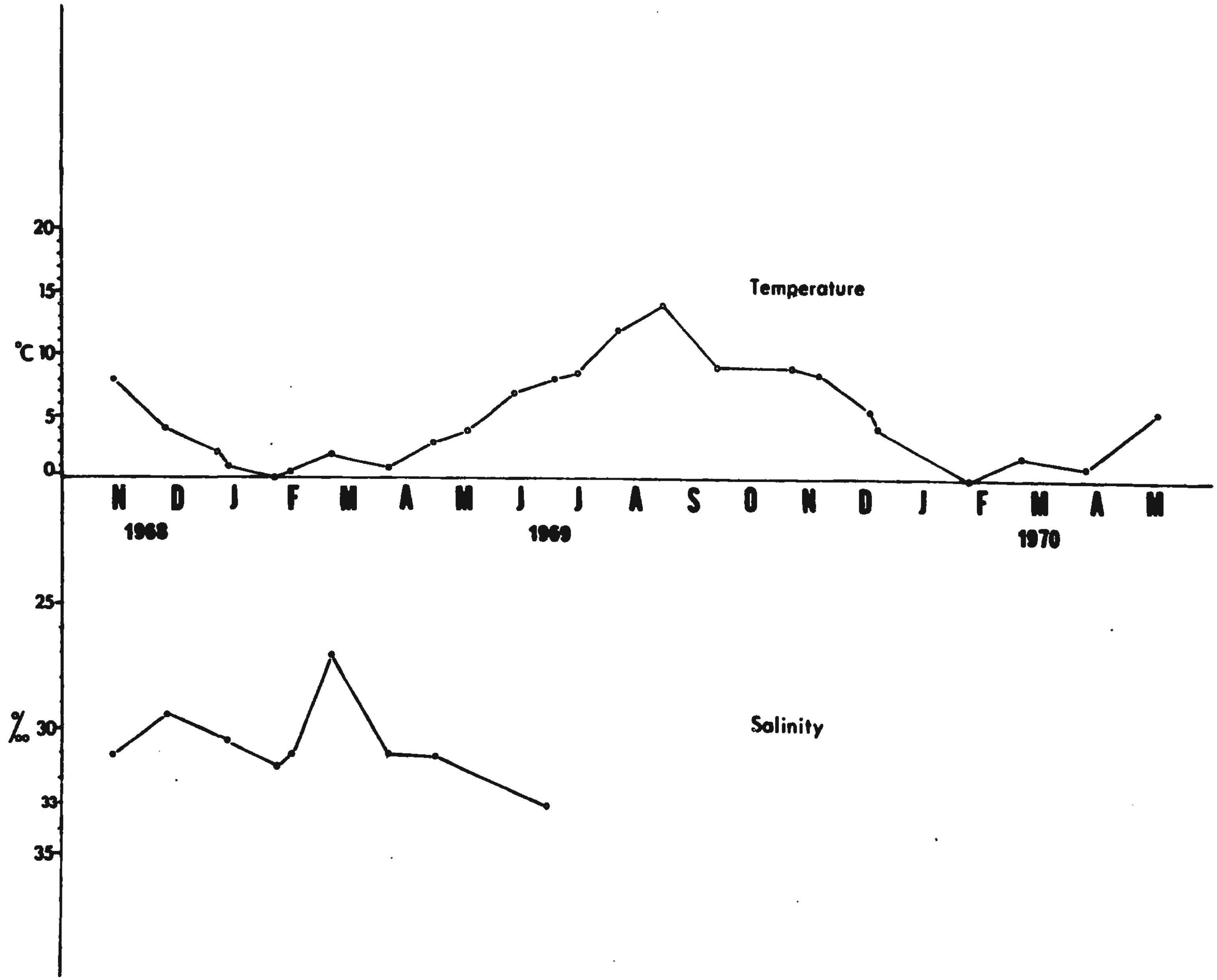
Figure 3. Collection Cove, Bellevue showing areas of Fucus sp., rock and sand.

Cross hatched lines indicate shoreline (MHW). Note ridge of rocks at west end of cove and location of Morleys Hole (insert).


Tickle Bay
Morley's Hole
Bellevue
area enlarged
Broad Lake
1.0mi.
N
shed
stage
slipway
grass
beach
Fucus
rock
sand
Collection Cove
GUT
100ft.

Salinity readings indicate that the waters of the cove are brackish (Fig. 4). Temperatures fluctuate from a low in January of 0 C to a high in August of 14 C (Fig. 4).

Figure 4. Surface water temperature (October 1968 - May 1970) and salinity (October 1968 - June 1969) records from Collection Cove, Bellevue.


Temperature
Salinity
°C
‰
20
15
10
5
0
25
30
33
35
N D J F M A M J J A S O N D J F M A M
1968
1969
1970

FOOD AND FEEDING

INTRODUCTION

The study of feeding can be divided into two major components - food habits and feeding habits. The former refers to the determination of the type and quantity of food items eaten whereas the latter refers to behavioural aspects of the search for, and ingestion of, food.

A study of food habits based on contents of the digestive tract reveals information on the types of matter ingested, i.e. the diet. This information is affected by differential digestion rates of different food items and the time of feeding. It is therefore useful in such studies to know the feeding chronology of the fish.

In this study four aspects of feeding were considered: the diet; the relationship between diet and fish size; seasonal changes in the diet; and feeding chronology.

METHODS AND MATERIALS

Monthly collections were made at Collection Cove, Bellevue, from October 1968 to December 1969. Stomach content analysis was carried out on all collections made in 1969. Generally specimens were collected within one day but in July they were collected on four seperate days - July 23, 24, 26 and 28. The collection made on May 3 is referred to as the April collection; the May collection being taken May 29.

Specimens were collected with a slurp gun and dip net. Collections generally were made in the afternoon and usually took less than an hour. Immediately after being collected, fish were preserved in 60% ethyl alchohol. The body cavities of larger specimens were injected with preservative.

In the laboratory, specimens were individually marked by placing numbered paper tags in their mouth. Total wet weight of each specimen was measured to the nearest .01 g on a balance (Mettler Model no. P160N). Surface moisture was removed by rolling each specimen in a paper towel prior to weighing. The total and standard lengths of each specimen were measured with dial calipers to the nearest .1 mm. Measurements were taken as described by Hubbs and Lagler (1958).

The stomach contents of individual fish were removed and volume determined by displacement in a 5 or 10 ml graduated cylinder. The contents were then placed in a glass petri dish, indentified and the proportionate volume of each type of food estimated. A count was then made of each food item. The small volume of food contained in the stomachs of many shannies less than 6 cm total length was not detectable with the method used, hence volumetric analysis was done on only those smaller fish whose stomachs were distended with food. If a stomach contained a large number of one food item (e.g. copepods) the total number was determined by counting an estimated proportion. For certain items occurrence only was noted. Algae and tube feet often could not be discerned as individual food items and hence numerical analysis was not applicable to them.

The intestine of each specimen was examined and any food items were recorded seperately from the stomach contents. Accumulated chitinous parts (e.g. mouth parts of scaleworms and nereids) or shells were frequently found and these often aided in identifying the stomach contents. Food items from each specimen were stored in individually labelled vials.

During a 24 hr period, June 25 - 26, 1969, a total of 12 collections were made at Collection Cove. Six radiated shannies, greater than 6 cm total length, were collected every two hours and immediately preserved. During each collection observation was made of fish abundance and activity.

The stomach of each specimen was subsequently examined to determine the amount of food present. Each stomach was described as full, part full or empty: a stomach distended with food was considered full; one containing food but not distended was classed as part full and one devoid of food, or containing minute quantities of ingested matter, was classed as empty.

RESULTS AND DISCUSSION

Diet

The length frequency of monthly collections including those used for stomach content analysis is shown in Fig. 15. A total of 389 specimens were examined of which 304 (78%) were found to contain food items. Volumetric analysis was carried out on 178 specimens, representing 60% of those containing food. The only noticable fluctuation in the percentage of specimens with empty stomachs (Fig. 5) occurred in July. This may be because of an increased digestion rate during the relatively warm summer months. No difference was found in the proportion of empty stomachs between sexes through the year.

Table 1 shows the combined results of stomach content analysis for all collections. No single food item predominated in all three analyses. Copepods dominated in frequency of occurrence and numerical abundance while nereid polychaetes comprised over 50% of the food volume. The only other food items of volumetric significance were scaleworms (Polynoidae) and amphipods.

These four food items form the basic diet of the radiated shanny. Two other food items comprised a significant proportion of the total volume. Two occurrences each of

Table 1. Stomach content analysis of radiated shannies collected January - December 1969 from Collection Cove.

Food Organisms	Frequency no.	Frequency %	Numerical no.	Numerical %	Volume cc.	Volume %
PROTOZOA						
Foraminifera -	2	0.67	2	0.07	-	-
COELENTERATA						
Actiniaria -	3	1.00	3	0.10	0.11	0.51
ANNELIDA						
Polychaeta						
Polynoidae -	30	10.00	44	1.47	4.67	21.60
Lepidonotus squamatus						
Harmothoe imbricata						
Nereidae -	72	24.00	90	3.00	11.68	53.80
Nereis virens						
Nereis pelagica						
Oligochaeta -	11	3.70	28	0.93	0.45	2.10
ARTHROPODA -						
Amphipoda -	111	37.00	179	5.97	1.36	6.30
Gammarus oceanicus						
Ischyrocerus anguipes						
Corophium sp.						
Pontogencia inermis						
Isopoda -	17	5.60	21	0.70	0.02	0.09
Decapoda						
Hyas araneus -	2	0.67	2	0.07	0.63	2.90
Copepoda -	143	47.80	2053	68.47	0.14	0.64
Ostracoda -	68	22.70	208	6.90	0.03	0.14
Acarina -	19	6.30	22	0.70	-	-
Diptera						
Cricotopus sp. -	24	8.00	39	1.30	0.07	0.32

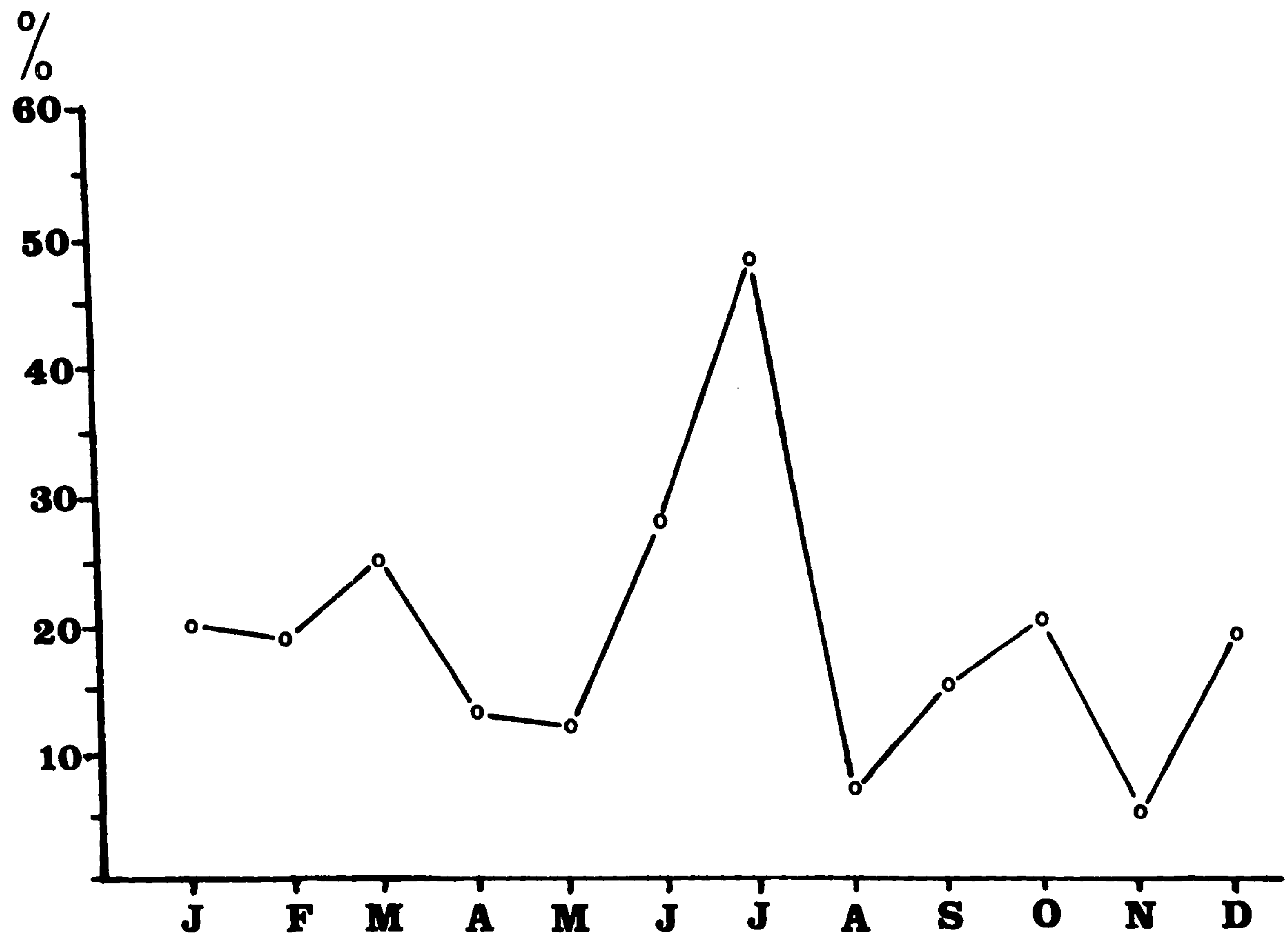
Table 1 (contd.). Stomach content analysis of radiated shannies collected January - December 1969 from Collection Cove.

Food Organisms	Frequency no.	Frequency %	Numerical no.	Numerical %	Volume cc.	Volume %
MOLLUSCA						
Gastropoda -	47	15.70	66	2.20	0.43	2.00
Acmea testudinalis						
Littorina obtusata						
Littorina saxatilis						
Buccinum undatum						
Margarita helicina						
Cingula aculeus						
Pelecypoda						
Mytilus edulis -	10	3.34	13	0.40	-	-
ECHINODERMATA						
Strongylocentrotus droebachiensis	25	8.40	n/a	n/a	0.53	2.40
CHORDATA						
Ammodytes americanus	2	0.67	2	0.07	1.30	5.99
Fish eggs	8	2.67	227	7.60	-	-
ALGAE						
Ptilota sp.	22	7.40	n/a	n/a	0.23	1.06

Number of stomachs containing food - 304

Total volume - 21.65 cc.

Figure 5. Percentage of stomachs devoid of food in monthly collections from Collection Cove, 1969.


%
60
50
40
30
20
10
J
F
M
A
M
J
J
A
S
O
N
D

the sand lance (*Ammodytes americanus*) and the toad crab (*Hyas araneus*) in large fish gave disproportionate importance to these as food items.

On two occasions Forminifera were found in the stomach and three times they were found elsewhere in the digestive tract. Anemones (Actiniaria) occurred in three medium sized specimens. Small *Mytilus edulis* occurred in several fish from the September to December collections.

In June and July fish eggs comprised a significant numerical proportion of the food items, rising from 4% in June to 89% in July. Eggs were found only in fish less than 8 cm total length. The eggs corresponded in size, color and general appearance to those of capelin (*Mallotus villosus*). It is during this time of year that schools of capelin are inshore spawning.

The only part of the sea urchin, *Strongylocentrotus droebachiensis* found in the stomach contents was the tube feet. Pieces of the red algae, *Ptilota* sp. occurred in some specimens. This alga was observed to wash ashore in substantial quantities after storms and heavy seas. Because neither algae nor tube feet could be distinguished as seperate items, they were not included in the numerical analysis.

Diet and Fish Size

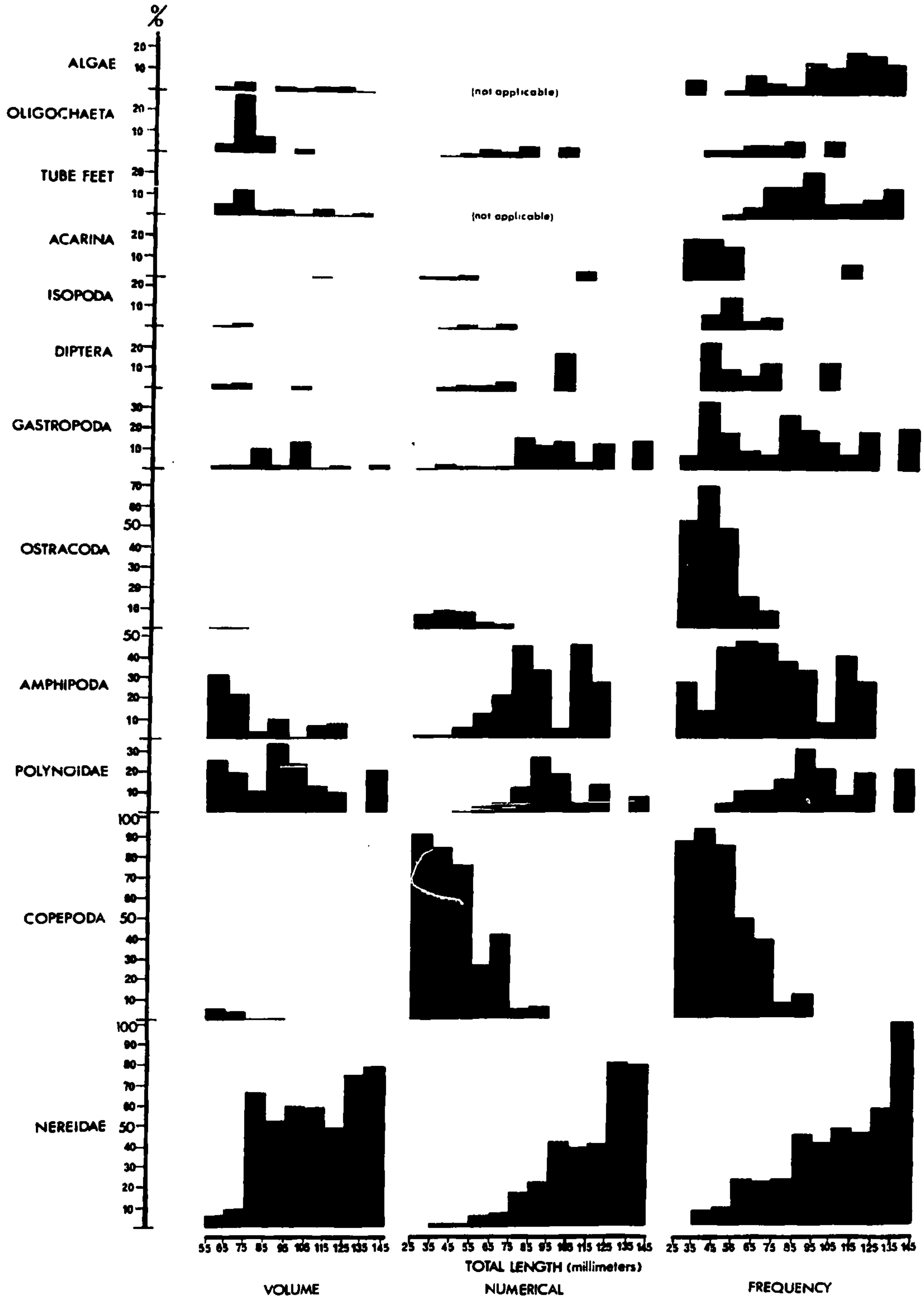
Figure 6 presents the relationship between diet and fish size for selected food items. Note that volumetric analysis refers to the 60 mm and larger fish only.

Nereids are the major food item of radiated shannies 75 mm and longer, and are absent from the diet of only the smallest size class. All three methods of analysis indicate that as radiated shannies increase in size they feed almost exclusively on nereids.

Copepods exhibit a trend directly opposite to that of nereids. They comprise the major part of the diet of size classes up to 60 mm and decrease in importance with increasing fish size, none occurring in specimens larger than 95 mm. Ostracods follow a similar trend and were almost always found with copepods.

Although amphipods show a decline in percent volume with increasing fish size they increase in numerical abundance and occur with relatively high frequency in all size classes. These trends indicate that radiated shannies consume a fairly consistent number and volume of amphipods throughout life.

Figure 6. Relation between diet and fish size for selected food items from samples collected from Collection Cove, Bellevue, 1969.



%
ALGAE
OLIGOCHAETA
TUBE FEET
ACARINA
ISOPODA
DIPTERA
GASTROPODA
OSTRACODA
AMPHIPODA
POLYNOIDAE
COPEPODA
NEREIDAE
(not applicable)
(not applicable)
TOTAL LENGTH (millimeters)
VOLUME
NUMERICAL
FREQUENCY

Scaleworms (Polynoidae), like nereids, are not eaten by the smallest fish. They are most prevalent in the 90 mm size class, tending to decrease in importance as food of larger fish.

Seasonal Changes in the Diet

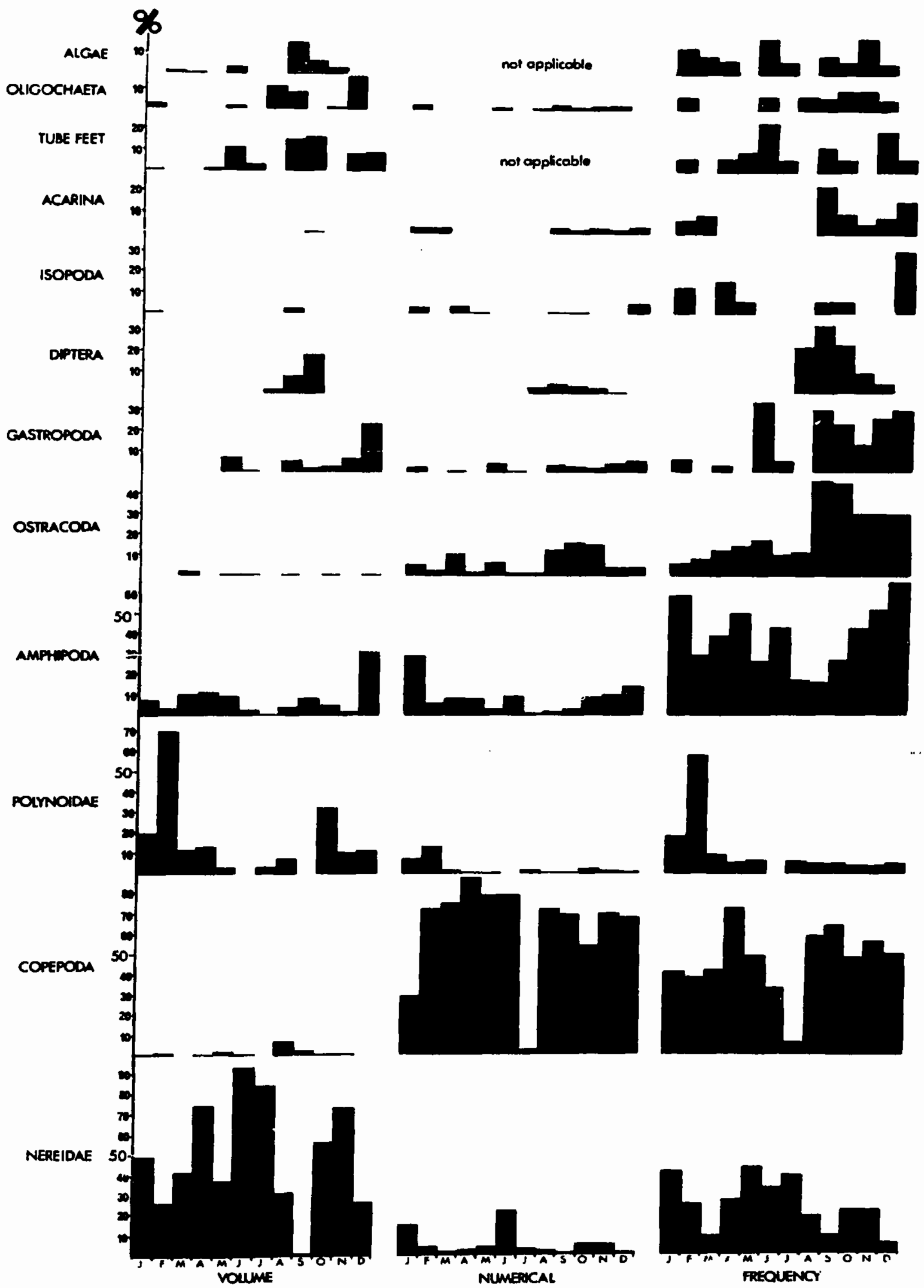
Figure 7 shows the breakdown of food items for each of the monthly collections. The major food items (nereids, copepods, polynoids and amphipods) occur year round. The volumetric predominance of nereids was replaced in the September collection by anemones which accounted for 49% of the total volume of food found in that collection. The only other month in which anemones occurred was October when they contributed 3% of the total volume.

Copepods were abundant in all but the July collection. No fish less than 55 mm total length occurred in this collection (Fig. 15) and, as seen in Figure 6, small fish consumed the greatest numbers of copepods. In July, fish eggs accounted for 89% of the total number of food items.

Scaleworms (Polynoidae) occurred year round except for the June collection. They tended to be more abundant in the months of January, February and March. They were a moderately important food item; percent volume was small but consistent.

Gastropods occurred sporadically and only comprised a significant proportion of the food volume in December.

Figure 7. Seasonal changes in the diet for selected food items from samples collected from Collection Cove, Bellevue, 1969



%
ALGAE
OLIGOCHAETA
TUBE FEET
ACARINA
ISOPODA
DIPTERA
GASTROPODA
OSTRACODA
AMPHIPODA
POLYNOIDAE
COPEPODA
NEREIDAE
not applicable
not applicable
J F M A M J J A S O N D
VOLUME
NUMERICAL
FREQUENCY

Diptera (chironomid) larvae occurred from midsummer to the end of fall. These midges belong to the subfamily Orthocladinae, which contains several species whose larvae are restricted to intertidal rocks on seacoasts (Mason, 1968).

Isopods were found in six collections with no seasonal trend apparent. They did not contribute significantly to food volume. Acarina occurred from midsummer to the end of winter and were absent from March until August. Their contribution to the total volume of food was insignificant. Tube feet, oligochaetes and algae all occurred irregularly throughout the year.

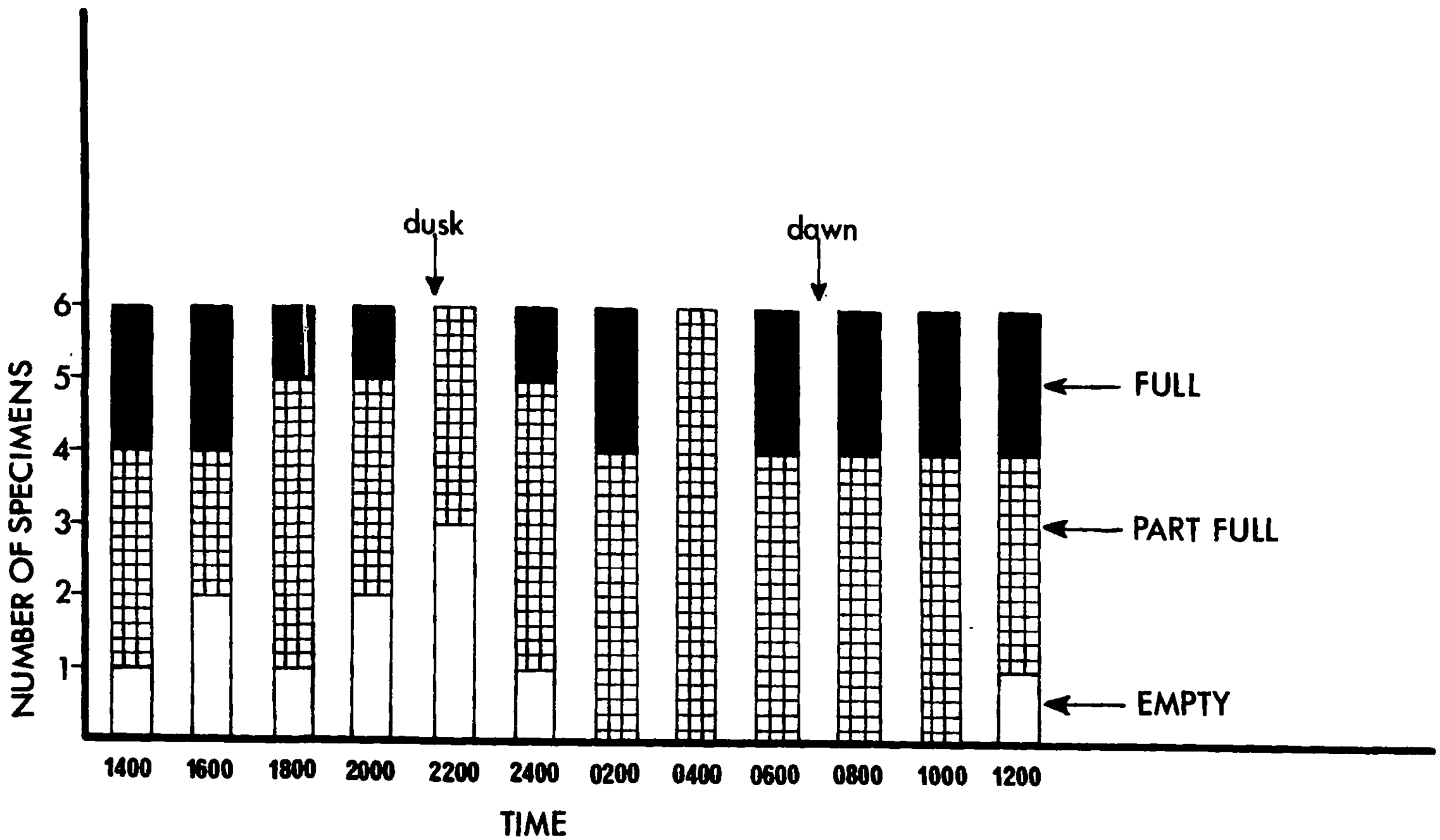
Some miscellaneous food items were found in single collections or during definite seasons. Small mussels (*Mytilus edulis*) occurred from September until December but were absent the rest of the year. Forminifera were found in the stomach contents in November and March, however scattered occurrences in the intestine were noted in other collections. A small crab was found in one individual from the January collection.

To conclude, major food items were taken throughout the year. Minor items occurred sporadically either because of their incidental nature or because of seasonal availability related to stages of their life cycle.

Feeding Chronology

Diving observations indicated that adult U. subbifurcata are active at night. Rarely were any but small radiated shannies seen out in the open during the daytime. After dark however radiated shannies were commonly seen sitting on rocks or out on sandy spots between the rocks. The result of the 24 hour collection confirms that larger radiated shannies feed at night (Fig. 8). The number of specimens whose stomachs were empty increased from noon until 2200 hr at which time any food items present were at an advanced stage of digestion. The number declined to zero at 0200 hr. Laboratory studies indicate that adult fish are most active just after dark and just before light (Green, unpublished data).

Figure 8. Degree of fullness of stomachs from specimens collected at Collection Cove, Bellevue, June 25 - 26, 1969.



dusk
dawn
FULL
PART FULL
EMPTY
NUMBER OF SPECIMENS
6
5
4
3
2
1
1400
1600
1800
2000
2200
2400
0200
0400
0600
0800
1000
1200
TIME

ACTIVITY AND MOVEMENTS

INTRODUCTION

For any population whose movements are restricted two terms have been used to describe the area over which movement occurs. The first, home range, was defined by Hayne (1949) as, "the area over which an animal normally travels". Nice (1941) defined the second term, territory, as, "any defended area". This latter definition implies an agressive response for the protection of an area whereas no such response is assumed for the term home range.

In natural populations it is difficult to determine whether a fish is defending an area, so that studies of fish movement, especially those based on tagging experiments, generally deal with the broader term, home range.

Attempts to determine the size of the home range have in general been unsuccessful because the investigator rarely has any idea of the magnitude of the home range before the experiment begins. Hence, if the sampling area is large in relation to the area over which an individual fish moves, a high proportion of recaptures will occur within the sampling area. Conversely, if the sample area is small in relation to the home range a high proportion of strays will occur. Williams (1957) stated that any quantitative expression about the size of the home range and the degree of straying describes the techniques of the investigator as much as the behaviour of the fish.

When studying the movements of a particular fish species Gerking (1959) stated that; "the best we can hope to do is to determine whether or not the movements of a particular species are restricted, to get a general idea about the degree of movement, and to base experiments on the population upon this knowledge."

The term homing refers to the choice that a fish makes between returning to a place formerly occupied instead of going to other equally probably places, whether displaced experimentally or by natural (reproductive or non-reproductive) migratory habits (Gerking 1959). This definition encompasses most of those presented in earlier works (Williams 1957, Allee et al. 1949). Homing, according to this definition, covers the distant spawning migrations of salmon as well as the activity pattern of reef fishes which return to a particular location after undergoing a daily feeding migration (Winn 1964).

This study was undertaken to determine whether the movements of U. subbifurcata are restricted; to investigate the possibility of a homing behaviour; and to determine daily, as well as seasonal, activity patterns.

METHODS AND MATERIALS

Anaesthetic

Because U. subbifurcata is quite active when handled it was necessary to use an anaesthetic during tagging operations. The reaction of radiated shannies to the anaesthetic MS-222 (Tricaine-Methanosulfonate) was tested. A known quantity of anaesthetic was dissolved in 4 ℓ of sea water. Fish placed in the solution were considered unconcious when they remained on their sides after being nudged and displayed no signs of motion other than opercular movements. They were then removed and placed in fresh sea water to recover. When fish resumed swimming they were considered to have recovered. Water temperatures ranged from 2 to 5 C during the test. Total length was measured while specimens were unconcious. Results from 12 specimens are given in Table 2.

The recovered fish were kept in a separate aquarium for five days. During this period no mortalities or changes in behaviour, which might have been due to the anaesthetic, were noted.

It was concluded that, during field operations, concentrations could be approximated provided fish were removed immediately after they became immobile.

Table 2. Effect of various concentrations of MS-222 on *Ulvaria subbifurcata*.

Specimen no.	Conc. MS-222 (gm/ℓ)	Specimen total length	Elapsed time (minutes) to succumb	Elapsed time (minutes) to recover
1	0.025	9.5	*	-
2	0.050	9.4	5	8.5
3	0.075	10.8	7	6.0
4	0.075	5.6	7	10.5
5	0.075	6.1	7	10.0
6	0.075	9.8	7	7
7	0.100	6.9	7	10.5
8	0.100	10.8	7	10.0
9	0.100	6.1	7	9.0
10	0.100	9.6	7	14.0
11	0.125	13.6	5	8.0
12	0.125	15.5	7	8.0

* - Did not succumb after 10 minutes.

Marking Techniques

Two marking techniques were tested. One was an electric-branding technique similar to that described by Owens and Gebhardt (1968), the other utilized embroidery beads attached by monofilament nylon. Both methods offered the advantages of conspicuous individual identification and easy application.

A comparison of these two techniques was made on 12 fish. Anaesthetized fish were placed in a pan containing gauze soaked in sea water. The marks were then applied, total length measured and the fish placed in fresh sea water to recover. Subjects were held for 33 days with observations being made on their condition after 4, 15 and 33 days.

An electrodessicator (National Electric Model no. 710-13) was used for electric branding. Fish were placed on their right side and the area posterior to the anus was dried. A numerical mark was then applied with a fine tipped probe. No visible sign of the mark could be discerned immediately after branding.

After branding was completed, with the fish still anaesthetised, the bead tag was applied. One or two embroidery beads (2 × 2 mm) were tied by a loop to a short piece of nylon monofilament fishing leader (4 lb test). The end of the leader was threaded through a fine needle and the needle passed through the musculature of the back just under the dorsal fin, in the area of the fourth to the sixth ray. The bead end of the tag was then pulled close to the body of the fish and leader end sewn through the bead, knotted and trimmed.

Table 3 shows the condition of the marks during the observation period. The brands took several days to become clearly discernable. All but one of the bead tags stayed on for the full study period. No chafing of the flesh was evident and the bead tag did not seem to hinder movement.

Because the brand was not immediately discernable this marking technique was rejected and embroidery bead tags were used in field operations.

Table 3. Results of test application of two marking techniques on radiated shannies.

Specimen		Electric Branding					Embroidery Beads				
No.	Total length (cm)	Electrodessicator Setting	Electrodessicator Brand	Condition of brand (days after marking) 4	15	33	Number of beads	Color	Condition of tag (days after marking) 4	15	33
1	11.0	8	2	n s[1]	n s	c[2]	2	clear blue	ok[5]	ok (F)[6]	bead missing
2	6.5	7	3	p c[3]	b[4]	b	2	dark green	ok	ok	ok
3	7.5	6	4	p c	b	c	1	orange	ok	ok	ok
4	15.5	8	5	p c	c	c	1	pink	ok (F)	ok	ok
5	7.5	6	6	n s	c	c	1	clear pink	ok (F)	ok	ok
6	10.5	6	7	p c	c	c	1	red	ok	ok	ok
7	9.5	7	7	n s	c	c	2	yellow	ok	ok	ok
8	10.5	5	9	n s	c	c	1	clear red	ok (F)	ok	ok
9	11.5	7	11	b	c	c	1	clear green	ok	ok	ok
10	8.0	5	12	n s	c	c	1	clear brown	ok (F)	ok	ok
11	10.5	7	13	n s	c	c	1	pale green	ok	ok	ok
12	7.0	5	14	b	c	c	1	dark brown	ok	ok	ok

(1) n s - no sign of brand
(2) c - brand clearly visible
(3) p c - part of brand visible
(4) b - brand visible but blurred
(5) ok- bead secure no sign of chafing or fungus growth
(6) F - color of bead faded

Field Tagging

Specimens for tagging were captured by slurp gun and dip net and held in a plastic bucket containing approximately 18 ℓ of sea water before being individually removed and placed in a bucket containing the anaesthetic. Strips of monofilament with beads attached and loops set for tagging were prepared prior to tagging. Once anaesthetized, the fish was removed, placed in a dissection tray partially filled with sea water, wrapped in cheese cloth and tagged as described previously. Before being replaced into the open water, fish were retained until they had completely recovered from the anaesthetic. On June 21, 1969 three specimens were taken and tagged as controls. They were placed in Collection Cove in a minnow trap, fed and observed every second day for ten days. The tags remained well affixed and the fish appeared to be healthy throughout the observation period.

Field Experiments

Site Preparation

Group and individual tagging experiments were conducted during June and July, 1969. For group tagging, square grids (3 × 3 m) were laid out. Labelled cork marker buoys attached by nylon cord to a weight were placed at the corners of each grid. Rocks labelled with a felt pen were placed along each side. The borders of a grid were visible from above and below the water surface. Grids were laid out on two types of bottom. Areas covered at least 90% by loose rocks of a size sufficient to provide cover for the largest radiated shanny were designated as rocky. A sandy bottom was defined as an area consisting of a least 90% sandy bottom with no available cover. All grids were placed below the extreme low water mark.

For individual tagging experiments plastic seine buoys, labelled with a felt marker, were used. These were tied to a weight by nylon string and placed on, or immediately adjacent to, the rock where a tagged fish was first captured.

All specimens used for tagging experiments were greater than 6 cm total length. Tagged fish were observed at the time of their release to ensure that they reached bottom.

Group Tagging

The purpose of the first experiment (O) was to determine whether the movements of *U. subbifurcata* are restricted.

A collection was made within a marked grid, the fish tagged, and replaced within the grid. Recaptures were made within the grid one and three days after tagging. The grid itself and the surrounding area for a distance of 4 m were thoroughly searched. All fish recaptured after one day were replaced inside the grid. The two tagging series - O(a) and O(b) were started on June 20, and June 21 respectively.

Experiment (R) was carried out to determine whether *U. subbifurcata* will return to an area after being displaced. Twenty fish were captured within a grid, tagged and placed within a similar grid (i.e. same bottom composition) some distance from the capture grid. Recaptures in both grids were attempted one, three and seven days after tagging. All recaptures were retained.

Series R-5 was started on June 22. Specimens were transplanted to a grid 5 m from the capture grid (measured between the nearest boundaries of the two grids). In this series no recaptures were attempted on the seventh day after tagging. Series R-10 commenced on July 16, with the transplant grid being located 10 m from the capture grid. Series R-20 was started on July 18 with the capture and transplant grids being located 20 m apart.

The final experiment (S) was similar to the one just described except that the transplant grids were in a sandy area. The purpose of this experiment was to determine whether radiated shannies would return to a rocky area after being transplanted to an area which provided no cover.

As with series R, three transplants were carried out over distances of 5, 10 and 20 m. Series S-5 was carried out on July 16 with 20 tagged fish being displaced 5 m; series S-10 was started on July 17 with 20 tagged specimens being displaced 10 m; series S-20, with 19 fish displaced 20 m, was started on July 20. Recaptures were attempted after one, three and seven days for series S-5 and series S-10; one, three and nine days for series S-20.

Individual Tagging

Individual tagging of radiated shannies was carried out in an attempt to acquire information on the activity pattern and extent of movements of *U. subbifurcata*.

Five fish in each of two experiments were marked along with their initial capture location, and each was returned to the capture location. Various colour combinations of three embroidery beads distinctly marked each fish.

The first set of five radiated shannies (Experiment 4) were tagged on July 22. It was hoped to observe closely the movements of these fish throughout a one hour period during daylight and another one hour period after dark. Checking all the sites took approximately ten minutes so that six observations could be made in each one hour period. Unfortunately because of bad weather only two observations were attempted after dark.

On July 25 another five radiated shannies (Experiment 5) were individually marked. On this occasion an attempt was made to locate the subjects once every hour throughout daylight and twice after dark.

Diving Observations

In addition to the tagging study, observations were made during dives at Collection Cove and other sites (Fig. 1). Dives were made from October 1969 to March 1971 during all seasons, several of which were during the night. Observations were made on abundance, activity, and movements of U. subbifurcata as well as any other species encountered. Subsequent references to dive numbers refer to the physical data on 81 snorkel and SCUBA dives contained in Appendix 1.

RESULTS AND DISCUSSION

Group Tagging

Table 4 shows the results of recaptures from the two replacement series (Experiment O). After one day 54% of 38 tagged shannies were recaptured in the replacement grid. This represents 87% of the total recaptures for that day. On the third day only 32% of the number tagged were recaptured in the replacement grid, however, this represents the total recaptures made.

The number of recaptures was not high. Because of the nature of the bottom, even the most thorough search would not expose all the hiding places for radiated shannies, hence limiting the number of possible recaptures. Another factor was the disturbance caused by moving rocks, etc. during collections which could be expected to encourage dispersal to other areas. The results verify that *U. subbifurcata* exhibits restricted movements, that is, it has a home range.

Table 5 shows the recapture results for the three series in Experiment R over the recapture period. Twenty-two out of 23 recaptures were made in the capture or O grid. The total recaptures represented 38% of the number tagged.

The data were subjected to a chi-square test based on the hypothesis that if fish distribute themselves randomly

Table 4. Experiment O - Replacement - Record of recaptures.

Series	No. tagged	Recaptures: one day, within grid	Recaptures: one day, elsewhere	Recaptures: three days, within grid	Recaptures: three days, elsewhere
Oa	20	9	1	5	0
Ob	18	11	2	7	0
Total	38	20	3	12	0
% of number tagged		54	8	32	0
% of number recaptured		87	13	100	0

Table 5. Experiment R - recaptures from Transplant to Rocky grid.

Series	No. tagged	One day				Three days				Seven days				Total					
		O[1]		T[2]		O		T		O		T		O		T		both grids	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
5	20	4	(20)	0	(0)	7	(35)	0	(0)	-[3]	-	-[3]	-	11	(55)	0	(0)	11	(55)
10	20	4	(20)	0	(0)	1	(5)	1	(5)	0	(0)	0	(0)	5	(25)	1	(5)	6	(30)
20	20	1	(5)	0	(0)	1	(5)	0	(0)	4	(20)	0	(0)	6	(30)	0	(0)	6	(30)
Total	60	9	(15)	0	(0)	9	(15)	1	(2)	4	(7)	0	(0)	22	(37)	1	(2)	23	(38)

1. - O. Grid of original capture
2. - T. Transplant grid
3. - No recapture attempted

their probability of recapture (allowing sufficient time for dispersal) is the same for any grid in the study area. Hence the number of recaptures in the O grid where the fish were originally caught would be expected to be the same as the number of recaptures in the transplant grid T.

Results were accumulated for each series and for the whole experiment (Table 6). Data from the seventh day of the R-10 series are omitted since no recaptures were made in either grid.

The grand total values confirm that the hypothesis must be rejected. Movements have occurred in the direction of the O grid. This is presented as evidence that radiated shannies do exhibit homing behaviour under conditions of experimental displacement.

Table 7 shows the recapture results from the series of transplants to sandy grids (Experiment S). There were no recaptures in the transplant grids. A comparison of all values of percentage recaptures was made between the S and R series, however no significant difference was found.

It is possible that increased susceptibility to predation caused by placing tagged fish in an area some distance from cover cancelled out any effect of encouraged dispersal caused by this lack of cover. Specimens transferred

Table 6. Results of chi-square test on data from Experiment R

Series (day of recapture)	Recaptures: Grid "O" observed	Recaptures: Grid "O" expected	Recaptures: Grid "T" observed	Recaptures: Grid "T" expected	Chi-square	Degrees of freedom	Sig.
R-5 (1)	4	2	0	2	4.0	1	95%
(3)	7	3.5	0	3.5	7.0	1	99%
Total	11	5.5	0	5.5	11.0	2	99%
R-10 (1)	4	2	0	2	4.0	1	95%
(3)	1	1	1	1	0.0	1	n.s.
Total	5	3	1	3	2.67	2	n.s.
R-20 (1)	1	0.5	0	0.5	1.0	1	n.s.
(3)	1	0.5	0	0.5	1.0	1	n.s.
(7)	4	2	0	2	4.0	1	95%
Total	6	3	0	3	6.0	3	n.s.
Grand Total	22	11.5	1	11.5	19.17	7	99%

Table 7. Experiment S - recaptures from transplant to Sandy grid.

Series	No. tagged	One day				Three days				Seven days				Total					
		O[1]		T[2]		O		T		O		T		O		T		both gric	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
5	20	0	(0)	0	(0)	3	(15)	0	(0)	3	(15)	0	(0)	6	(30)	0	(0)	6	(30)
10	20	1	(5)	0	(0)	2	(10)	0	(0)	1	(5)	0	(0)	4	(20)	0	(0)	4	(20)
20	19	0	(0)	0	(0)	3	(15)	0	(0)	3	(15)[3]	0	(0)[3]	6	(30)	0	(0)	6	(30)
Total	59	1	(2)	0	(0)	8	(13)	0	(0)	7	(12)	0	(0)	16	(27)	0	(0)	16	(27)

1. O - Grid of original capture
2. T - Transplant grid
3. - Recapture after 9 days

to sandy grids were apparently just as capable of returning to their home area as were those transferred to rocky grids.

Table 8 gives the results of two way analysis of variance of the study variables; recapture time, transplant distance, and type of transplant grid.

The nine day collection in series S-20 was considered the same as a seven day collection in the calculations. A value for the seven day collection missing from the R-5 series was derived from the equation described by Steel and Torrie (1960) from Yates:

$$X = \frac{rB + tT - G}{(r - 1)(t - 1)}$$

where r = number of blocks

t = number of treatments

B = total of block values

T = total of treatment values

G = grand total of all values

The value thus derived does not affect the results.

None of the study variables can be shown to account for the variation in recapture rate in the original capture (O) grid.

Table 8. Results of two way analysis of variance on recaptures in the "O" grid expressed as percent of the total number tagged.

Experiment			Degrees of freedom	F	Test F .05
S	Blocks	Recapture period	2	6.20	6.94
	Treatments	Transplant distance	2	0.72	6.94
R	Blocks	Recapture period	2	0.10	6.94
	Treatments	Transplant distance	2	0.48	6.94
S + R	Blocks	Recapture period	2	0.52	6.94
	Treatments	Transplant distance	2	1.84	6.94
S + R	Blocks	Recapture period	2	1.11	19.0
	Treatments	Type of transplant grid	1	2.00	18.5
S + R	Blocks	Transplant distance	2	2.00	19.0
	Treatments	Type of transplant grid	1	1.11	18.5

Individual Tagging

Table 9 shows the results of observations of individual radiated shannies from Experiment 4. On several occasions fish moved when disturbed by the observer and consequently one subject (4C) left the observation area.

Subjects A, B and D were observed throughout the daylight period. Almost no movement occurred and they remained under the rocks where these fish were originally captured. During the first night observation only one tagged fish was seen (4D), and none were seen during the second observation although an area of approximately 2 m radius around each marker buoy was searched.

On July 23 at 1000 hr a check of the five capture locations did not result in any sightings, however, on July 24 at 1100 hr subject 4C was found 0.2 m north of the original capture site.

Disturbance of subjects was a problem in Experiment 5 as well and only one subject (5E) was observed throughout the daylight period (Table 10). Two subjects (5C and 5D) are known to have left the observation area after being disturbed by the observer. After dark, subject 5D was observed on sandy bottom 0.5 m south of the marker buoy. This was the only sighting made after dark. On August 15, 1969 during

Table 9. Experiment 4; Location of individually marked *U. subbifurcata* relative to original place of capture.

Time (22-07-69)	Subject A	B	C	D	E
1930	O	O	O(S)	O	O
1940	.6m west	O	n s	O	.3m east (S)
1950	.3m s/west	O	n s	O	.3m east
2000	.3m s/west (S)	O	n s	O	n s
2010	.3m n/west	O	n s	O(S)	n s
2020 (dusk 2130)	.3m n/west	O	n s	O	n s
2200	n s	n s	n s	O	n s
2215	n s	n s	n s	n s	n s

O - Under rock where initially captured

S - Observer disturbed fish causing it to move

n s - No sign of subject

Table 10. Experiment 5. Location of individually marked *U. subbifurcata* relative to original place of capture.

Time (25-07-69) (26-07-69)	Subject A	B	C	D	E
1230	O	O	O	O	O
1330	.5m n/west	O	O	O	O
1430	O	.5m east	O	O	O
1535	n s	n s	O	O(S)	O
1630	n s	n s	.5m west	n s	O
1730	n s	n s	.5m west (S)	n s	O
1845 (dusk 2130)	n s	n s	n s	n s	O
2245	n s	n s	n s	.5m south in open	n s
0030	n s	n s	n s	.5m south in open	n s

O - Under rock where initially captured

S - Observer disturbed fish causing it to move

n s - No sign of subject

a daylight dive this same fish was observed under its marker buoy, 21 days after its original capture (Table 11).

The results of these two experiments indicate that adult _U. subbifurcata_ move very little during the daylight hours. Radiated shannies leave their cover and move further than 2 m during the night. They move onto sandy areas at night but return to the rocks before dawn.

Incidental Recaptures

Several recaptures of tagged radiated shannies have been made in Collection Cove subsequent to the completion of the experiments (Table 11). The most notable recaptures were made after periods of 92, 114 and 259 days.

In all, 23 tagged fish were recaptured after completion of the tagging experiments. A total of 167 radiated shannies were tagged and 52 of these were captured and retained during the study leaving 115 tagged fish in Collection Cove. Discounting tag loss and mortality, the recaptures account for 20% of the available fish.

Table 11. Incidental recaptures of tagged *U. subbifurcata* in Collection Cove.

Experimental series	Date of initial capture (1969)	Subsequent capture date	No. caught	Elapsed time (days)
O (a)	20-06-69	17-07-69	1	27
		18-07-69	2	28
		22-07-69	1	32
O (b)	21-06-69	19-07-69	2	28
		22-07-69	1	31
		23-07-69	1	32
		24-07-69	2	33
		25-07-69	1	34
		07-03-70	1	259
R-5	22-06-69	16-07-69	1	24
		25-07-69	5	33
R-10	16-07-69	15-08-69	1	30
		08-11-69	1	114
R-20	18-07-69	18-10-69	2	92
5 (D)	25-07-69	15-08-69	1	21

Diving Observations

Observations made during the 24 hr collection of radiated shannies (dive no. 34a - 34ℓ) indicate that larger fish (> 6 cm total length) are active at night. During the four collections made from 1400 hr until 2000 hr fish were found under rocks and appeared inactive. Dusk was at 2130 hr and at 2200 hr radiated shannies were observed out from under cover actively moving about in gravel-sand areas. At midnight and 0200 hr fish appeared less active and fewer numbers were sighted out in the open. By 0400 hr no activity was noted. Dawn occurred at 0500 hr and during the four collections made from 0600 hr to 1200 hr radiated shannies were once again inactive and found only under cover of rocks.

A night dive made on July 25, 1969 (dive no. 38) revealed a similar situation. Radiated shannies were observed out in the open sitting on rocks or moving about the sandy areas (Fig. 9).

This pattern apparently changed somewhat during the fall and winter. During the period October - March radiated shannies were more lethargic both day and night and, during several night dives, were not always found out from under cover (dive no. 43, 44, 49, 57 and 61). Possibly the period of night activity shifts or shortens during the winter months.

Figure 9. Night photograph taken at Collection Cove July 25, 1969. Note radiated shanny on sandy bottom, lower 1/3 of picture just to the right of centre.

Juvenile radiated shannies up to approximately 6 cm total length and probably one to two years old exhibited an activity pattern somewhat different from larger, older fish. Small radiated shannies were frequently observed during the daytime in the sandy or gravel areas of Collection Cove. These fish could find cover even on this fine material, however their daylight activity made them susceptible to predation. The grubby, Myoxocephalus aeneus is common in Collection Cove and these fish were observed feeding on small radiated shannies (dive no. 27). A collection of 48 M. aeneus, 5 - 15 cm total length, was taken from Collection Cove during June and July, 1969. Examination of the stomach contents (Appendix II) revealed that, of the 34 stomachs containing food, seven contained radiated shannies. These radiated shannies varied in length from 3.0 cm to 5.9 cm total length.

Territoriality

On May 3, 1969 during a dive (no. 13) in Morleys Hole (Fig. 3) a rock gunnel (*Pholis gunnellus*) was frightened from under a rock. As the rock gunnel approached another rock a radiated shanny poked its head out from under this rock. When the rock gunnel moved to go under the rock the radiated shanny nipped it. A second approach by the rock gunnel elicited the same response. When the rock (approximately 0.5 m diameter) was turned over, an egg mass was found.

On May 2, 1970 an egg mass and accompanying radiated shanny were taken from Collection Cove (dive no. 67). They were placed alone in an aquarium at the Marine Sciences Research Laboratory and observed periodically. On May 18 the fish was found wrapped around the egg mass and during subsequent observations was always in this position or in front of the mass fanning it. Prior to May 18 the fish had not tended the egg mass.

On May 24 the fish responded to a thermometer placed in the aquarium by nipping vigorously at it. On May 25 a small mirror was placed in the aquarium approximately 15 cm from the egg mass. The fish started a fanning motion and extended its head. It slowly moved toward the mirror, fanning vigorously. The shanny stopped three times with a direct head on, or a sideways stance in relation to the mirror. When approximately 4 cm from the mirror the fish moved forward in one quick motion and nipped at it. The thermometer was again placed in the aquarium and was nipped at as before.

These field and laboratory observations indicate that the egg masses and nest site are defended by the radiated shanny. It has not been determined whether *U. subbifurcata* is territorial during non spawning periods as has been shown for *Stichaeus punctatus* (Farwell, 1970).

REPRODUCTION

INTRODUCTION

Little is known about the reproductive habits of any member of the family Stichaeidae. Breder (1966) in his review of modes of reproduction in fishes cites information about only one species, Anoplarchus purpurescens, of the Pacific Ocean. For the nine species of stichaeids occurring along the Atlantic coast of Canada there is no information other than reports of collections of larvae and young-of-the-year fish.

The only account of larval U. subbifurcata is given by Bigelow and Schroeder (1953) who stated that: "the eggs have not been seen but the fact that we have taken larvae as small as 8 to 11 mm in our tow nets in June, July and October points to a spawning season lasting from late spring throughout the summer (if our identification is correct)".

It is the purpose of this section to provide data on fecundity and duration of the breeding season; to describe the eggs and larvae; and to describe the parental care of the eggs.

METHODS AND MATERIALS

Preserved specimens from the monthly collections caught in Collection Cove during 1969 were examined for external characteristics which would distinguish the sexes. The head and the anal area in particular were examined and colouration was noted.

The gonads of each specimen were removed, and their condition and wet weight were determined. Gonad weight for each specimen was calculated as percent of total body weight.

Ripe ovaries were removed from six preserved specimens from the monthly collections of January 31 and March 22. The volume of each was determined by displacement in a graduated cylinder. Egg diameter and total number of eggs were obtained by the method of Von Bayer as described by Lagler (1956). A known number of eggs taken from several areas of the ovary were placed in a row in a trough, excess water removed and total diameter measured to the nearest .01 mm with a set of dial calipers. Five sets of measurements were made to obtain an average egg diameter for each ovary. The Von Bayer Table was referred to and number of eggs per quart was divided by 946.4 to give the number per cc. An actual count was made of the eggs of one ovary.

Eleven egg masses were collected during the spring of 1969 and preserved in Bouins solution. Volume of each egg mass was determined by displacement. Mean egg diameter was determined for four of the masses and an estimate of total number of eggs was made by the Von Bayer method. An overall mean value for egg diameter was used in estimating numbers of eggs for the remaining seven egg masses. An actual count was made of three egg masses.

Adults and guardians with egg masses were collected on dives at various locations during the spring of 1969. These were transported to the Marine Sciences Research Laboratory in a plastic bucket containing approximately 18 litres of sea water. Adults were placed in large (60 × 30 × 30 cm) glass aquaria. Each egg mass and guardian was placed in a separate, smaller (37 × 30 × 25 cm) aquarium. Aquaria bottoms were covered with a layer of sand and gravel. Cover was provided by scallop shells, rocks or sections of plastic piping. Prior to hatching the egg masses were transferred to fine nylon mesh bags stretched over 10 × 10 × 15 cm plexiglass frames suspended in a large aquarium. After hatching, the larvae were distributed into several of these containers.

Live eggs and larvae were observed and drawings were made with the aid of a dissection microscope. A micrometer eye piece was used in making measurements. Samples of eggs and larvae were preserved in formalin. Measurements of the total length of preserved larvae were made to the nearest .01 mm with dial calipers.

Larvae which hatched on July 2, 1969 were subjected to a light test. The lights were turned off and the laboratory darkened. A Bausch and Lomb microscope lamp was placed facing the side of the aquarium and turned on. The reaction of larvae was noted, the lamp turned off and the larvae given time to react to the darkness. This procedure was repeated with the light source placed above, and then below, the aquarium. Larvae at age 4 hr, 24 hr and 5 days were tested. A water blockage on the night of July 6 resulted in the death of many larvae and few of those remaining alive were sufficiently active to provide subjects for the 5 day test.

RESULTS AND DISCUSSION

Sexual Dimorphism

In many blennioid fishes the males are larger than the females with brighter colors and numerous other secondary sex characters. For example in Anoplarchus purpurescens the male is brightly coloured during the breeding season and the cockscomb becomes more enlarged than that of the female (Peppar, 1965).

In the radiated shanny no secondary sex characters were discerned. During the breeding season ripe females had a noticably swollen belly, however their appearance is little different from that of a shanny distended with food. It was thought that dark colouration was a male characteristic but this proved unrelated to the sex of the individual. As is true with other blennioid fish (Breder, 1966) adult males tend to be larger than females of the same age (Fig. 14).

Sex can be determined by examination of the gonads for all but the smallest individuals. The bilobed, elongate testes lie at the posterior end of the body cavity against the dorsal wall. In immature or spent individuals they are translucent. In mature or ripe fish the testes are a milky white.

The ovaries lie in relatively the same position as the testes. They appear fused into a single spherical body. The granular texture is discernable in all but the most immature specimens. At all stages of development the ovaries are comparatively larger than the testes. In mature or ripe individuals the eggs are clearly visible.

Fecundity

Table 12 shows the results of egg counts for ripe ovaries and for fertilized egg masses. Actual counts compare well with estimates. Number of eggs in the ovary appears to be related to the size of the fish. The size of the female parent is known for only one egg mass as most masses were collected in the field. These counts indicate that the egg production of a female is contained in a single egg mass.

The mean number of eggs found in the ovaries (1512) and in egg masses (2706) is comparable to the number reported for Anoplarchus purpurescens (1613) by Schultz and De Lacy (1932). Peppar (1965) for the same species found a mean of 2738 eggs in the ovaries and 2685 in the egg masses.

The mean egg diameter of unfertilized eggs was 1.07 mm, and for fertilized eggs 1.55 mm. Schultz and De Lacy (1932) reported a range in diameter for unferitlized eggs of 0.693 - 1.112 mm for A. purpurescens. These figures are comparable with findings for U. subbifurcata. The eggs of the radiated shanny are smaller than those of Pholis gunnellus which average about 2.0 mm diameter (Gudger, 1927).

Table 12. Fecundity: egg counts of 5 ovaries (A) and eleven egg masses (B) (preserved in Bouins solution).

Specimen total length (cm)	Volume of eggs (cc)	Mean egg diameter[1] (mm)	No. of eggs Estimated	Actual count
A				
9.32	0.90	1.02	1,005	
10.52	1.45	1.04	1,504	
9.44	1.20	1.09	1,079	
12.52	3.00	1.10	2,697	2,532
9.67	1.60	1.10	1,438	
B				
15.5	8.5	1.51	2,958	
	6.0	1.53	1,986	1,682
	4.0	1.61	1,144	1,496
	3.5	1.53	1,159	1,215
	8.0	(1.55)	2,520	
	8.0	(1.55)	2,520	
	5.5	(1.55)	1,733	
	12.0	(1.55)	3,780	
	27.0	(1.55)	8,505	
	5.0	(1.55)	1,575	
	6.0	(1.55)	1,890	

(1). Values in brackets refer to mean egg diameter from measurements of other egg masses.

Gonad Growth

Figure 10 shows the relationship between percent gonad weight and fish size for both sexes from three collections taken in January, February and March. No male less than 8 cm total length had gonads comprising more than 0.01% of the total body weight while all fish 10 cm total length or larger had gonads comprising 0.5 - 2.0%. All females 9 cm total length or greater had relatively large ovaries (10 - 20%) compared with those of smaller fish.

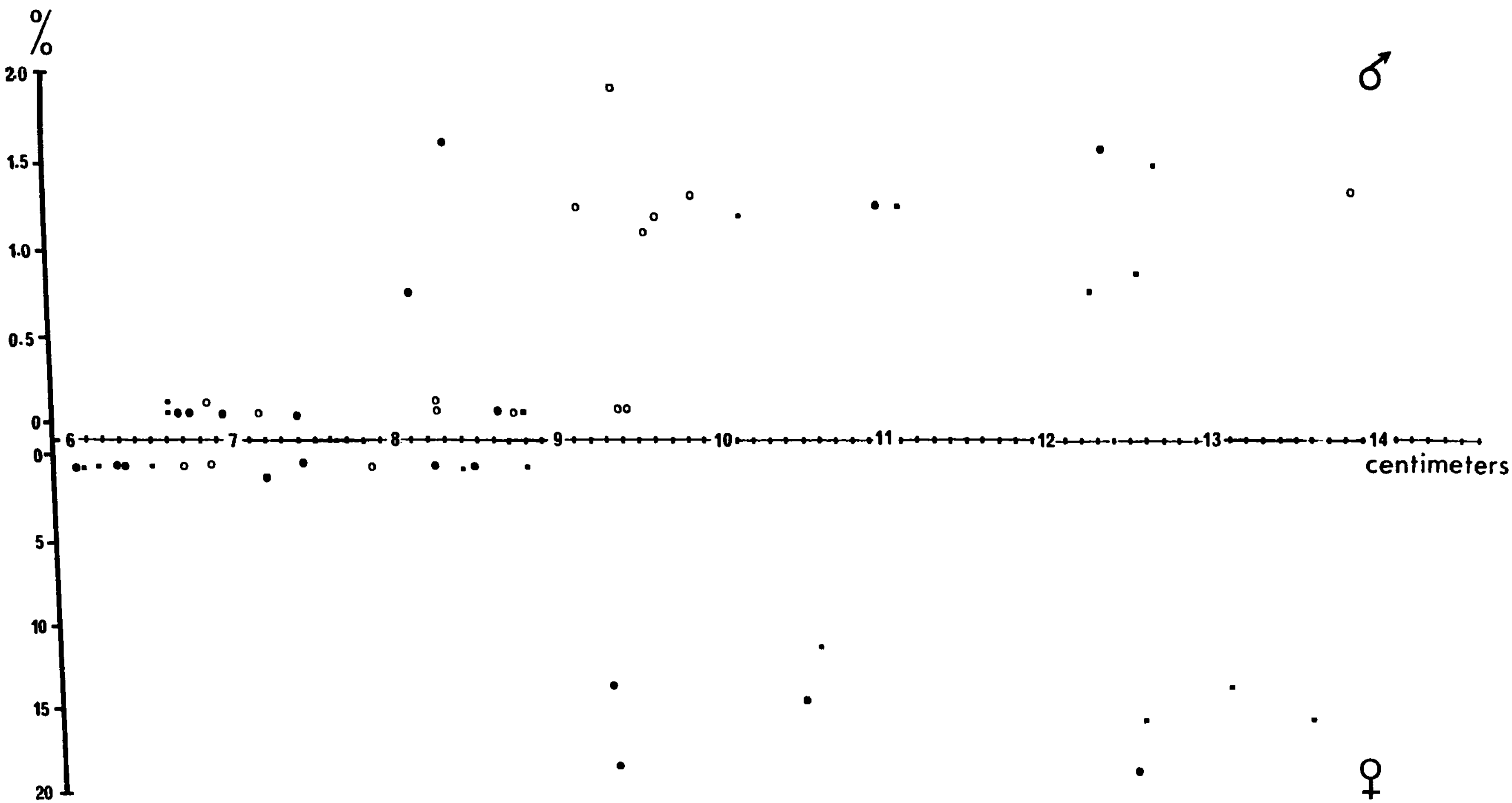
It was assumed that enlarged gonads indicated a ripening condition. Fish whose gonads were not enlarged by this time of the year would not have spawned in the spring. Referring to Fig. 14 these results indicate that some fish as young as age three could spawn and, at age five, all fish of both sexes are capable of spawning.

Table 13 traces the seasonal change in gonad size for specimens over 9 cm total length. Males reached maximum gonad size in March with ripe, partially spent and spent individuals occurring in May. By June 30, males were either spent or recovering. Gonad size increased throughout the remainder of the year. Females had a similar cycle, however no partially spent individuals were found, confirming that the eggs are extruded in a single spawning act. All females

Table 13. Seasonal change in Gonad size for radiated shannies > 9 cm total length.

Collection date (1969)	Male: Gonad wt. (% of total wt.) mean	Male: range	Male: n	Female: Gonad wt. (% of total wt.) mean	Female: range	Female: n
Jan. 25 – Jan. 31	1.11	0.78-1.48	5	14.01	11.08-15.64	4
Feb. 22	1.04	0.08-1.95	8	-	-	0
Mar. 22	1.42	1.25-1.58	2	16.23	13.65-18.66	4
May. 3	0.31	0.10-0.54	4	10.07	0.62-19.52	2
May. 29	1.06	0.15-3.02	12	0.78	0.44-1.04	4
June 30	0.17	0.08-0.21	5	0.52	0.47-0.63	3
July 23-28	0.22	0.04-0.56	7	0.61	0.45-0.72	5
Aug. 15	0.11	0.09-0.13	4	0.74	-	1
Sept. 14	0.14	-	1	0.71	0.68-0.73	2
Oct. 18	1.09	0.85-1.42	4	2.31	0.59-3.47	5
Nov. 8	1.27	1.23-1.31	2	3.17	1.79-4.54	2
Dec. 6	0.99	0.62-1.34	4	6.59	-	1

Figure 10. Gonad weight expressed as percent of total body weight plotted against total length for males and females for samples from Collection Cove, Bellevue taken during 1969. Squares represent samples collected January 25 and 31; Open circles February 22; and dark circles March 22.


%
2.0
1.5
1.0
0.5
0
0
5
10
15
20
6
7
8
9
10
11
12
13
14
centimeters
♂
♀

were spent by May 29. Recovery took longer in females and by October ovaries were only 0.6 - 3.5% of the total body weight, well below the ripe condition.

Spawning and Hatching

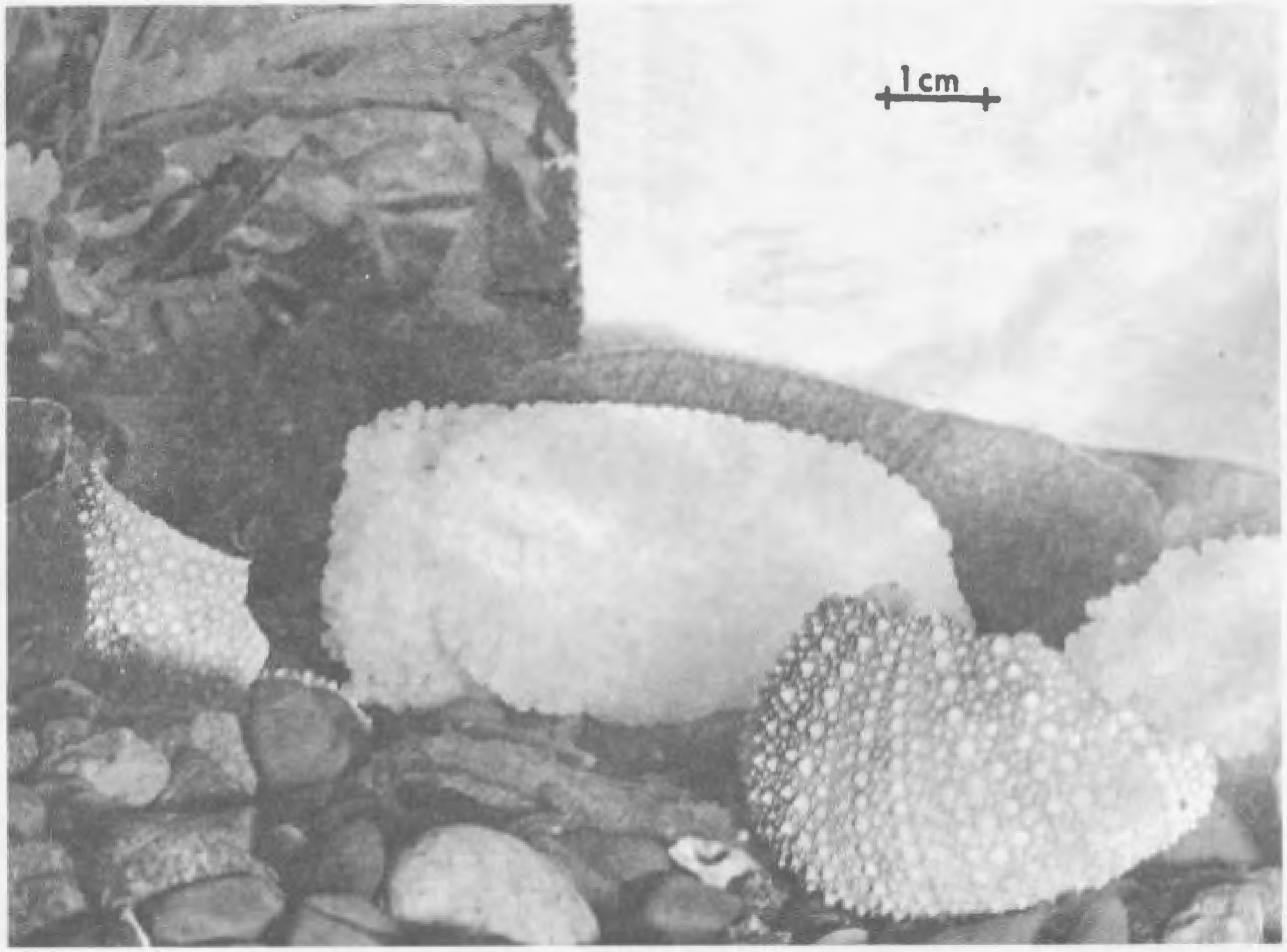
Four spawnings occurred in the laboratory during the spring of 1969. On April 19, two egg masses were found in an aquarium containing five adults (Fig. 11). A water blockage the previous night had resulted in a temperature rise from 1 to 6 C. Other spawnings took place on May 12, 14 and 27 at a water temperature of 4 C.

Egg masses were observed at depths of 1 - 10 m during several dives from May 3 to June 5, 1969 (dive no. 13 - 16 and 20 - 23) and from May 2 to May 23, 1970 (dive no. 67, 70 and 71). Water temperatures rose during these periods from 3 to 5 C and from 4.5 to 5.5 C respectively.

The eggs spawned on May 12, 1969 were eyed on May 27, however they did not hatch. The eggs spawned on May 27, 1969 hatched 35 days later on July 2. During this period the temperature increased from 4 to 9 C.

Other hatchings occurred in the laboratory on June 12, 1969 (6.5 C) and June 6, 1970 (6 C) from masses collected on May 3 and May 2 respectively.

Figure 11. Egg mass of Ulvaria subbifurcata spawned April 19, 1969.


1 cm

Description of Eggs and Larvae

Egg masses were spherical to ovoid in shape. A groove extended around the longest circumference of each mass (Fig. 11). The egg mass was a translucent white color except at the eyed stage when the mass took on a silvery sheen.

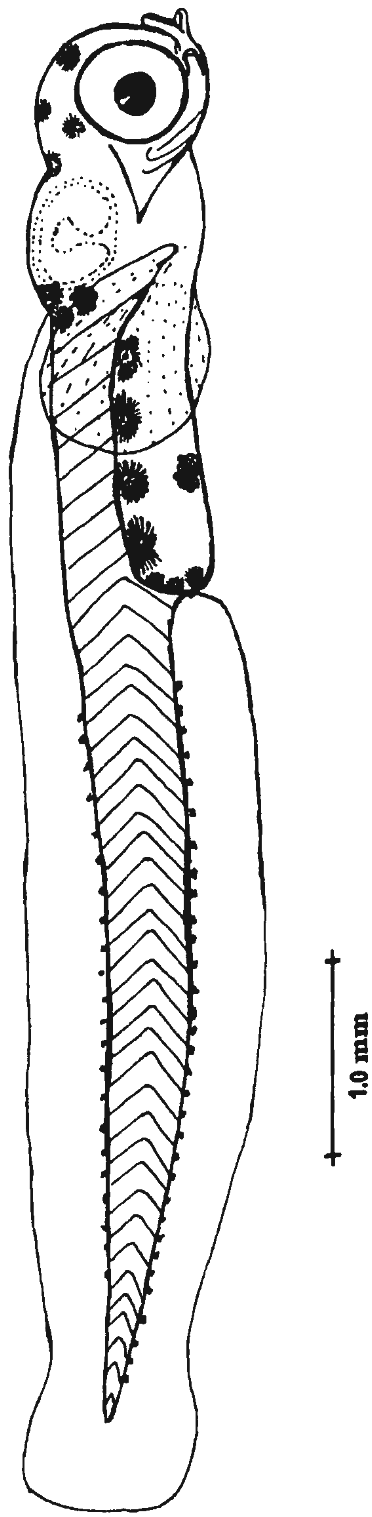
The spherical eggs are demersal and adhered to each other, but not to any other material. Each egg was enclosed in a transparent membrane from which cylinder-like projections attached to similar projections from adjacent eggs. These attachments firmly secured the eggs together. The granular yolk contained a single, large, highly refractile oil globule.

A mass obtained at Mt. Carmel, Salmonier on May 12, 1969 (dive no. 15) was eyed on May 17 and measurements of eggs were made on May 18. Dorsal myomeres as well as dorsal tail pigments were visible in the eyed eggs. Movements of the unhatched larva occurred. Ten eggs were measured and had the following mean dimensions (range in brackets); egg diameter 1.73 mm (1.62 - 1.80 mm), eye diameter 0.372 mm (0.340 - 0.408 mm), yolk diameter 1.245 mm (1.020 - 1.408 mm), and oil glouble diameter 0.421 mm (0.306 - 0.544 mm).

Figure 12 shows a larva four hours after hatching on July 2, 1969. The median finfold showed no sign of fin rays. It extended from a point dorsal to the attachment of the pectoral fins around to the anus. Two slight indentations marked the posterior ends of the dorsal and anal fins. Pectoral fins were well developed at hatching, the fin rays being visible. Pectorals, along with the median fins, were used in swimming. The yolk sac was resorbed except for several small bright orange particles visible in the body cavity. The mouth was open and appeared to be functional. Five melanophores were located on the head dorsal to the eyes. One was centrally located with the other four evenly spaced about it, one anterior, one posterior and two laterally. Four melanophores occurred immediately anterior to the median finfold. Within the body cavity a row of four large melanophores were distributed dorsally along the body wall. Three smaller ones were crowded near the anus. Along the base of the dorsal fin was a row of 20 very small pigment spots. Thirty-three such spots were spaced along the length of the base of the anal fin. An average of 43 myomeres were counted (range 42 - 46, n = 6); thirty-three of these (range 32 - 35, n = 6) posterior to the end of the body cavity.

Mean total length of 25 larvae (preserved in formalin) from the same egg mass was 6.58 mm (range 6.00 - 7.21 mm). This is smaller than that reported for

Figure 12. Ulvaria subbifurcata larva, age four hours. (hatched July 2, 1969).


1.0 mm

Pholis gunnellus (family Pholidae) by Gudger (1927) who stated that larva were about 9 mm at hatching. It is comparable to the hatched larvae of Anoplarchus purpurescens, reported by Peppar (1965) to range from 7.4 to 7.6 mm total length. Recently hatched Acanthoclinus quadridactytus (family Blenniidae) were 4.75 mm (Jillet, 1968).

The results of the light test showed that larvae are positively phototropic. Regardless of position of the lamp, all larvae immediately swam towards the light on the first two occasions. After a brief period of darkness they became randomly distributed throughout the aquarium. Because of the small number remaining alive when the test was repeated on five day old larvae, results were less dramatic, but two larvae did react positively to the light. Larvae of Anoplarchus purpurescens are positively phototropic at birth, however by the fifth day they were negatively phototropic (Peppar, 1965).

Pelagic larvae (mean length 12.0 mm) of U. subbifurcata were observed in the water column on August 30, 1969 (dive no. 41) and August 1, 1970 (dive no. 75). Settlement took place about this time as young-of-the-year (mean length 18.4 mm) were found on the bottom for the first time that year during the latter dive.

Lebour (1927) reported that the larvae of *Blennius gattorugine* and *Blennius pholis* remain in the plankton throughout the summer during which time they attain lengths up to 20 mm and 18 mm respectively.

Parental Care of Eggs

Out of 21 field sightings of egg masses, guardians were found in all but three cases. Those guardians which were subsequently examined internally were males.

It was not uncommon to find males guarding more than one egg mass. Out of 18 observations of guardians, 13 were tending a single egg mass, four were tending two masses and one dead fish, presumed to be the guardian, was found with four egg masses.

On May 23, 1970 (dive no. 70) a radiated shanny was collected along with the two egg masses it was guarding. It was placed with the egg masses in an aquarium at the Marine Sciences Research Laboratory. When it did not resume tending the masses after several days it was removed and placed in an aquarium with two gravid females. A spawning subsequently occurred and the male tended the egg mass.

Besides actively defending the site (page no. 55) guardians spent considerable time vigourously fanning the egg mass with their tail; occasionally nudging the mass with their head. Both these actions probably serve to aereate the eggs

Breder (1966) listed 17 species of the suborder Blennioidae in which parental care of the eggs is known.

In blennioid fishes, reproductive success is enhanced by parental care of a relatively small number of eggs. Thus by enhancing the individuals chances of survival species survival is aided.

In the radiated shanny parental care takes the form of the male parent guarding one or more egg masses and tending them by fanning the eggs.

AGE AND GROWTH

INTRODUCTION

The scale method of age determination requires validation for the radiated shanny as it has not been shown that the marks which occur on the scales can be interpreted as annuli. The length frequency (Petersen) method of age determination, although useful in discerning only the younger age classes, is commonly used to validate other methods of age determination.

The value of fitting growth curves by mathematical expressions is that they assist in interpolation or extrapolation; the expressions are useful in some production computations; and they may shed light on the physiology of growth (Ricker, 1958).

The purpose of this study was to validate the method of ageing by scales for *U. subbifurcata* and calculate a theoretical growth curve. Also a length-weight curve, condition factor values and a total length to standard length conversion formula could be derived from the data collected.

METHODS AND MATERIALS

Scale Sampling

Three collections (n = 120) taken on May 20, May 27 and June 5, 1969 from St. Phillips were caught with a slurp gun and dip net (dive no. 19, 20 and 23). Specimens were fixed in formalin and preserved in 40% isopropyl alchohol. Scale samples, taken from an area ventral to the lateral line and just posterior to the pectoral fin (Lagler, 1956), were stored in labelled coin envelopes. Scales were mounted in water between glass slides and read on a Bausch and Lomb microprojector.

Length, weight and sex was determined as described for the monthly collections (page no. 9).

Length-Weight Relationship and Condition

Data from the St. Phillips collection were used to derive the logarithmic form of the length-weight equation:

$$\log W = \log a + n \log L$$

where
W = weight (g)
L = total length (cm)
a = constant
n = constant

The constantswere derived by solving the equations:

$$\log a = \frac{\Sigma \log W \cdot \Sigma (\log L)^2 - \Sigma \log L \cdot (\Sigma \log L \cdot \log W)}{N \cdot \Sigma (\log L)^2 - (\Sigma \log L)^2}$$

$$n = \frac{\Sigma \log W - (N \cdot \log a)}{\Sigma \log L}$$

where N = number of specimens

The condition factor, K, was calculated according to the formula:

$$K = 100 \frac{W}{L^3} \qquad \text{(Hile, 1936)}$$

Conversion between Standard and Total Length

If body proportions do not change with growth a single factor can be calculated for conversion between standard and total length. However, if this proportion shows a consistent change, a formula must be derived to express the relationship. Beckman (1945) outlined such a technique. Total length data from the St. Phillips collection were grouped into 5 mm size classes and a conversion factor for each size class was determined by dividing mean standard length into mean total length. The results were plotted, a least squares line drawn and the correlation coefficient, r, was determined.

RESULTS AND DISCUSSION

Age Determination

The radiated shanny has extremely small, embedded cycloid scales which cover the entire body except for the head and fins. The focus is relatively small and is located in the posterior one-third of the scale. More or less concentric circuli interrupted by two to eight radii occur on the outer surface. The most common irregularity found is caused by regeneration. These latinucleate scales have an expanded central area lacking circuli. Such scales were quite common in larger fish.

There is no report in the literature as to when scales first appear. By checking through collections of young-of-the-year fish it was found that scales were not present when settlement occurred in August, however specimens collected in October had scale platelets which showed up to five circuli.

Annulus formation could be discerned by two principal characteristics. First, "summer" growth produced well spaced, regular circuli while "winter" growth produced thin, crowded circuli. Secondly, "winter" circuli were often incomplete and crossing over was a common distinguishing feature.

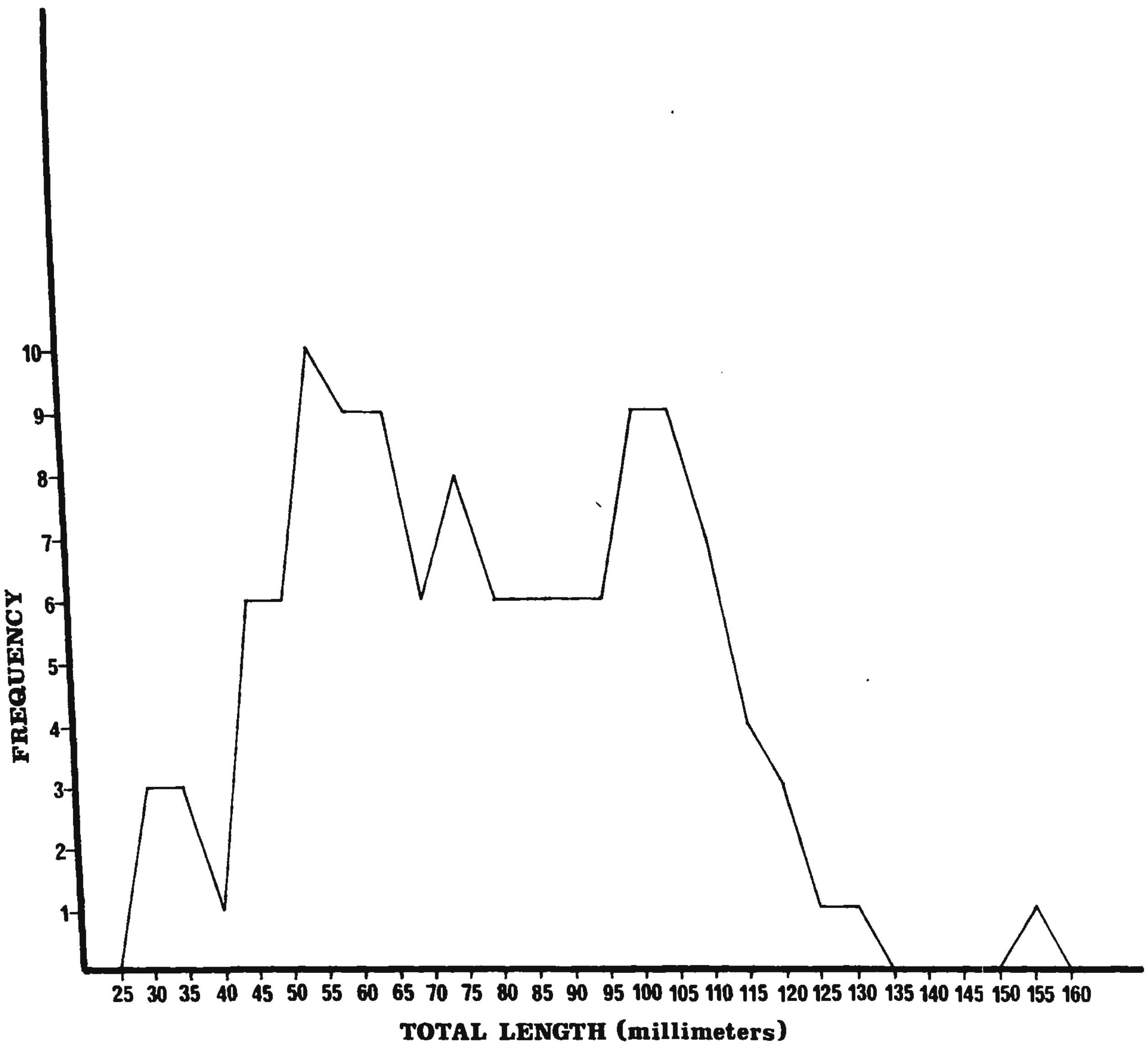
In some species, older, slow growing fish form annuli later than younger, faster growing fish. For example McFadden (1959) found that by the middle of April in a Wisconsin stream 74% of age one speckled trout had formed the annulus compared with 63% of the two year olds and only 30% of the three year olds. Because of the time of year in which the St. Phillips collection was taken, it is probable that some of the older fish had not completed annulus formation. This provided a potential source of error in ageing along with the crowding together of circuli which occurred with older fish.

Spawning checks could not be discerned for any fish in the sample. This may have been because spawning occurred at approximately the same time as true annulus formation.

Age was determined using criteria mentioned for annulus recognition. No prior reference was made to the size of the fish to avoid bias. The scales were read twice, at different times, and any specimens showing disparites were read a third or fourth time.

Figure 13 shows the length frequency distribution for the St. Phillips collection. It was assumed that the three peaks which occur on the left of the curve represent the first, second and third year classes. The peak at the

Figure 13. Length frequency distribution of 120 Ulvaria subbifurcata collected at St. Phillips, May 20 - June 5, 1969.


FREQUENCY
10
9
8
7
6
5
4
3
2
1
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160
TOTAL LENGTH (millimeters)

10.5 cm size class is too far separated from the first three to represent fish in their fourth year and probably comprises several year classes.

Mean total lengths of the first three year classes as determined from scales were 39.6 mm, 55.5 mm and 72.3 mm. Modal analysis of the first three peaks in the length frequency curve yielded values of 33.5 mm, 56.5 mm and 75.0 mm. Mean total length of young-of-the-year taken in the monthly collections of May 3 and May 29 was 34.8 mm. The very close values confirm the validity of ageing the radiated shanny by reading scales.

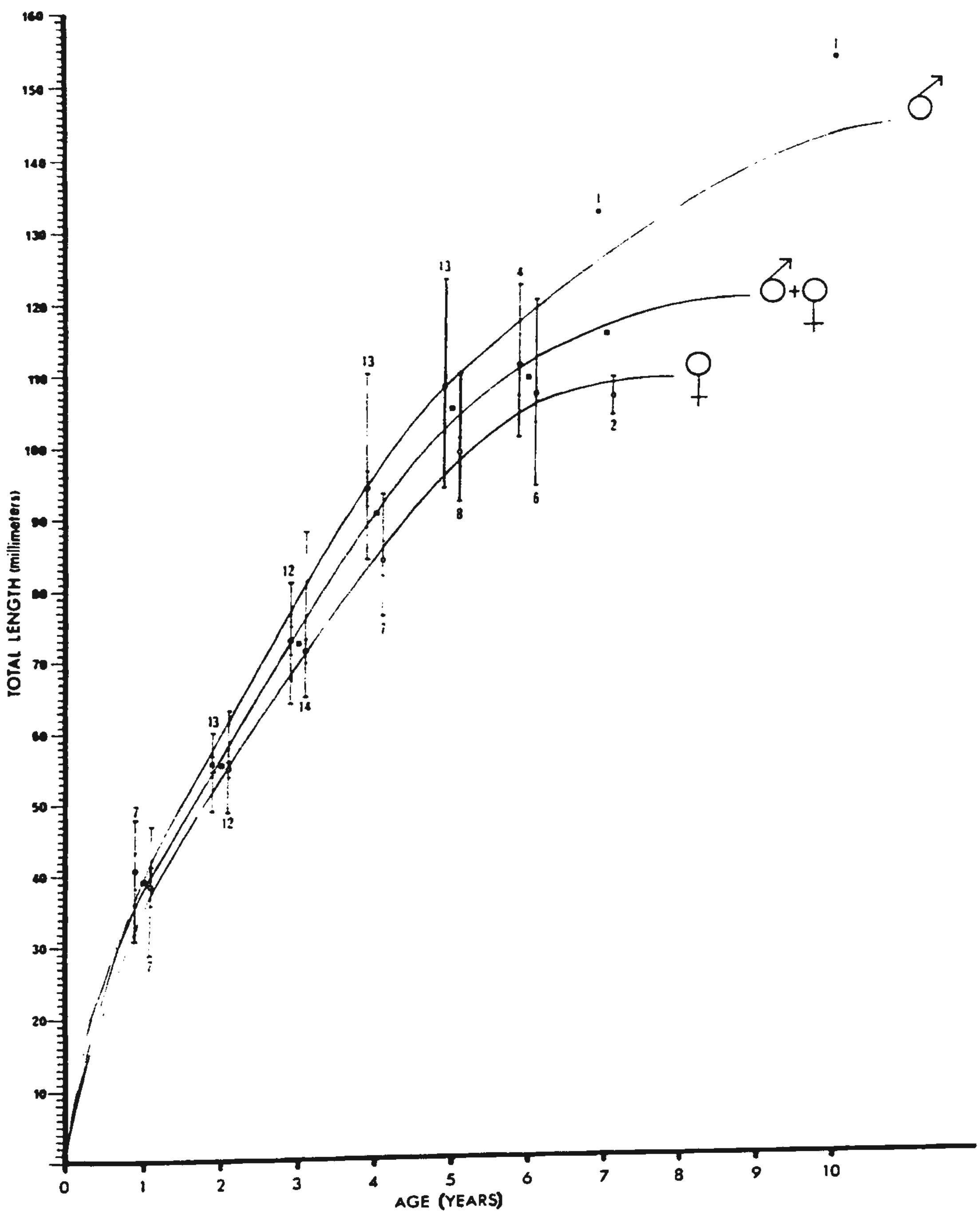
Table 14 shows the age length composition of the radiated shanny for the St. Phillips collection. The first three year classes are fairly distinct, however subsequent year classes show much overlap. The single specimen age ten was 15.3 cm total length. This is not an unusual size for radiated shannies (specimens up to 17 cm total length have been collected at the other localities) but is much larger than other specimens found at this site. The overall mean age of the collection was 3.48; males 3.55, females 3.41. The male to female ratio was 1 : 1.14.

Figure 14 presents the mean total length for each age with sexes presented separately and combined. Growth curves were fitted by sight.

Table 14. Age length composition of the radiated shanny from the St. Phillips Collection for males (M) and females (F).

Length classes (mm)	Age 1		2		3		4		5		6		7		8		9		10		Total		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Both sexes
27.5-32.4	1	2																			1	2	3
32.5-37.4	2	1																			2	1	3
37.5-42.4	0	1																			0	1	1
42.5-47.4	3	3																			3	3	6
47.5-52.4	1		3	2																	4	2	6
52.5-57.4			3	7																	3	7	10
57.5-62.4			7	2																	7	2	9
62.5-67.4				1	3	5															3	6	9
67.5-72.4					3	3															3	3	6
72.5-77.4					2	4		2													2	6	8
77.5-82.4					4	1		1													4	2	6
82.5-87.4						0	4	2													4	2	6
87.5-92.4						1	3	1		1											3	3	6
92.5-97.4							1	1	1	2		1									2	4	6
97.5-102.4							2		2	3	1	1									5	4	9
102.5-107.4							2		4	1		1		1							6	3	9
107.5-112.4							1		1	1	2	1		1							4	3	7
112.5-117.4									3			1									3	1	4
117.5-122.4									1		1	1									2	1	3
122.5-127.4									1												1	0	1
127.5-132.4													1								1	0	1
132.5-137.4																					0	0	0
137.5-142.4																					0	0	0
142.5-147.4																					0	0	0
147.5-152.4																					0	0	0
152.5-157.4																			1		1	0	1
Total	7	7	13	12	12	14	13	7	13	8	4	6	1	2					1		64	56	120

Figure 14. Growth curve (length) of U. subbifurcata for the St. Phillips collection. Numbers indicate sample size: vertical lines, range; horizontal bars, standard error of the mean. Mean values for males are shown by black circles; females, open circles; both sexes, squares.



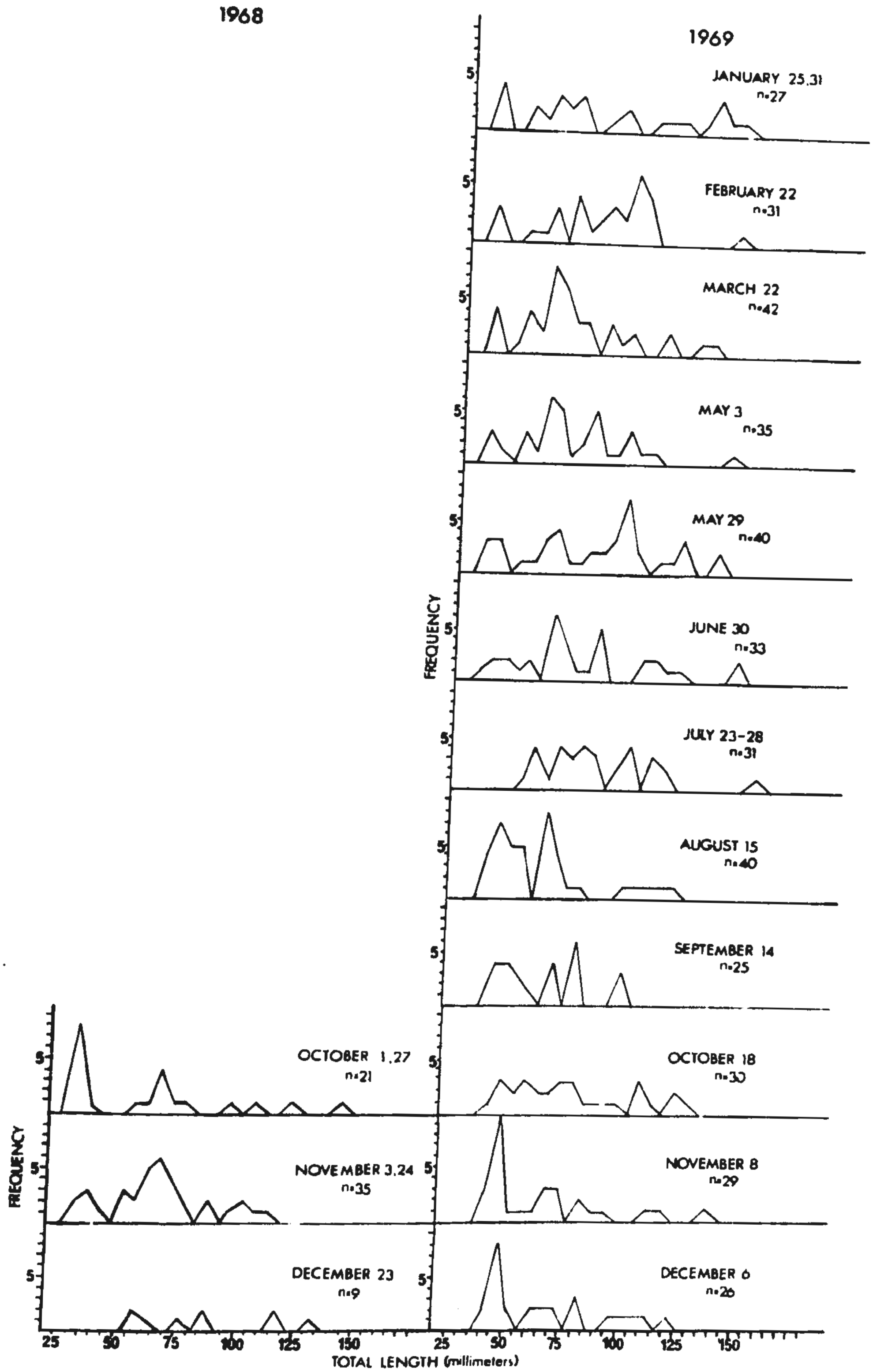
TOTAL LENGTH (millimeters)
AGE (YEARS)
0
1
2
3
4
5
6
7
8
9
10
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
♂
♂+♀
♀

Sexes were compared at each age (Students's test) and significant differences were found in fish at age four ($t = 2.759$, 18 d.f., $P < 0.01$) and age five ($t = 2.509$, 19 d.f., $P < 0.05$). These differences indicate that, in adult fish of the same age, males tend to be larger. No difference was found in the age six fish, however this may be attributed to the small number of specimens.

Some indication of year class growth for the young-of-the-year is shown in the seasonal collections taken from Collection Cove (Fig. 15). Young-of-the-year fish occurred in October 1968 as a distinct peak. Some growth is indicated by the shift of the peak in November. From January through March the peak remained distinct and showed little shift, indicating cessation of growth. From April through June the peak shifted to the right indicating a resumption of growth. The July collection contained only the largest one year old fish. Further growth is indicated from August until October. In November and December growth again ceased. In 1969 no young-of-the-year appeared in the collections. This may have been the result of poor year class survival, late settlement or selectivity in the collections.

By combining the information from these monthly collections with that from specimens taken at Dyers Gulch,

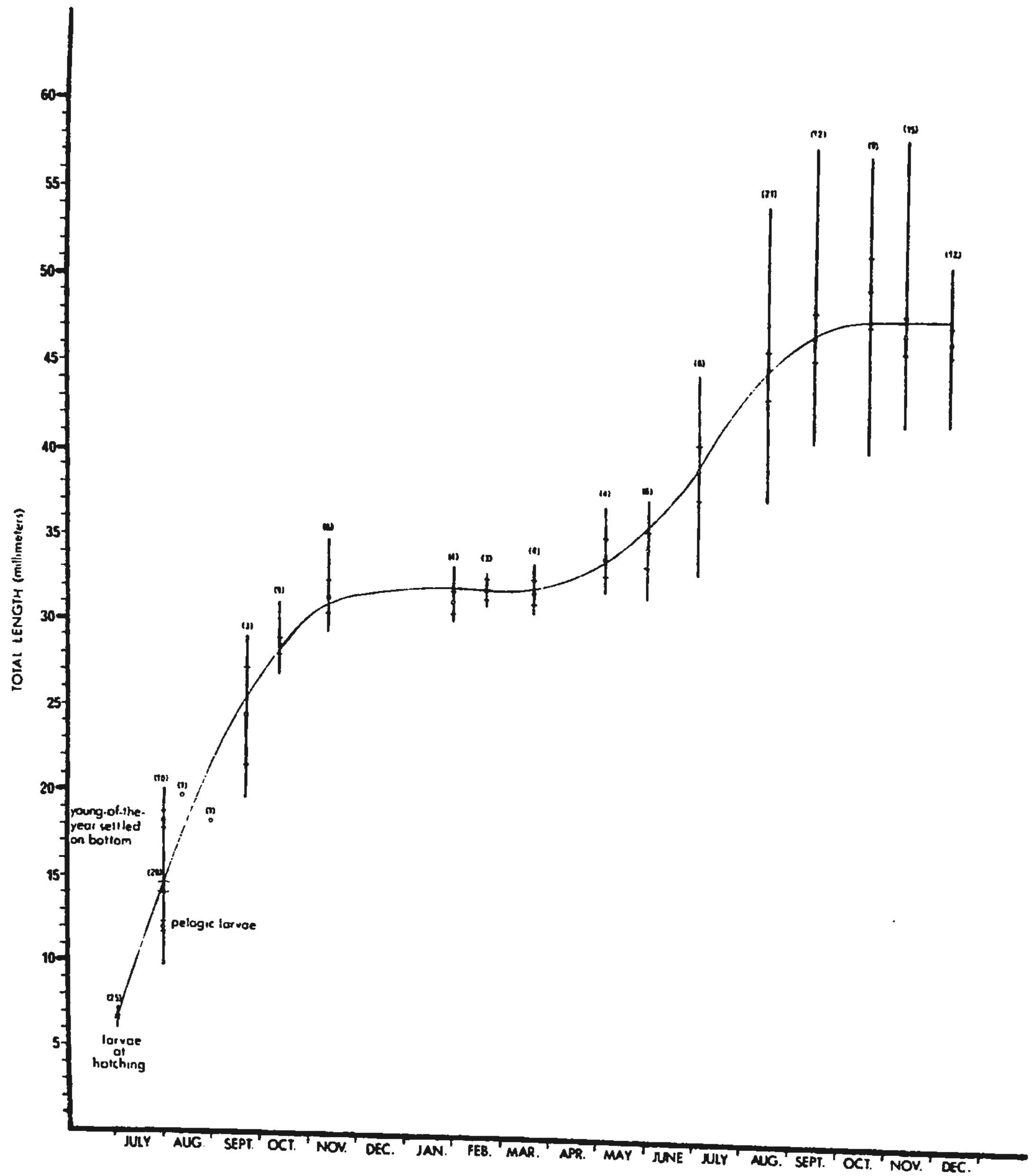
Figure 15. Length frequency of monthly collections taken from Collection Cove, Bellevue.


1968
1969
JANUARY 25,31
n=27
FEBRUARY 22
n=31
MARCH 22
n=42
MAY 3
n=35
MAY 29
n=40
JUNE 30
n=33
JULY 23-28
n=31
AUGUST 15
n=40
SEPTEMBER 14
n=25
OCTOBER 1,27
n=21
OCTOBER 18
n=30
NOVEMBER 3,24
n=35
NOVEMBER 8
n=29
DECEMBER 23
n=9
DECEMBER 6
n=26
FREQUENCY
5
25
50
75
100
125
150
TOTAL LENGTH (millimeters)

Logy Bay (dive no. 41, 42), and larvae hatched at the Marine Sciences Research Laboratory, a curve was drawn showing the periodic pattern of growth in length (Fig. 16).

Summer growth started in May and continued until October. In the first summer young-of-the-year grew approximately 25 mm. Growth in the second growing season was approximately 18 mm.

Figure 16. Growth curve of *U. subbifurcata* showing periodic pattern of growth in length for the first two growing seasons. Numbers indicate sample size; circles, the mean; vertical lines, the range; horizontal bars, the standard error of the mean.


TOTAL LENGTH (millimeters)
60
55
50
45
40
35
30
25
20
15
10
5
young-of-the-year settled on bottom
pelagic larvae
larvae at hatching
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

Mathematical Description of Growth - Walford Line

An equation describing the decelerating section of the growth curve has been developed by von Bertalanffy (Ricker, 1958):

$$L_t = L_\infty\left(1 - e^{-k(t - t_0)}\right) \qquad (1)$$

where L = length

L_∞ = value which L assumes as age increases infinitely.

k = constant determining the rate of change in length increment.

t = age

t_0 = theoretical age at which the fish would have been zero length if it had always grown in the manner described by the equation.

Manipulating this equation by replacing t with t + 1 and subtracting the resulting equation from (1) yields:

$$L_{t+1} = L(1 - K) + KL_t \qquad (2)$$

where $K = e^{-k}$

This expression, developed by Ford (1933) and Walford (1946), describes growth in which each years increment decreases over that of the previous year by the fraction (1 - K) starting from a hypothetical initial size $L_\infty(1 - K)$ at true age zero. The graphical expression of this equation is commonly known as the Walford line.

Plotting size at age t against size at age t + 1 generally yields a straight line with a slope, k, of less than one. The point where the line intersects the 45° diagonal determines the asymptotic length, L_∞, and the Y axis intercept is $L_\infty(1 - K)$.

Because of the erratic fit of some points, especially the two terminal values which are used only once and are most subject to sampling error, it is often better to go to another equation to derive the L_∞ which best fits the data (Ricker, 1958).

An estimate of L_∞ is obtained from a freehand Walford line and is used as a trial value in the expression:

$$\log_e(L_\infty - L_t) = \log_e L_\infty + kt_0 - kt \qquad (3)$$

Plotting $\log_e(L_\infty - L_t)$ against t should yield a straight line and this straightness is sensitive to changes in L_∞. By testing a series of values of L_∞ the one yielding the best (straightest) line can be determined.

Data from the St. Phillips collection are shown in Table 15. Freehand fitting of this information to a Walford graph gave an estimated L_∞ of 12.5 cm. This was used as a trial L_∞ for equation (3) along with a series of values ranging from 12.0 to 14.0 cm. An L_∞ of 13.0 cm

Table 15. Average weight (g) and average total length (cm) of *Ulvaria subbifurcata* collected at St. Phillips, and data for fitting a Walford line to length.

				Trial L_∞ 12.5 cm		Final L_∞ 13.0 cm		
Age	n	Wt	L(t)	L-Lt	Log_e(l-Lt)	L-Lt	Log_e(l-Lt)	Adjusted age
1	14	.40	3.96	8.54	4.448	9.04	4.505	0.90
2	25	1.20	5.55	6.95	4.242	7.45	4.312	1.90
3	26	2.83	7.23	5.27	3.965	5.77	4.056	2.90
4	20	5.81	9.05	3.45	3.542	3.95	3.677	3.90
5	21	8.80	10.49	2.01	3.001	2.51	3.224	4.90
6	10	10.33	10.86	1.64	2.798	2.14	3.064	5.90
7	3	12.11	11.50	1.00	2.303	1.50	2.709	6.90

yielded the best fit (Fig. 17, upper graph). From this line the following were derived:

$$\text{slope} = 0.310 = k$$

$$\text{Y axis intercept} = 4.90 = \log_e L_\infty + kt_0$$

$$\log_e L_\infty = \log_e 130 = 4.868$$

When $t = t_0$ equation (3) becomes -

$$t_0 = \frac{(\log_e L_\infty + kt_0) - \log_e L_\infty}{k}$$

$$= \frac{4.90 - 4.87}{.310}$$

$$= 0.0968$$

which was rounded off to

$$t_0 = 0.10$$

K was derived from k = 0.31,

$$K = e^{-k}$$

$$= e^{-.031}$$

$$= 0.733$$

These values were fitted to equations (1) and (2) to yield -

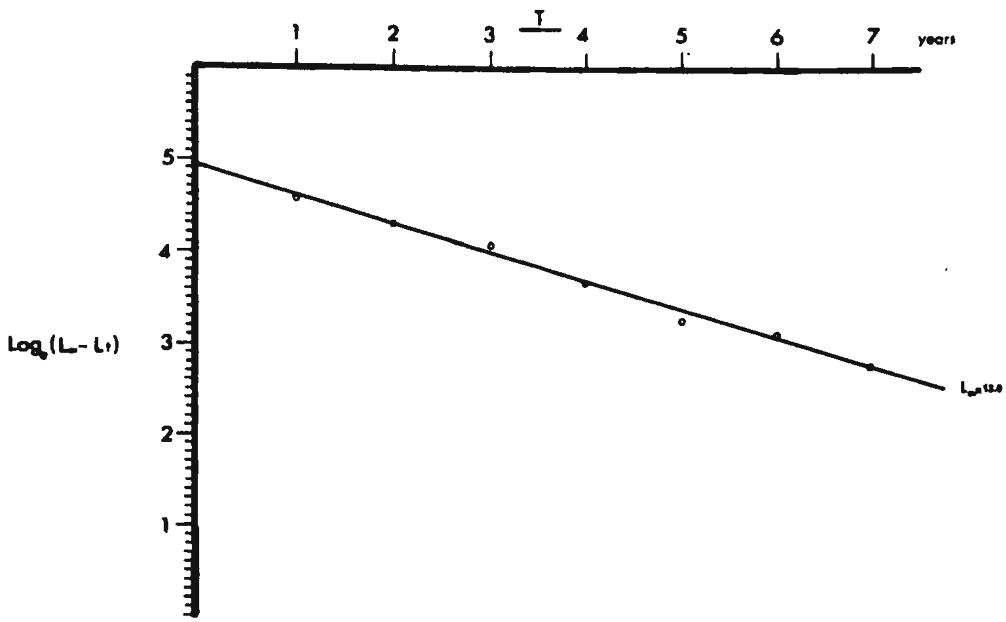
$$L_t = 130(1 - e^{-0.31(t - 0.10)})$$

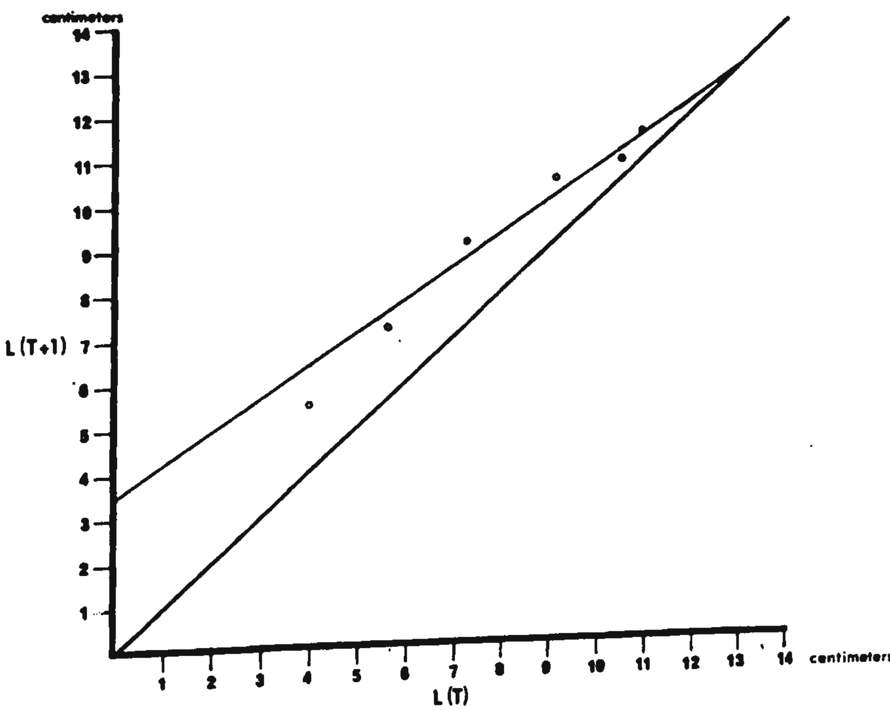
$$L_{t+1} = 34.7 + 0.733L_t$$

Figure 17. Data from specimens of the St. Phillips collection.

Upper graph: $\log_e(L - L_t)$ plotted against age for trial value of $L_\infty = 13.0$ cm

Lower graph: A Walford graph for length of radiated shannies.


T
1 2 3 4 5 6 7 years
5 4 3 2 1
$Log_e(L_\infty - L_t)$


centimeters
14 13 12 11 10 9 8 7 6 5 4 3 2 1
L (T+1)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 centimeters
L (T)

An accurate line was drawn (Fig. 17, lower graph) intersecting the 45° line at 13.0 cm (= L_∞), the Y axis at 3.47 cm (= $L_\infty(1 - K)$) and having a slope of 0.733 (= K).

A value for W_∞ of 17.6g was derived from the length-weight curve (Fig. 18).

One fish (15.3 cm total length, weight 29.8g) in the St. Phillips collection exceeded these values, however no other fish in the collection exceeded 13.2 cm total length.

Ricker (1958) suggested that consistently low readings of scales from older fish may cause a depression of the right end of the line and hence an underestimate of L_∞. Although ageing of older radiated shannies is relatively difficult, the error would have to be gross to affect the results. Cooper (1961) questioned the logic of calculating the asymptotic lengths by extrapolation from segments of a growth curve. Many species change their ecological niche as they grow bigger, and thereby may well revise the ultimate size that may be reached. Evidence in this study indicates that such a change occurs with _U. subbifurcata_ in the early years of life and there may be another change in later years. Ricker (1958) also pointed out that the left end of the Walford line may be depressed due to selection for large size among the younger fish. With the collection technique used, involving active capture of specimens, this is not considered a probable source of error.

Length-Weight Relationship and Condition

Figure 18 shows the length-weight relationship calculated from grouped data. The points indicate empirical values while the curve was fitted to the equation:

$$\log W = 3.275 \log L - 1.392$$

which can be expressed as -

$$W = (0.0405) L^{3.275}$$

Sexes were considered separately and the following equations derived:

males - $\log W = 3.222 \log L - 1.345$

$$W = (0.0452) L^{3.222}$$

females - $\log W = 3.384 \log L - 1.476$

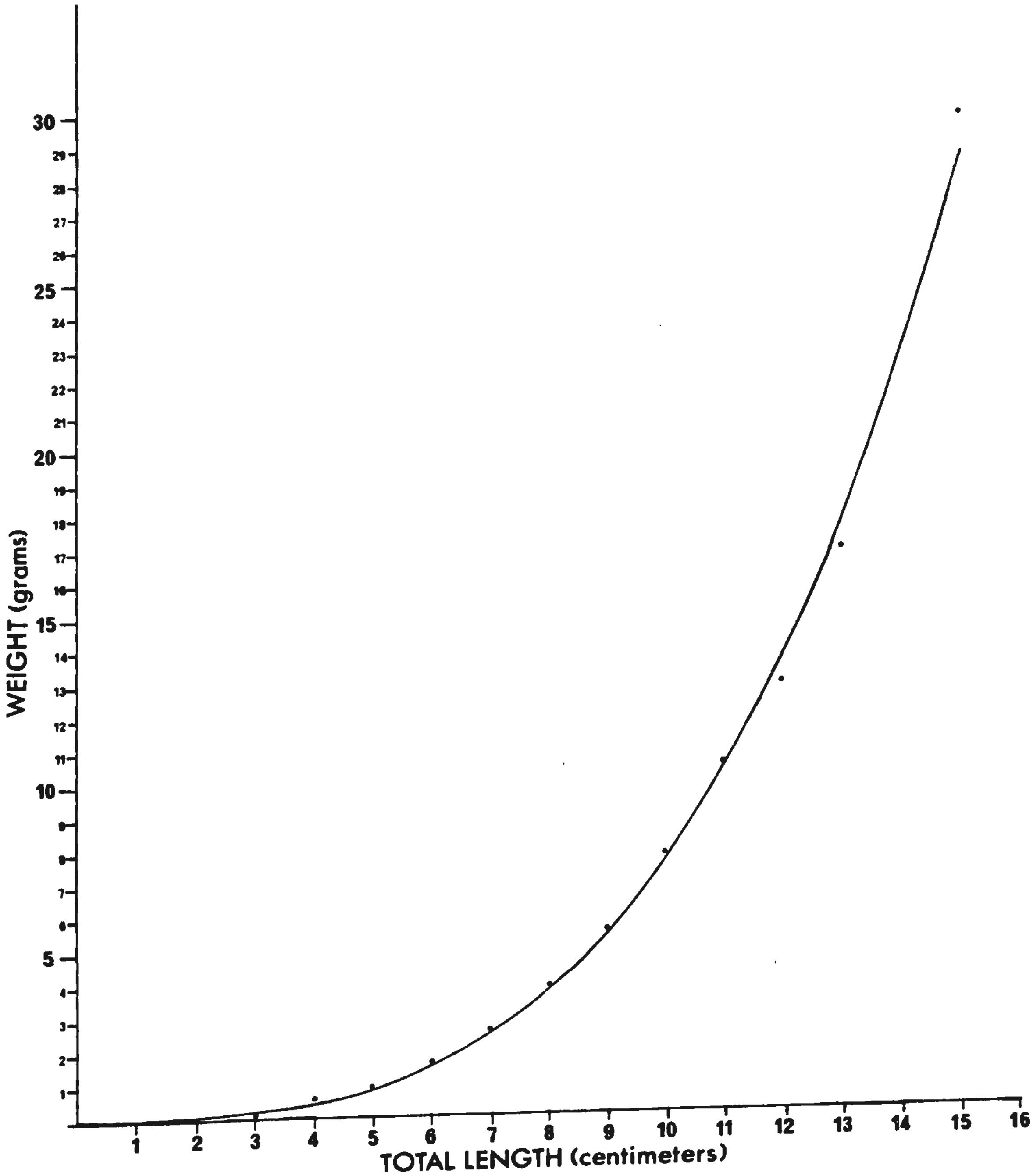
$$W = (0.0334) L^{3.384}$$

Males weighed slightly less than females of the same length.

The mean condition factor (K) for each of the monthly collections did not show a seasonal trend (Fig.19). Mean values showed little variation compared with the overall range. K values for the sexes were compared (Student's t test) for each of the monthly collections. The differences were not significant. The relationship between condition factor and fish length is shown for the St. Phillips

Figure 18. Length weight relationship of U. subbifurcata as calculated from grouped data from the St. Phillips collection. Points represent empirical data. The curve is plotted from the equation

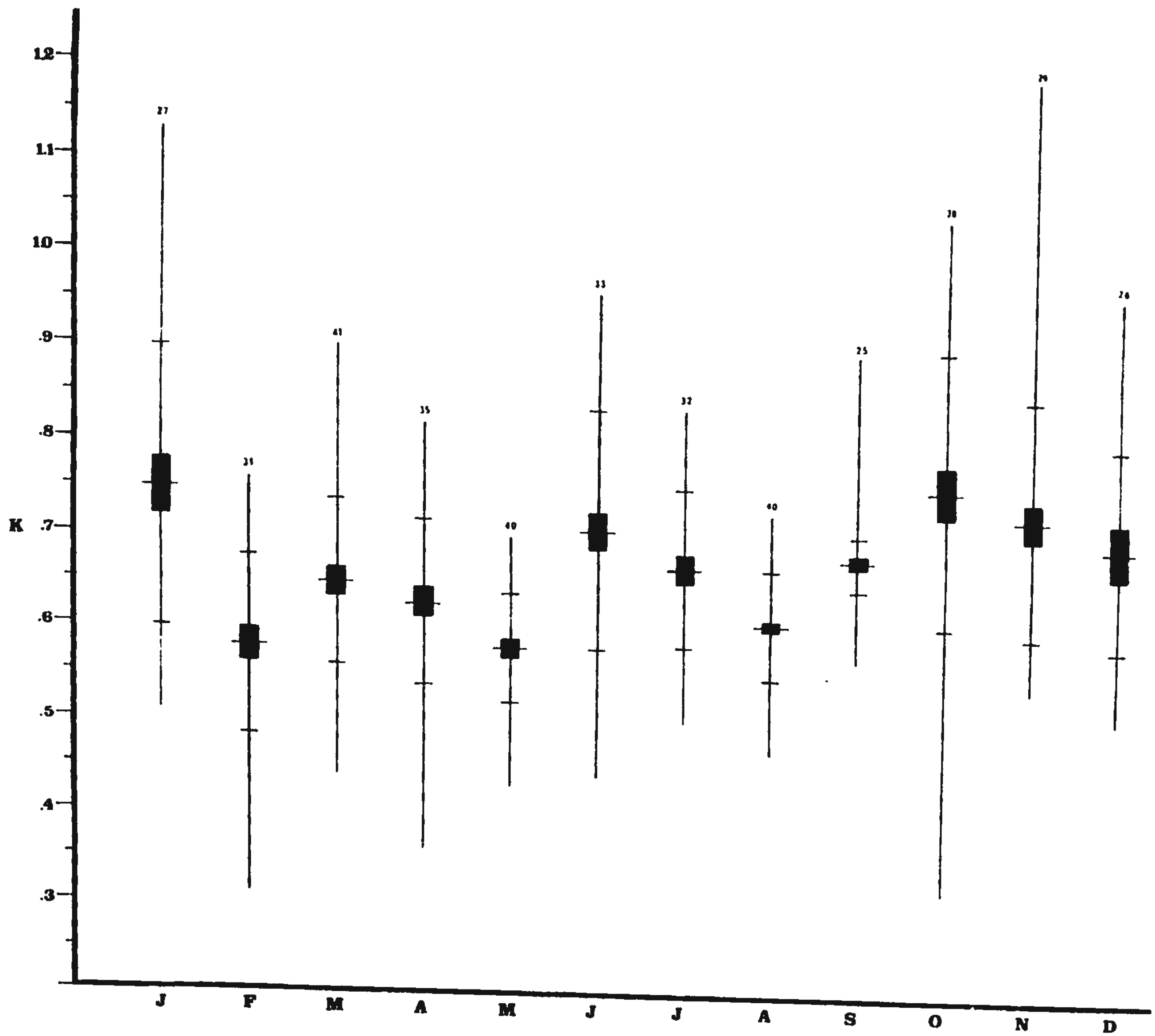
$$W = (0.0405)L^{3.275}$$



WEIGHT (grams)
TOTAL LENGTH (centimeters)

Figure 19. Condition factor (K) for monthly samples of U. subbifurcata taken from Collection Cove, Bellevue, 1969.

Numbers indicate sample size; vertical lines, range; short horizontal bars, standard deviation; solid rectangles, standard error of the mean; wide horizontal bars, the mean.

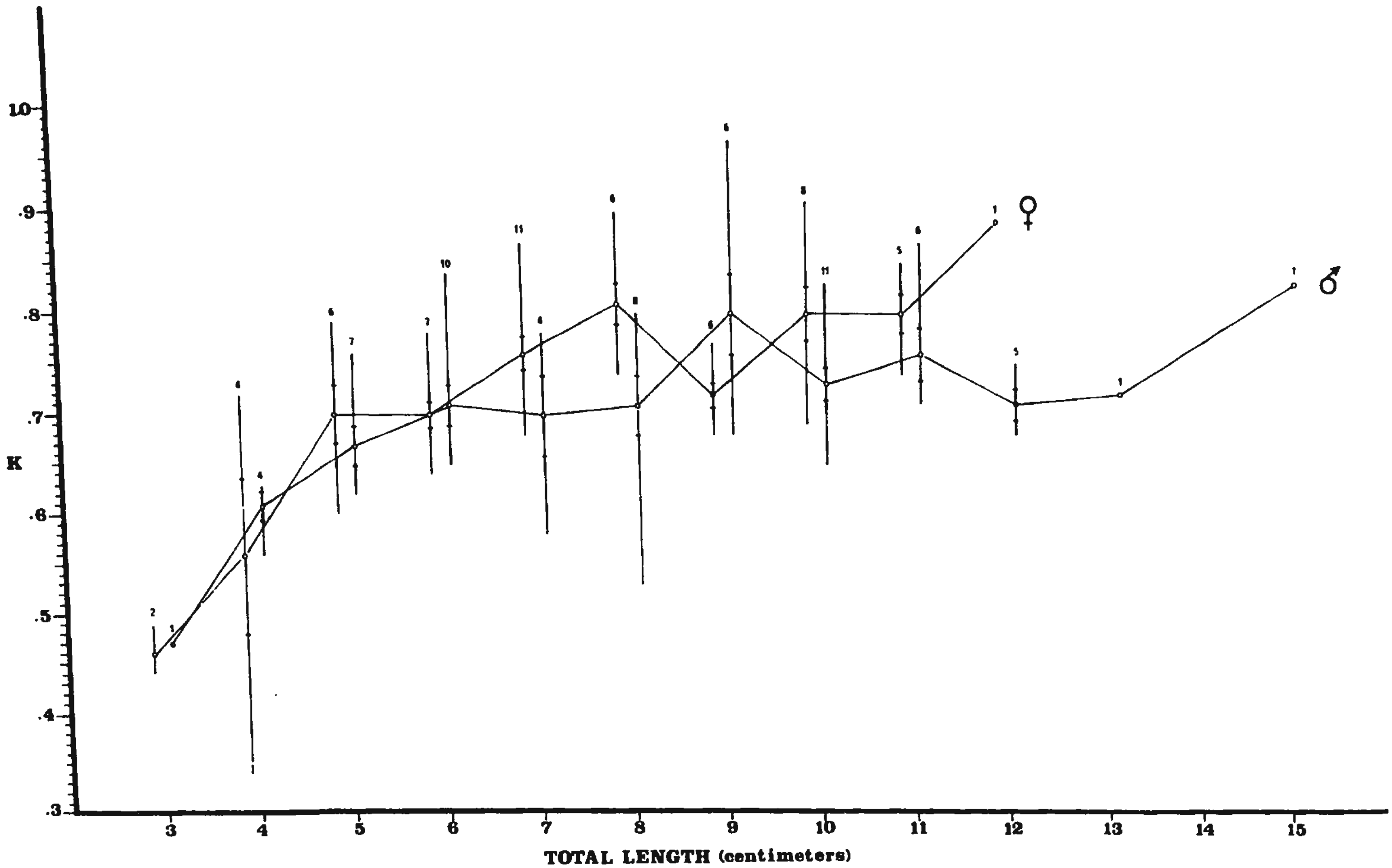


1.2
1.1
10.0
.9
.8
K
.7
.6
.5
.4
.3
27
31
41
35
40
33
32
40
25
30
29
26
J
F
M
A
M
J
J
A
S
O
N
D

collection in Figure 20. A sharp increase in K occurs before a levelling off at the 5 and 6 cm length classes for females and males respectively. Fish of this size are probably two years old (Fig. 14). A change in feeding habits and activity pattern have also been noted in fish at this length, both of which could be expected to cause a change in the condition factor.

Condition factor values for the sexes were compared (Student's t test) for different length classes. No differences were found in the 4, 5, 6, 7, 9 or 11 cm classes. The 8 cm class showed a higher K value for females ($t = -2.222$, d.f. = 12, $P < 0.05$) as did the 10 cm length class ($t = -2.275$, d.f. = 17, $P < 0.05$). Females in the larger size classes tended to have a higher condition factor than males as was indicated by the length-weight equations.

Figure 20. Relationship between condition factor (K) and fish length of U. subbifurcata from the St. Phillips collection. Values for females are displaced slightly to the left; males, slightly to the right. Numbers indicate sample size; vertical lines, the range; horizontal bars, standard error; open circles, the mean.


1.0
.9
.8
.7
K
.6
.5
.4
.3
3
4
5
6
7
8
9
10
11
12
13
14
15
TOTAL LENGTH (centimeters)
♀
♂

Conversion between Standard Length and Total Length

The conversion factors for standard length to total length showed a tendency to decline (from 1.192 to 1.125) as fish length increased. This relationship was significant ($r = -0.748$, d.f. = 21, $P < 0.01$).

The formula for the line fitted to the data (Fig. 21) is:

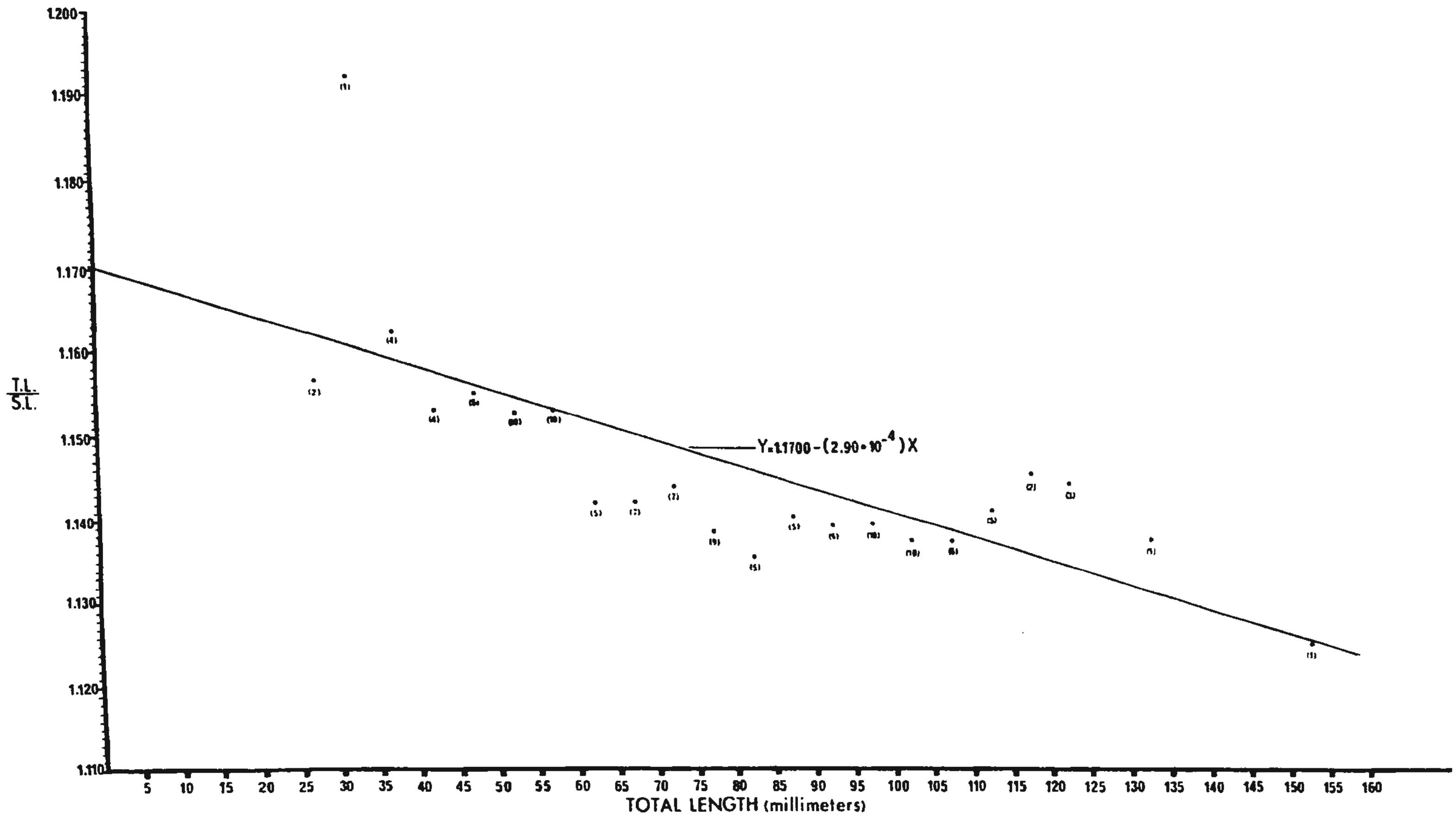
$$Y = 1.170(2.90 \times 10^{-4})X$$

where $$Y = \frac{\text{total length}}{\text{standard length}}$$

X = total length

The relationship indicates that as the radiated shanny increases in size its body proportions (in this case the ratio - length of caudal fin: standard length) exhibit a small but consistent change.

Figure 21. Relationship between fish length and the conversion factor for standard length to total length (T.L./S.L.) for specimens from the St. Phillips collection. Numbers in brackets indicate sample size.



T.L. / S.L.
1.200
1.190
1.180
1.170
1.160
1.150
1.140
1.130
1.120
1.110
Y=1.1700-(2.90·10^-4)X
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160
TOTAL LENGTH (millimeters)

GENERAL DISCUSSION AND SUMMARY

This study illustrates the advantages of snorkel and SCUBA diving in conducting research on subtidal fish populations. Using a slurp gun and dip net, collections of specimens could be made at all times of the year. These collections were relatively free of the gear selectivity inherent in other techniques. More important however was the ability to make direct observations of fish in their natural habitat. From these observations it was apparent that the radiated shanny, Ulvaria subbifurcata along with the rock gunnel, Pholis gunnellus were by far the most abundant demersal fish species found on rocky bottom at all dive sites. None of the other demersal fish species observed during the study (Liparis atlanticus, Stichaeus punctatus, Myoxocephalus aeneus, Myoxocephalus scorpius and Myoxocephalus octodecimspinosus) were as abundant as these two. Results of this study indicate some of the interrelations which may exist between these fish and U. subbifurcata.

Adult U. subbifurcata fed at night, mainly on nereid worms, scaleworms and amphipods. Juveniles were duirnal and their diet consisted mainly of copepods, ostracods and amphipods. P. gunnellus were observed to be active during daylight and inactive after dark. Its diet is similar to that of U. subbifurcata. Sawyer (1967) reported gammarids and isopods as the major food items. Qazim (1957) found polychaetes, amphipods, isopods and copepods among the food items. The difference in the diel pattern of activity of these two species probably reduces direct interaction between adults during feeding.

Sticheus punctatus, the arctic shanny, was never sighted in Collection Cove, however individuals (predominantly juveniles) were observed at Dyers Gulch, Mt. Carmel and Bread and Cheese Cove (Fig. 1). Farwell (1970) has shown that juvenile S. punctatus are diurnal. Stomachs of juveniles which he collected contained copepods, amphipods, ostrocods and polychaetes. Atlantic seasnails (Liparis atlanticus) which moved inshore to spawn in Collection Cove during the period December - May (dive no. 5, 13, 51, and 65) were reported by Detwyler (1963) to feed on gammarids and polychaetes. Detwyler observed that seasnails were free swimming at night. They were immobile and attached to the undersides of rocks when observed during daylight in Collection Cove. These fish species probably would compete with the radiated shanny for some food items when or where these food items were limited.

Tube feet of sea urchins, although not a major food item of radiated shannies formed a renewable source of food since the seas urchin itself was not killed and lost parts could be regenerated. A similar cropping behaviour has been described for young plaice (Pleuronectes platessa) which fed on siphons of Tellina sp. and polychaete palps (Steele et al., 1969).

Juvenile U. subbifurcata were vulnerable to predation because of their diurnal pattern of activity. A significant proportion of the diet of Myoxocephalus aeneus consisted of small shannies (3.0 - 5.9 cm total length) (Appendix 2). A substantial population of these predators was found in Collection Cove. Myoxocephalus scorpius and Tautogolabrus adspersus are both diurnal and have been observed pursuing S. punctatus in other locations. These two species are probably also predators on juvenile radiated shannies, but not on the adults which are nocturnal.

Radiated shannies (> 6 cm total length) displayed short term (3 days) fidelity to a small area (3 × 3 m) and long term (up to 259 days) fidelity to a large area (Collection Cove). Practically no movement of adults occurred during daylight but, after dark, fish wandered distances greater than 2 m.

If the small area occupied by U. subbifurcata during daylight is "solitary and exclusive" (Wynne-Edwards, 1962), i.e. a territory, as has been shown for juvenile

S. punctatus (Farwell, 1970) this behaviour would function as a spacing mechanism for the species. In Collection Cove the population density of adult radiated shannies on rock bottom was approximately $2/m^2$ (20 shannies could usually be collected in a 3 × 3 m grid).

Adults displaced 5, 10 and 20 m returned to an area which was small compared to the area available. This was true whether the fish were transplanted to an area providing no cover (sandy) or one apparently as attractive as the capture site (rocky bottom). These results indicate the presence in U. subbifurcata of a homing behaviour of the sort defined by Gerking (1959) as, "the choice a fish makes between returning to a place formerly occupied instead of going to other equally probable places."

These results do not, however, give evidence for the presence of a directed movement back to the original capture location. Gibson (1967) speculated that Blennius pholis and Acanthocottus bubalis, retained a memory of the home area and, once they reached it in the course of random wandering, recognized it and resumed occupancy. He concluded that directed movement was not involved in their homing behaviour.

In coral reef fishes homing ensures that a safe refuge from predators will be found (Bardach, 1958; Hobson, 1965). Williams (1957) stated that homing of tide pool fishes serves to ensure that fish will not be stranded at low tide. No tide pools occur at Collection Cove and, in that area homing probably serves the former function. Of all the sites where radiated shannies were collected, only once was one found at low tide in a tide pool. In other parts of its range radiated shannies do evidently inhabit tide pools (Detwyler, 1963). In these localities homing may also serve the latter function.

During the spawning season (May - June) the male radiated shannies while tending the egg mass (or masses) occupied a defended area. This behaviour is common in blennioid fishes, however, unlike most blennioid fishes, no secondary sex characters were noted in U. subbifurcata. The demersal egg masses were found at depths from 1 to 10 m. They consisted of 1215 - 8505 eggs which adhered to each other but not to any other material. The diameter of the eggs (1.55 mm) and the size and shape of the mass make it distinct from other egg masses found at the various diving locations. Egg masses of rock gunnels were found earlier than those of radiated shannies (November - January; dive no. 48, 52) and occurred at depths of 8 and 13 m. The eggs are larger, and the mass itself smaller than that of the radiated shanny (Sawyer, 1967). The eggs of S. punctatus have not been observed, however, larvae which have been collected along with those of U. subbifurcata (dive no. 64) were the same size, therefore it is likely that the breeding season of this species is close to that of the radiated shanny.

Eggs of U. subbifurcata hatched after 35 - 40 days during which time the temperature rose from 4 to 9 C. Hatching took place during June and July. Larvae were well developed and positively phototropic at birth. After one to two months of planktonic existence they settled on the bottom (mean total length 18 mm). The period of planktonic life would cause larvae to become widely dispersed and recruitment to a given locality would be relatively random with respect to hatching locality (within a certain geographic area). Population homogenity would therefore be unlikely and spawning success in a given area would not be related to year class recruitment.

Larvae of P. gunnellus are longer at birth than larvae of U. subbifurcata and were found in the water column earlier in the year (March 28, dive no. 64). Thus with young-of-the-year fish, assuming earlier settlement occurs as well, P. gunnellus could be expected to have the advantage of larger size and prior residency over U. subbifurcata in any bottom area where the two species might compete for space.

The fairly short spawning season of U. subbifurcata partially accounts for the distinct peaks which occurred in the length frequency distribution. Scale platelets appeared on young-of-the-year after the fish had settled on bottom and up to five summer growth circuli were laid down before the first winter, thus the first growing season was detectable on the scales. A comparison of the length frequency distribution with age determination by reading scales confirmed the validity of the latter.

Growth curves of *U. subbifurcata* indicated that, as for many blennioid fishes, adult males tend to be larger than females of the same age. The L_∞ calculated by the Walford line (130 mm) is an underestimate of the asymptotic length achieved by this species. A deficiency in sampling (no age eight or nine fish were collected) made the estimate of L_∞ subject to error (Cooper, 1961).

Only one radiated shanny was older than seven years. This specimen, 15.3 cm total length was ten years old. The largest shanny collected in this study was 17 cm total length (measured unpreserved). Leim and Scott (1966) reported a maximum of 6½ inches (16.5 cm) for this species.

The relatively small number of fish species which compete with the radiated shanny for food and space, combined with the diel activity pattern of adults which enables them to escape potential predators may partly account for the longevity of *U. subbifurcata.*

The life history information on the radiated shanny presented in this study will hopefully form the basis on which future, more detailed, investigations can be conducted.

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Appendix 1. Physical data on observat

Dive no.	Date day,month,year	Time	(1) Location	Maximum depth (m)	Tem
					water
1	01-10-68	1100-1300	C.C.	2	9
2	27-10-68	1300-1400	C.C.	2	9
3	24-11-68	1530-1600	C.C.	2	3.7
4	23-12-68	1515-1545	C.C.	2	1.4
5	25-01-69	1530-1630	C.C.	2	0.6
6	31-01-69	1230-1400	C.C.	2	1.4
7	22-02-69	1545-1710	C.C.	2	2.0
8	22-03-69	1200-1330	C.C.	2	1.0
9	17-04-69	1200-1300	M.H.	5	3.0
10	26-04-69	1415-1445	D.G.	8	1
11	02-05-69	1500-1600	Mt.C.	8	4
12	03-05-69	1130-1200	C.C.	2	4
13	03-05-69	1330-1400	M.H.	5	3.8
14	04-05-69	1600-1630	P.C.S.	10	3
15	12-05-69	1300-1500	Mt.C.	10	3.5
16	13-05-69	1515-1600	B.C.C.	7	2.0
17	15-05-69	1300-1400	M.H.	5	7.0
18	15-05-69	1415-1500	C.C.	2	7.0
19	20-05-69	1500-1715	St.P.	3	5.0
20	25-05-69	1600-1700	M.H.	2	5
21	27-05-69	1130-1330	St.P.	3	4.5
22	29-05-69	1145-1315	C.C.	2	7.5
23	05-06-69	1200-1300	St.P.	3	5.0
24	14-06-69	1300-1330	C.C.	3	8
25	14-06-69	1500-1630	M.H.	4	8
26	20-06-69	1330-1500	C.C.	2	
27	21-06-69	1000-1030	C.C.	2	
28	21-06-69	1430-1630	C.C.	7	

a on observation and collection dives.

imum epth (m)	Temp. °C water	Temp. °C air	Condition water	Condition air	(2) Tide	Water visibility (m)	(3) Divers
2	9			cloudy	h-r		BL
2	9	4.5		cloudy	l		BL
2	3.7	2.5		sunny	l		BL
2	1.4	-1.5			l-f		BL
2	0.6	-0.3					BL
2	1.4	3.5		foggy	l		BL
2	2.0	1.0		clear	l-f		BL
2	1.0	-0.5	calm		h-f		BL,MF
5	3.0	6.5		sunny		7	BL,JMG
3	1	5	clear			3	BL,MF
3	4	14		clear		3	BL,MF
[illegible]	4	4			h-f	6	BL,MF
[illegible]	3.8	4			h-f	6	BL,MF
	3	9	clear	sunny		6	BL,MF
	3.5	10		cloudy		3	BL,MF
	2.0	17	calm	sunny	l	10	BL,MF
	7.0	15	calm	cloudy	l	3	BL,NB
	7.0	15	calm	cloudy	l-f	5	BL,NB
	5.0	11	calm	cloudy		10	BL,JO,NB
	5	14	choppy	cloudy		3	BL
	4.5	15	calm	cloudy		13	BL,JO,NB
	7.5				l-f	6	BL,JO,NB
	5.0	21	calm			5	BL,JO,NB
	8		calm	sunny		8	BL,JH
	8		calm	sunny		8	BL,JH
			calm	sunny			BL
							BL,JMG
			calm	sunny	l-r	10	BL,JMG

Appendix 1 (contd.). Physical data on obse

Dive no.	Date day,month,year	Time	(1) Location	Maximum depth (m)	Tem water
29	22-06-69	1030-1130	C.C.	2	
30	23-06-69	1000-1130	C.C.	2	
31	24-06-69	1230-1415	C.C.	2	
32	24-06-69	1545-1615	C.C.	2	
33	25-06-69	1030-1200	C.C.		
34	25-06-69	24hr. coll	C.C.	2	
a		1400			
b		1600			
c		1800			
d		2000			
e		2200			
f		2400			
g	26-06-69	0200			
h		0400			
i		0600			
j		0800			
k		1000			
l		1200			
35	16-07-69	1345-1445	C.C.	2	9
36	18-07-69	1530-1600	C.C.	2	13
37	22-07-69	2130-2145	C.C.	2	12
38	25-07-69	2245-2300	C.C.	2	
39	26-07-69	0030-0100	C.C.	2	
40	15-08-69	1400-1500	C.C.	5	14
41	30-08-69	1400-1445	D.G.	8	12.5
42	13-09-69		D.G.	17	
43	15-10-69	2120-2150	D.G.	10	9
44	17-10-69	2300-2400	C.C.	2	9

.cal data on observation and collection dives.

Maximum depth (m)	Temp. C water	Temp. C air	Condition water	Condition air	(2) Tide	Water visibility (m)	(3) Divers
2			windy	sunny		10	BL
2							BL
2							BL
2					l		BL
							BL
2							
					l		NB
					r		NB
					r		NB
					r		NB
			dark	rain	h		JO
			dark	rain	f		JO
			dark	clear	f		JO
			dark	clear	f		JO
			dawn		l		BL
			light		r		BL
			light		r		BL
			light		r		BL
2	9	19					BL
2	13						BL
2	12	18.5		dusk			BL
2				dark			BL
2				dark			BL,JMG
5	14				h-f		BL,MF
8	12.5		calm	rain	l	8	BL,MF
17			calm	over-cast		10	BL,JMG,MF
10	9		sl. swell	dark			BL,JMG,MF
2	9		sl. swell			poor	BL,JMG.MF

Appendix 1 (contd.). Physical data on obser

Dive no.	Date day,month,year	Time	(1) Location	Maximum depth (m)	Temp water
45	18-10-69	1200-1300	C.C.	2	9
46	18-10-69	1600-1700	Mt.C.	10	9.5
47	08-11-69	1130-1300	C.C.	2	9
48	22-11-69	1430-1515	P.Cv.S.	13	5
49	06-12-69	2130-2230	C.C.	2	6
50	07-12-69	1130-1230	M.H.	13	4
51	20-12-69	1430-1450	D.G.	12	3
52	10-01-70	1300-1430	Mt.C.	8	3
53	17-01-70	1330-1400	P.C.S.	17	1
54	24-01-70	1400-1435	P.C.N.	12	1
55	30-01-70	1300-1330	C.C.	2	0
56	07-02-70	1300-1400	Mt.C.	7	1
57	13-02-70	2300-2330	C.C.	2	0.7
58	14-02-70	0000-0100	C.C.	2	0.2
59	14-02-70	1200-1300	M.H.	20	0
60	07-03-70	1300-1330	C.C.	2	1.5
61	20-03-70	2220-2250	D.G.	17	0
62	27-03-70	1330-1400	C.C.	2	1
63	28-03-70	1015-1045	M.H.	5	1
64	28-03-70	1430-1515	Ch.Cv.	13	1
65	30-03-70	1510-1540	B & CC	12	0.5
66	04-04-70	1115-1200	Mt.C.	13	2
67	02-05-70	1400-1430	C.C.	2	5.5
68	02-05-70	1430-1500	M.H.	3	5.5
69	03-05-70	1200-1230	Mt.C.	10	5.0
70	23-05-70	1200-1300	M.H.	7	4.5
71	23-05-70	1545-1615	Ch.C.	13	4.5

data on observation and collection dives.

ximum epth (m)	Temp. °C		Condition		(2) Tide	Water visibility (m)	(3) Divers
	water	air	water	air			
2	9	9			h-r		BL,JMG,MF
10	9.5	10	over-cast			3	BL,JMG,MF
2	9	14		sunny	l-f		BL,MF
13	5		sl. swell	cloudy-windy		5	BL,MF
2	6	8	choppy	over-cast			BL,JMG
13	4		choppy	cloudy	f	10	BL,JMG
12	3	1	swell	cloudy		3	BL,MF
8	3		calm	clear	l-f		BL,MF
17	1			sunny		6	BL,JMG,MF
12	1		calm	snow	l	3	BL,JMG,MF
2	0	-4		sl. breeze	h-f		BL,MF
7	1	8	calm	cloudy	h-f		BL,JMG,MF
2	0.7	0	calm	drizzle snow	h-r		BL
2	0.2	-0.5		snow	h		MF,JMG
20	0	-2.0	clear	snow		10	BL,JMG,MF
2	1.5	0		cloudy	l-f	3	BL,MF
17	0		calm	full moon			BL,JMG,MF
2	1	6	calm	sunny	l-f	8	BL
5	1	3	calm	over-cast	h	9	BL,MF
13	1	3	sl. swell	overcast		10	BL,MF
12	0.5		calm	cloudy		11	BL,MF
13	2	2	choppy	windy snow		11	BL,JMG,MF
2	5.5	8.5	calm	sl. breeze	l	3	DP,BL
3	5.5	8.5	calm		l-r	3	BL,DP
10	5.0	13.5	sl. choppy	sunny clear	l	3	BL,JMG,MF
7	4.5	10.5	calm	cloudy	l-f	6	BL,MF,DF
13	4.5	11.0	sl. swell	cloudy		6	BL,MF,DP

Appendix 1 (contd.). Physical data on obse

Dive no.	Date day,month,year	Time	(1) Location	Maximum depth (m)	Ter wate
72	30-05-70	1100-1130	B.C.	12	4.5
73	21-06-70	1330-1430	F	12	5.0
74	27-06-70	1000-1045	D.G.	22	
75	01-08-70	1100-1215	D.G.	18	12
76	22-08-70	1100-1200	B & CC	15	12
77	13-09-70	1130-1220	P.C.N.	13	13
78	25-10-70	1200-1245	Mt.C.	13	9
79	09-01-71	1130-1200	Mt.C.	15	1
80	27-02-71	1200-1230	P.C.S.	12	-1
81	06-03-71	1130-1200	B & CC	13	-1.5

a on observation and collection dives.

m	Temp. C water	Temp. C air	Condition water	Condition air	(2) Tide	Water visibility (m)	(3) Divers
	4.5	10	calm	sunny	1	17	BL,MF
	5.0	12	calm	cloudy		10	BL,MF
			calm	cloudy	1	15	BL,MF
	12	17	calm	sunny		13	BL,MF
	12		calm	sunny		10	BL,MF
	13		calm	sunny		8	BL,MF
	9		windy	rain		3	BL,MF
	1			rain		11	BL,MF
	-1		ice on surface	sunny		16	BL,MF
	-1.5		clear	cloudy		16	BL,MF

Appendix 1 (contd.). Physical data on obse

(1) Location:

C.C.	Collection Cove, Bellevue	47°
M.H.	Morleys Hole, Bellevue	47°
D.G.	Dyers Gulch, Logy Bay	47°
Mt.C.	Mount Carmel, Salmonier Arm	47°
P.C.S.	Portugal Cove (South)	47'
P.C.N.	Portugal Cove (North)	47'
B.& CC.	Bread and Cheese Cove, Bay Bulls	47'
S.P.	St. Phillips	47
Ch.Cv.	Chance Cove	47
F.	Ferryland	47
B.C.	Beachy Cove	47

(2) Tide:

l - low

h - high

r - rising

f - falling

(3) Di

M.

J.

J.

N.

J.

D.

B.

ıta on observation and collection dives.

	47°38'17"N.	53°44'40"W.
	47°38'26"N.	53°44'39"W.
	47°37'30"N.	52°38'49"W.
	47°07'43"N.	53°31'30"W.
	47°37'31"N.	52°52'12"W.
	47°37'43"N.	52°51'49"W.
ls	47°18'48"N.	52°46'15"W.
	47°35'44"N.	52°53'02"W.
	47°40'42"N.	53°49'18"W.
	47°01'20"N.	52°52'11"W.
	47°37'09"N.	52°52'20"W.

(3) Divers:

M.F. - M. Farwell

J.M.G. - J. M. Green

J.O. - J. Osborne

N.B. - N. Bannister

J.H. - J. Himmelman

D.P. - D. Power

B.L. - B. LeDrew

Appendix 2. Stomach content analysis of *Myoxocephalus aeneus*

48 fish collected June 20 - July 24, 1969
Collection Cove, Bellevue, Trinity Bay.
Based on 34 (71%) found with food in the stomach.
Mean total length 9.93 cm (range 5.1 - 15.2 cm).

Food item	Number of occurrences	Frequency (%)
Sticklebacks (*Gasterosteus aculeatus*)	14	13 (39)
Radiated shanny (*Ulvaria subbifurcata*)	8	7 (21)
Nereid worms (Nereidae)	4	4 (12)
Crabs (Decapoda)	9	6 (18)
Gastropods (Prosobranchiata)	3	3 (9)
Scaleworms (Polynoidae)	2	2 (6)
Dip tera larvae (Chironomidae)	13	1 (3)
Amphipods (*Gammarus* sp.)	20	10 (29)
Sea urchins (*Strongylocentrotus droebachiensis*)	1	1 (3)
Copepods (Copepoda)	26	2 (6)