ASPECTS OF THE EARLY LIFE HISTORY OF THE AMERICAN EEL (**ANGUILLA ROSTRATA** (**LESUEUR**) IN NEWFOUNDLAND

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by

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A B S T R A C T

Elvers enter freshwater in Newfoundland later and at larger sizes than in more southerly areas. The growth of elvers and juveniles was much slower in freshwater than in the marine environment.

The food of elvers and juveniles consisted almost entirely of benthic insects. Dipteran larvae and annelid worms were the groups most frequently utilized as food. Elvers formed an appreciable part of the food supply of brook trout and large eels during the months of July, August and September. The food of elvers and juvenile eels corresponded closely to the benthic portion of the diet of small salmonids.

Late summer migrations of juveniles from the marine environment into freshwater were common in some areas of the island. These migrations contributed substantially to the eel population of some Newfoundland streams.

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FRONTISPIECE

Elvers of _Anguilla rostrata_ (LeSueur) feeding on the remains of a caplin _Mallotus villosus_. Magnification approximately 2.5X. Photographed by the author.

1. INTRODUCTION

The American eel, Anguilla rostrata (LeSueur) is one of the most common North American fishes, distributed from Greenland in the north to Central America in the south. Studies on the details of its biology have been few, especially ones dealing with the elver and juvenile stages of its life history.

The eel is abundant in many areas of Newfoundland and the potential for a commercial fishery appears to be good. Only two studies have been conducted on adult eels in the province, (Gray and Andrews, 1970 and 1971 and Vladykov, 1970). No literature could be found dealing specifically with the elver and juvenile stages of Anguilla rostrata in Newfoundland.

A thorough knowledge of the biology of the eel is essential if a commercial fishery is to be a success. This study was undertaken in view of the commercial potential and because of the apparent lack of information on the early life history of the species in Newfoundland.

The purpose of this study was to examine (1) the growth of elvers and juvenile eels in the freshwaters of Newfoundland, (2) the food of elvers and juveniles in the freshwaters of Newfoundland, (3) the competitive and predatory relationships between other fish and elvers and juvenile eels in inland waters and (4) the growth of marine elvers and juveniles and their migration into freshwater.

Studies on the development and growth of the elver are rare. The only detailed work appearing in the literature is that of Vladykov (1966 and 1970).

In the present investigation otoliths were used for age determination. The only studies to use this method to age the American eel are those of James and Vladykov (1967), Vladykov (1970) and Gray and Andrews (1971).

Few studies have been conducted which examine the food of the American eel in detail. Most of the studies of the food habits of the eel have resulted from investigations into its competitive and predatory relationships with the salmonids (Elson 1940b, 1941; Godfrey 1951, 1957 and Smith 1948, 1952a and 1956). No work appears in the literature examining the food habits of elvers in freshwater or of juvenile eels in their first few years of freshwater life. In addition no work has been reported examining the differences in food habits of the American eel as it matures and changes from elver to juvenile to adult.

There have been various records of Salmonids and large eels feeding upon elvers (Day 1941 and Godfrey 1951). No study could be found which examines the importance of elvers as a food of these groups. In this investigation an attempt was made to determine the degree to which elvers were eaten as a seasonal food of brook trout, Salvelinus fontinalis and of large eels.

Specific studies on competition between large and small American eels and brook trout are limited to brief comments in the literature (Elson 1940a). This study attompted to examine the feeding relationships of large and small eels and brook trout and to determine the similarities in their diets.

Secondary upstream movements of juvenile eels from the marine environment have been reported in the literature (Godfrey 1951). Because such movements can involve large numbers of eels their effects on freshwater populations could be substantial. A migration of this type was investigated in this study.

II. METHODS AND MATERIALS

A. Description of the Sampling Areas

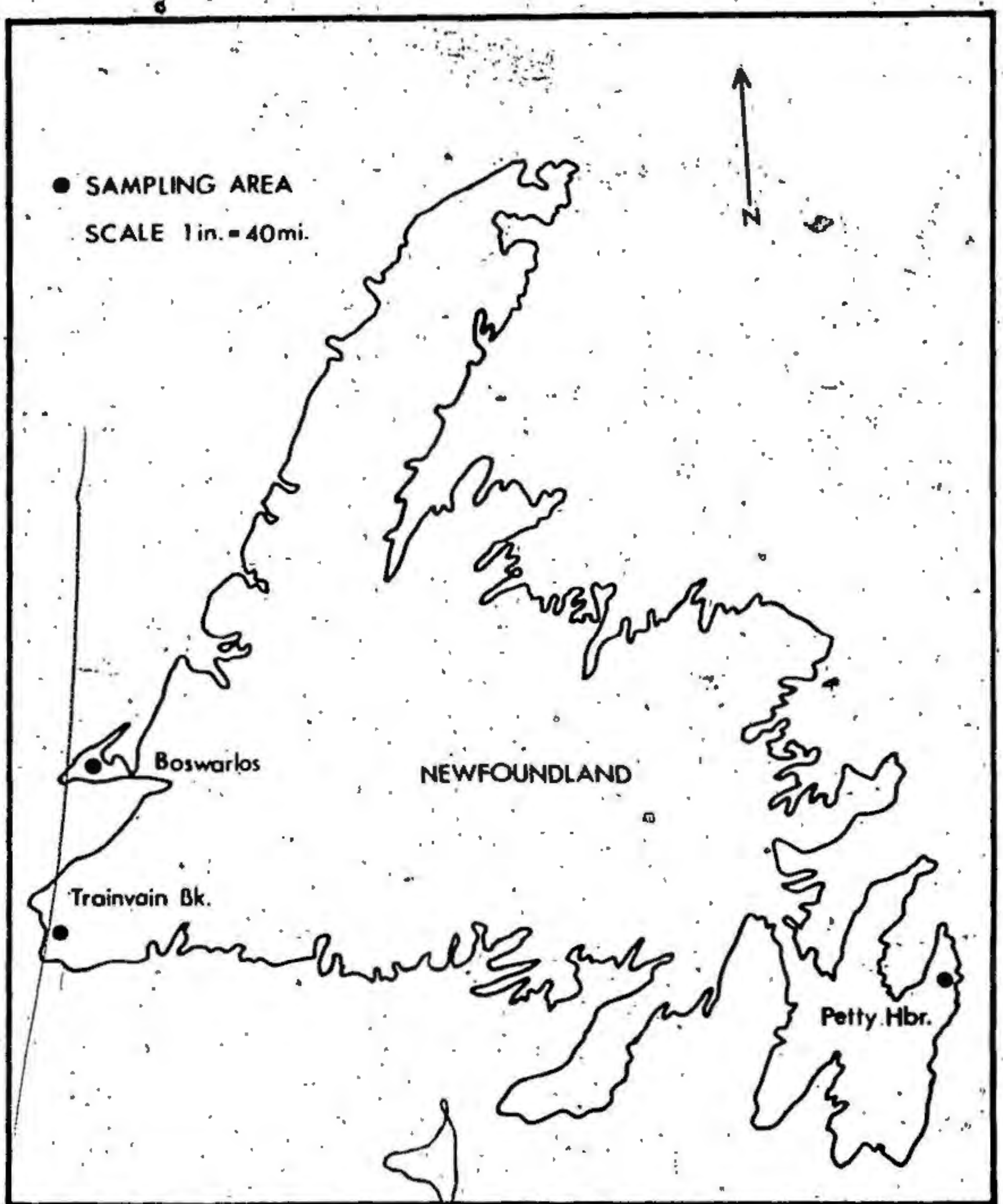
The sampling areas chosen for this investigation were, (1) a small tributary of Tailrace Brook at the Petty Harbour hydro-generating station; (2) Boswarlos on the Port au Port Penninsula and (3) Trainvain Brook near Port aux Basques on the southwest corner of the Island. Collections at these sites were made during the summer of 1971 and 1972. These sites were selected on the basis of their geographical location and special features which made then suitable for the collection and observation of elvers and juveniles. The geographical positions of the three sites are shown in Figure II. 1.

The Tailrace Brook area was chosen bacause the generating station provided a man-made barrier where specimens could be collected and their behavour observed. Tailrace Brook itself is a shallow (0.5 m) stream approximately 150.0 meters in length. A large pool is located at the base of the generating station where some collections were made. Other collections and observations were made in the small tributary flowing into Tailrace Brook. Details of this site are shown in Figure II. 2.

The brook at Boswarlos (Fig. II. 3.) was selected because of its small size, shallow water and because in its lower reaches it meanders through a sandy salt water beach. This creates ideal conditions for collecting recently arrived elvers as well as for observing their entrance into freshwater. Near its mouth this stream is slow moving, approximately 2.0 meters wide and has an average depth of about 15.0 cms.

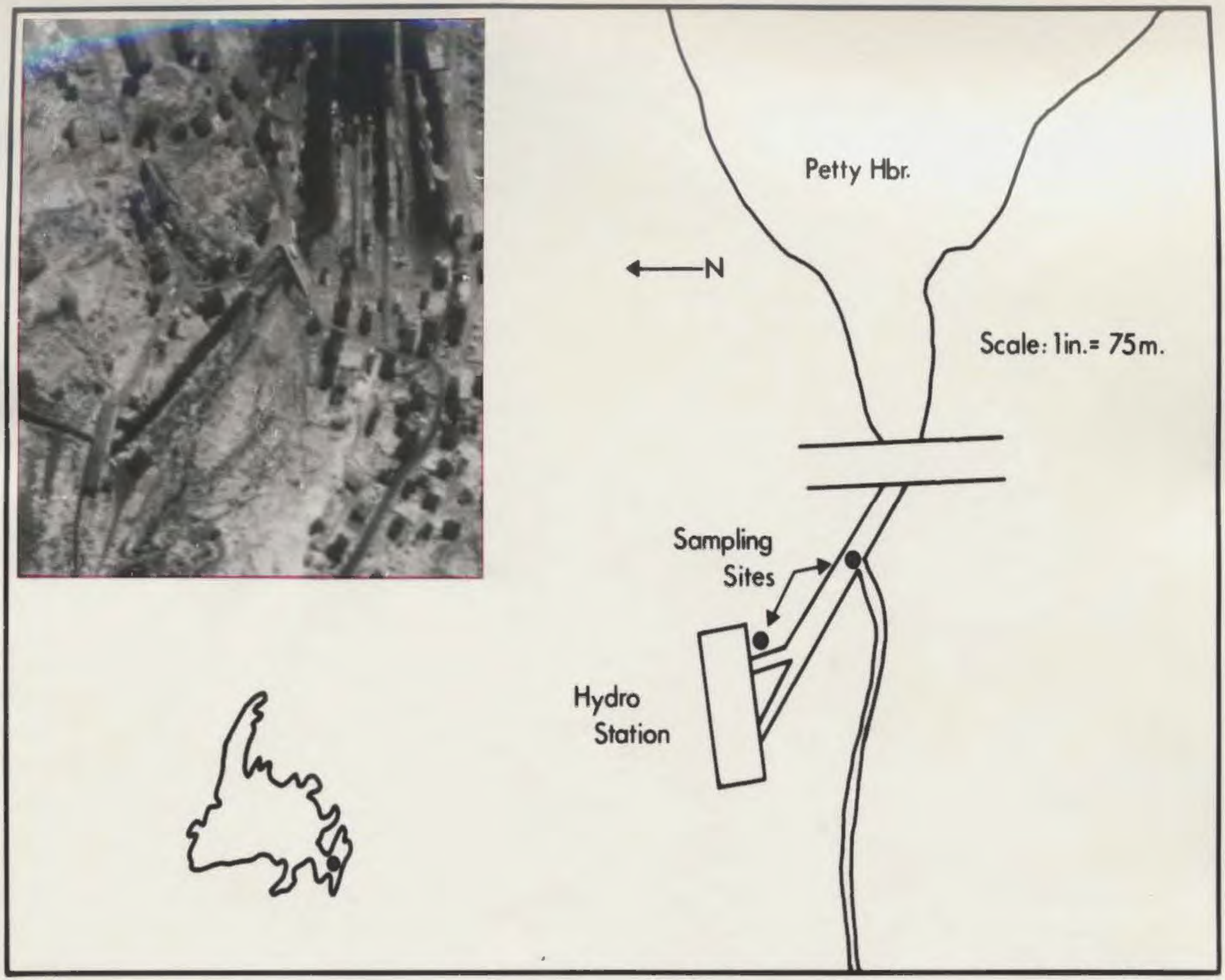
Trainvain Brook was chosen because of its geographical location and the presence of a waterfall approximately 200.0 meters from its mouth. This waterfall created ideal conditions for collection and observation of elvers and juveniles. The brook is cold and fast-flowing with an average depth of 0.5 meters and an average width of 5.0 meters. Details of this site are shown in Figure II. 4.

Figure II: 1. Map of the Province of Newfoundland showing the localities sampled.


● SAMPLING AREA
SCALE 1 in. = 40 mi.
N
Boswarlos
NEWFOUNDLAND
Trainvain Bk.
Petty Hbr.

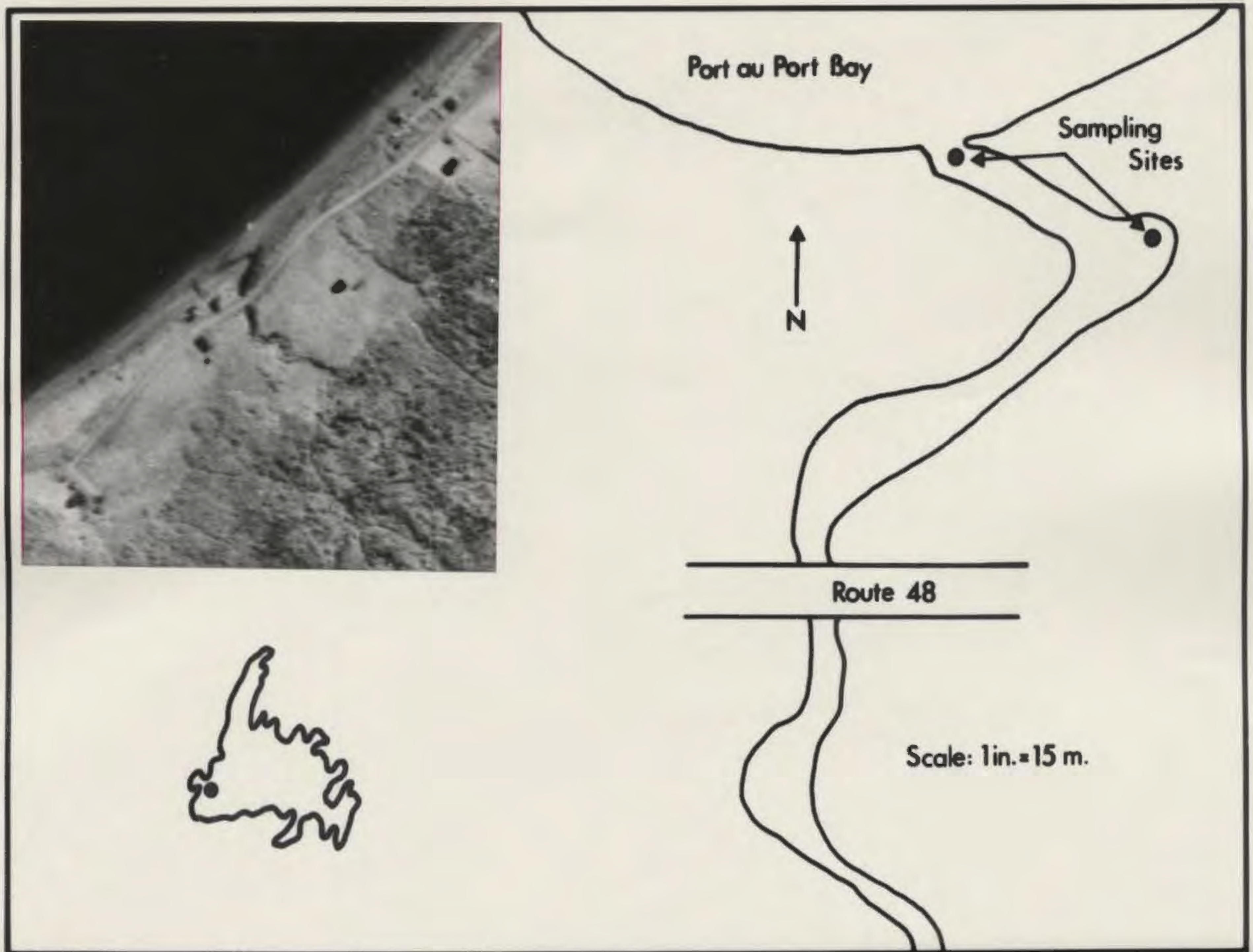
6

Figure II: 2. Details of Tailrace Brook sampling site.



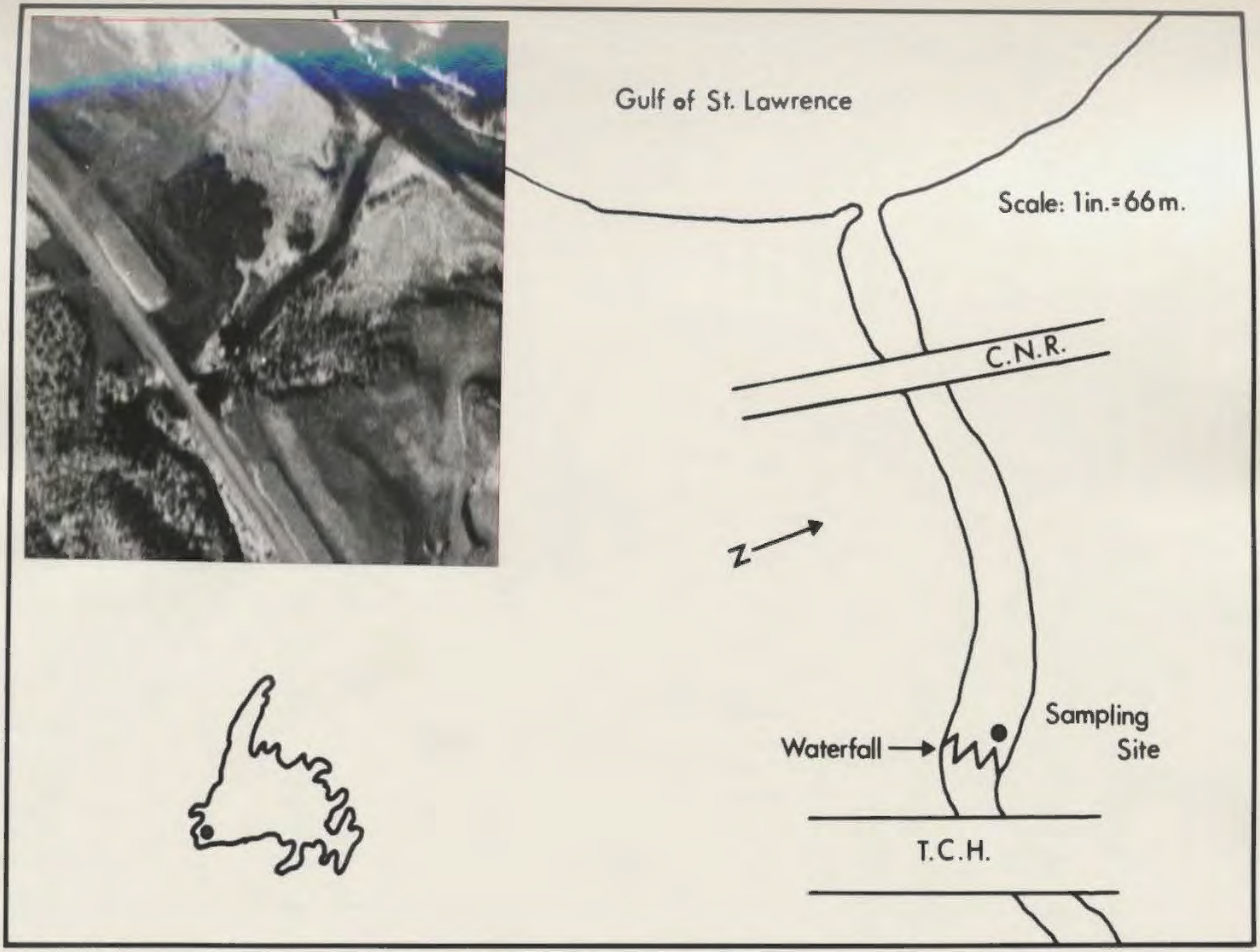
Petty Hbr.
N
Scale: 1in.= 75m.
Sampling
Sites
Hydro
Station

Figure II: 3. Details of the Boswarlos sampling site.



Port au Port Bay
Sampling Sites
N
Route 48
Scale: 1in.=15 m.

Figure II: 4. Details of the Trainvain Brook sampling site.


Gulf of St. Lawrence
Scale: 1in.=66m.
C.N.R.
N
Waterfall
Sampling Site
T.C.H.

B. Sampling Methods

During the summers of 1971 and 1972 elvers and juveniles were collected by use of a hand dipnet designed by the author for this purpose (Fig. II. 5). The standard hand nets available were not suitable due to their size and shape. Because elvers newly arrived from the sea spend most of their time hidden a net was needed which could cover fairly large areas of the substrate and gather bottom materials rapidly.

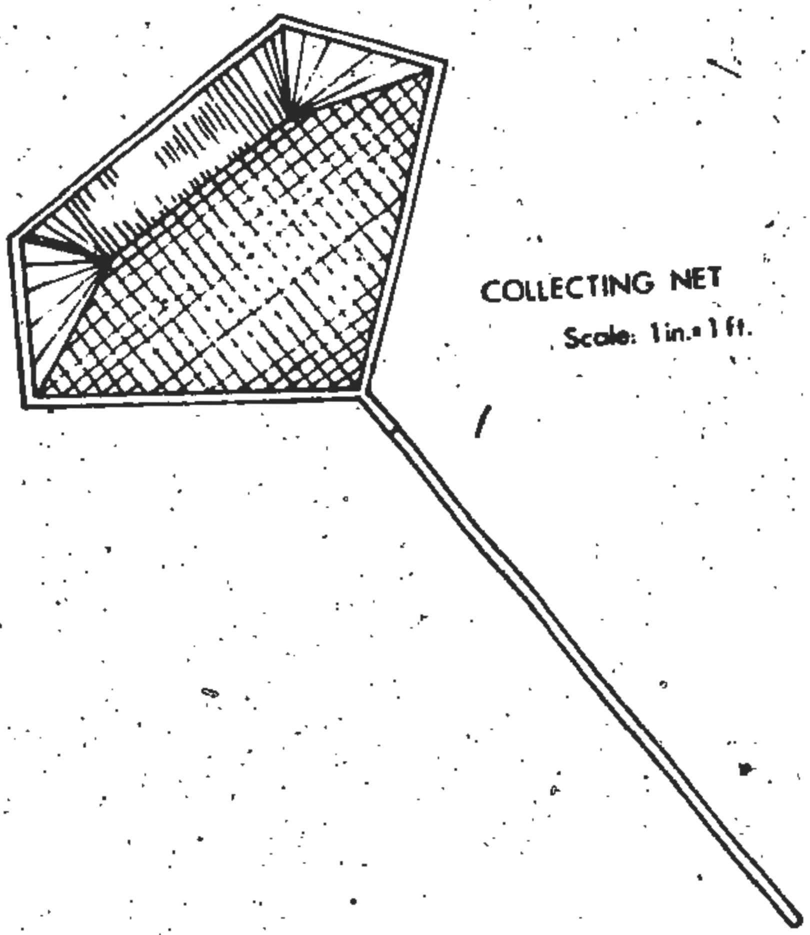
In areas where elvers were observed climbing obstructions such as rock faces and walls specimens were collected by means of a special scoop constructed from a section of rectangular heating duct (Fig. II. 5.)

C. Measurements

The length in mm and weight in gms of all specimens were recorded immediately upon returning from the field. To facilitate measuring the specimens were anesthetized using a 0.5% solution of urethane (Gerking 1949). Total length was measured from the tip of the lower jaw to the end of the caudal fin. This measurement was obtained by using a measuring board which closely resembled a conventional fishery measuring board.

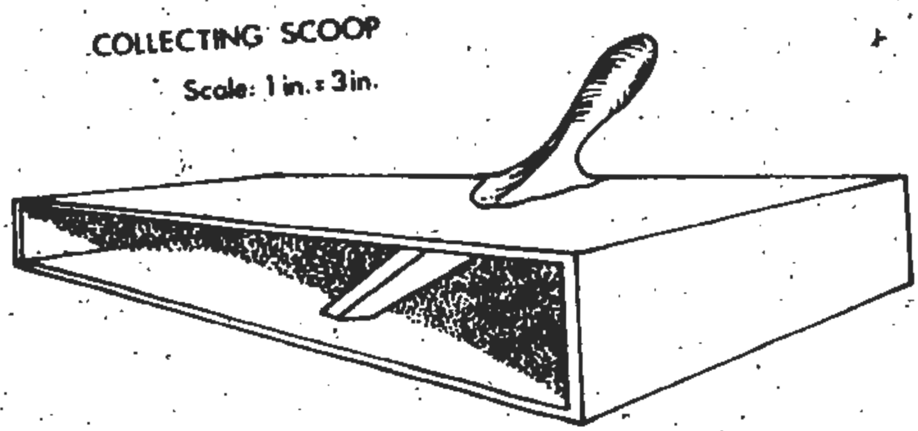
Weight was measured to the nearest hundredth of a gram on a Mettler top-pan scientific balance. Excess

Figure II: 5. Diagrams of special collecting equipment used in sampling elvers and juvenile eels.



COLLECTING NET
Scale: 1 in. = 1 ft.

COLLECTING SCOOP
Scale: 1 in. = 3 in.



water was removed from the surface of the fish by means of absorbent paper before the weight was determined. The specimens were placed in individually labelled vials which were then filled with water and frozen for future study.

D. Stomach Analysis

For stomach content analysis the frozen specimens, collected earlier in the summer were thawed and the entire stomach from the lower esophagus to the pyloric region was removed. The contents of each stomach was then placed in a labelled vial containing a 5.0% formalin solution. This treatment was needed because the food material was found to be too soft to be examined and some agent was needed to make the individual food organisms more rigid and thus easier to separate and count.

During examination the gut contents were emptied into a petri dish and examined under a dissecting microscope. In cases where soft parts were digested, heads which could be identified were counted as a whole organism. Food analysis was undertaken by (1) the number method, (2) the occurrence method and (3) the dry weight method (Lagler 1952).

Organisms were identified usually to Order, but in some cases to species. Identification of insects was assisted by reference to Pennak (1953), Needham and Needham (1962), Ward and Whipple (1959) and Usinger (1963).

E. Age Determination

Since scales had not yet appeared on the specimens examined in this study the otolith method was adopted for determination of age. The technique used for aging follows the standard terminology and notation for otolith reading (Jensen 1965).

The otolith used most frequently for age studies is the saggita because it is the largest and contains the most easily interpreted markings. After removal from the specimen the two saggitae were cleaned by immersion in 70.0% ethyl alcohol and also by rubbing them between the fingers to ensure that all remnants of tissue were removed. They were stored dry in labelled vials for future study.

The otoliths examined in this study were from elvers or small eels and therefore could be read directly without being ground down or treated with an acid solution to make the growth zones more visible. One otolith from each specimen examined was mounted, convex side up, in "Permount" mounting medium on a depression slide. The mounts were permanent and could be read immediatley or stored for subsequent study.

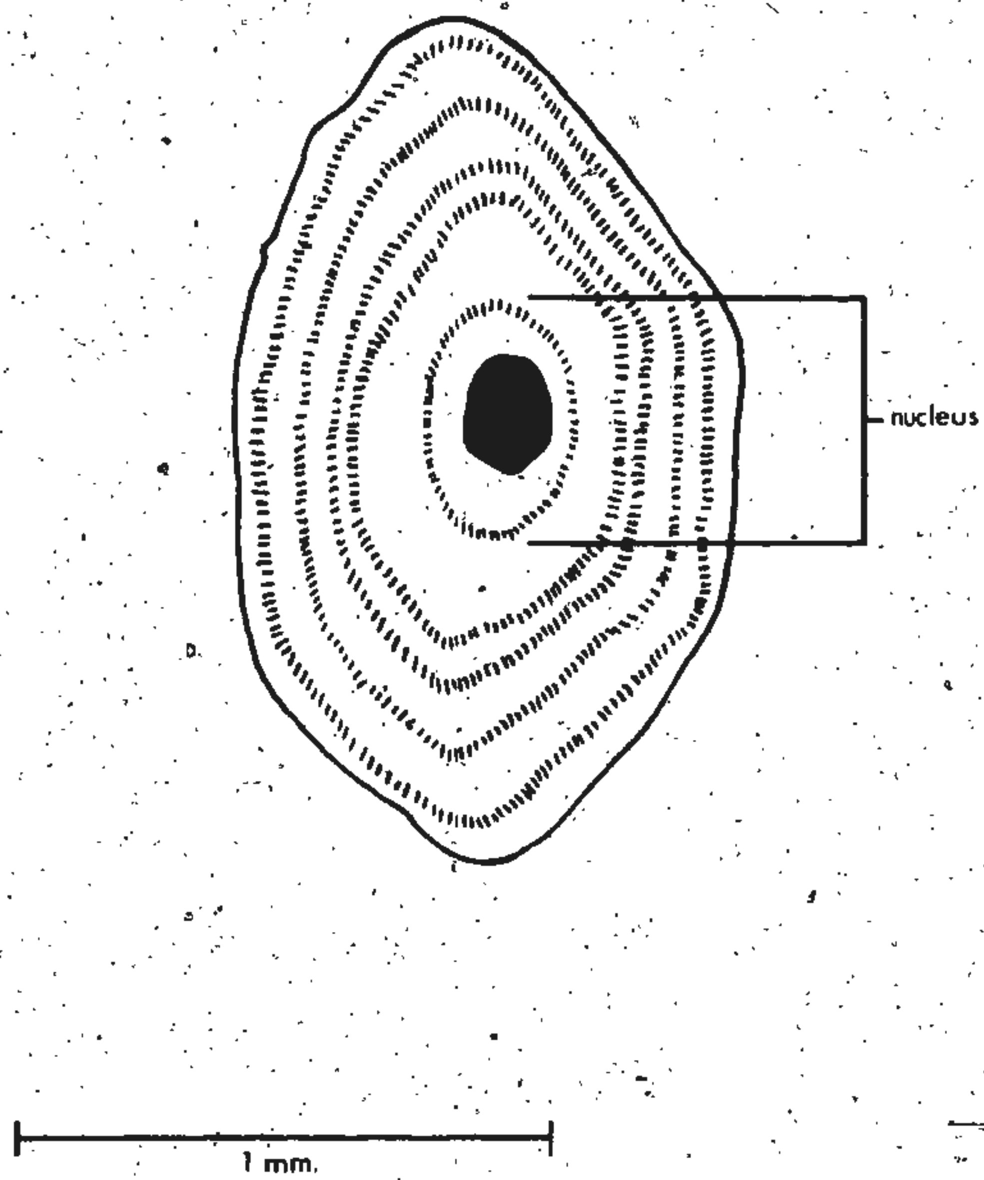
When examined, some of the otoliths mounted whole on depression slides could not be read with reasonable accuracy. An alternate method was needed to check those otoliths whose growth zones were not completly visible. Christensen (1964) successfully used the method of heating and breaking otoliths to determine age and this method was followed with excellent results in the present study.

The otoliths were placed in a 5.0 milliliter beaker and heated over a gasflame. During the burning process the color of the otolith changed from white to ash-gray and at this point was removed from the flame. The burnt otolith was then broken by pressing a needle very carefully toward the crack through its center, which develops as a result of the heating.

In the burnt otolith two different types of zones were found. A wide white summer zone of inorganic material and a narrow black winter zone of organic material were visible. Examination of both whole and burnt otoliths was carried out by use of a binocular microscope at approximately 20X magnification. Best results were obtained by using reflected light on a black background. The burnt otolith was mounted temporarily in "Permount" and discarded after the age of the specimen had been determined.

A typical otolith is shown in diagrammatic form in Figure II. 6. Examination on a dark background would show the summer zones as white opaque areas (white in diagram) and the winter zones as dark transparent areas (cross-lined in diagram). The nucleus or time spent in the sea is defined in the diagram. In this study the winter zones are considered annuli and age is counted from the time the elver enters freshwater. An eel is considered to have spent one year in freshwater if one completed summer and winter zone is present in addition to the nucleus. In the case of an eel which has lived four winters and five summers in freshwater and the fifth winter zone has not as yet been laid down the specimen is classed as a four year old. The otolith in the diagram (Fig. II. 6.) would represent this age group.

Figure II: 6. Diagram of a typical eel otolith from a four year old juvenile as seen under reflected light. The five summer zones are shown as white and the four winter zones as cross-lines in the diagram. These zones were formed in freshwater while the nucleus was formed in the sea.


nucleus
1 mm.

III. RESULTS.

A. Growth Studies

1. Frequency Distributions of Elvers

Length frequencies for the elver samples are shown in Table III. 1. and Figure III. 1. The Boswarlos 1971 sample ranged in length from 55.0 to 88.0 mm and had a mean length of 63.5 mm. The 1972 sample ranged in length from 57.0 to 82.0 mm and the mean length was 69.2 mm. In the 1971 sample the mode occurred at the 62.0 mm mark while the mode of the Boswarlos 1972 elvers was 67.0 mm.

Weight frequencies for the elver populations sampled are shown in Table III. 2. and Figure III. 2. The Boswarlos 1971 elver sample ranged in weight from 140.0 to 850.0 mg and had a mean weight of 260.0 mg. The 1972 group ranged in weight from 90.0 to 640.0 mg. and had a mean weight of 330.0 mg. The mode of both the 1971 and 1972 samples occurred at the 249.5 mg mark.

Tables III. 1. and 2. and Figures III. 1. and 2. are based on 143 specimens collected on August 1st. 1971 and 200 collected over a three week period - July 23 to August 13 - in 1972.

Table III: 1. Mean length, range in length and percentage length frequency for elvers of *Anguilla rostrata* (LeSueur).

Area	Year of collection	Length of elvers (mm.) Mean	Range	Frequency of length classes in % 55-59	60-64	65-69	70-74	75-79	80-84	85-89
Boswarlos	1971	63.5	55-88	14.94	52.29	24.07	4.15	1.66	1.66	0.83
Boswarlos	1972	69.2	57-82	4.08	18.36	32.64	23.46	18.36	3.06	

Figure III: 1. Length frequency distributions of elvers of Anguilla rostrata (LeSueur) collected in Newfoundland.

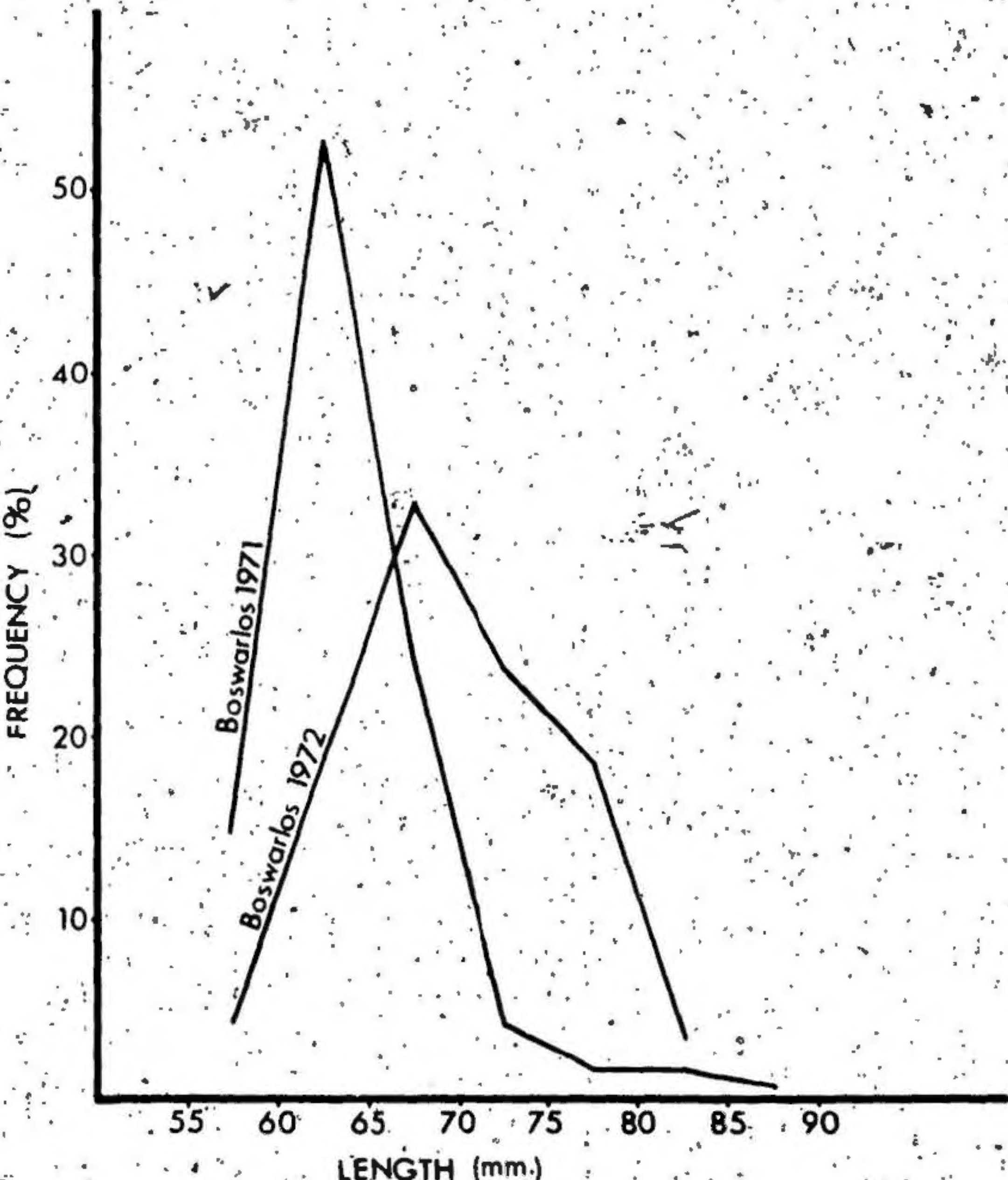
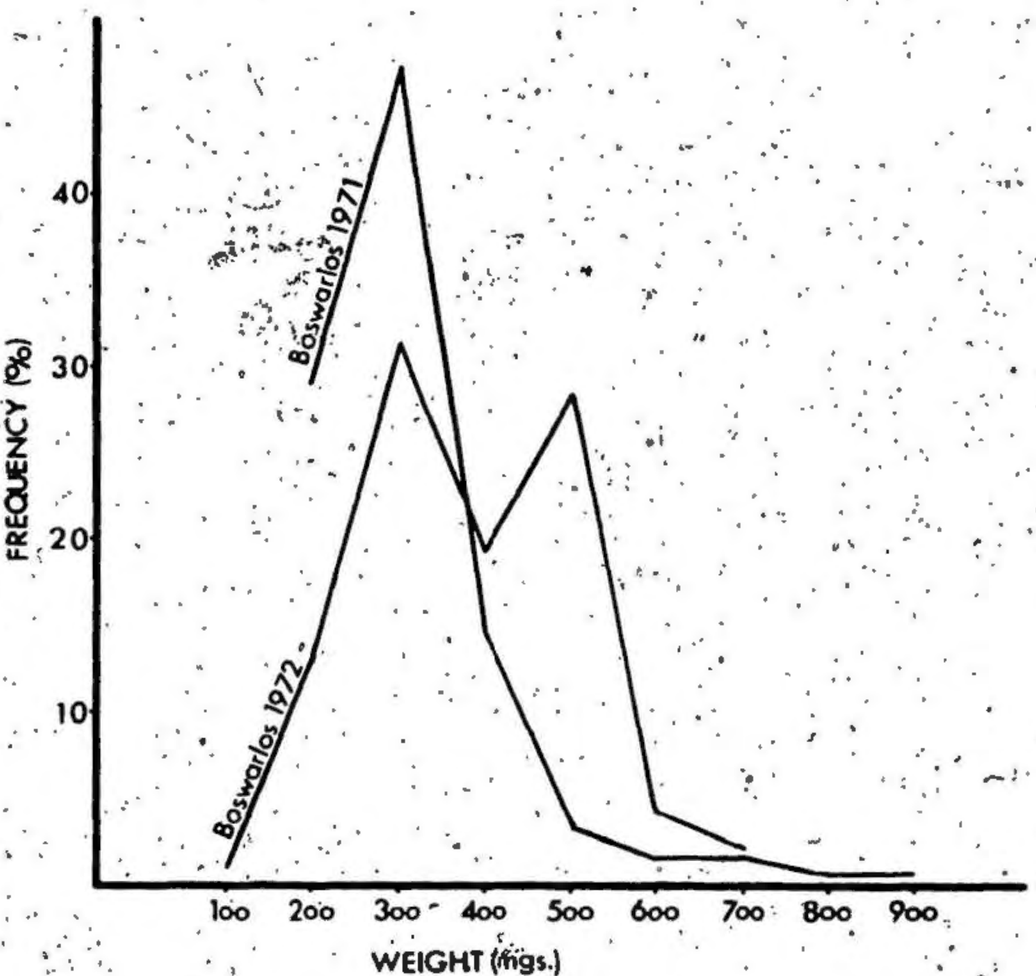

FREQUENCY (%)
50
40
30
20
10
Boswarlos 1971
Boswarlos 1972
55
60
65
70
75
80
85
90
LENGTH (mm.)

Table III: 2. Mean weight, range in weight and percentage weight frequency for elvers of *Anguilla rostsata* (LeSueur).

Area	Year of collection	Weight of elvers (mg.) Mean	Range	Frequency of weightclasses in % 0-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899
Boswarlos	1971	260	140-850	-	29.05	47.31	14.94	3.32	1.66	1.66	0.83	0.83
Boswarlos	1972	330	90-640	1.02	13.08	31.62	19.38	28.56	4.08			

Figure III: 2. Weight frequency distribution of elvers of *Anguilla rostrata* (LeSueur) collected in Newfoundland.



FREQUENCY (%)
40
30
20
10
Boswarlos 1971
Boswarlos 1972
100
200
300
400
500
600
700
800
900
WEIGHT (mgs.)

2. Length-weight Relationship of Elvers

The length-weight relationships of both samples were calculated by converting the data to the log regression form of the equation $W = aL^b$. The relationships derived are expressed by the following equations and are shown graphically in Figure III. 3.

Boswarlos 1971 -

$$\log W = \bar{1}.0293 + 1.0402(\log L)$$

Boswarlos 1972 -

$$\log W = \bar{1}.0576 + \bar{1}.8791(\log L)$$

The fastest growth pattern expressed by this relationship occurred in the Boswarlos 1971 group. The 1972 sample grew somewhat slower but the difference was very slight.

3. Geographical Differences in the Length and Weight of Elvers

a. Mean and Range in Length of Elvers Along the Western Atlantic Coast

The results of this analysis appear in Figure III. 5. Figure III. 4 shows the areas from which the samples were taken, ranging from Florida in the south to Newfoundland in the north.

Figure III: 3. Calculated Length-weight relationship of elvers of <u>Anguilla</u> <u>rostrata</u> (LeSueur) collected in Newfoundland.

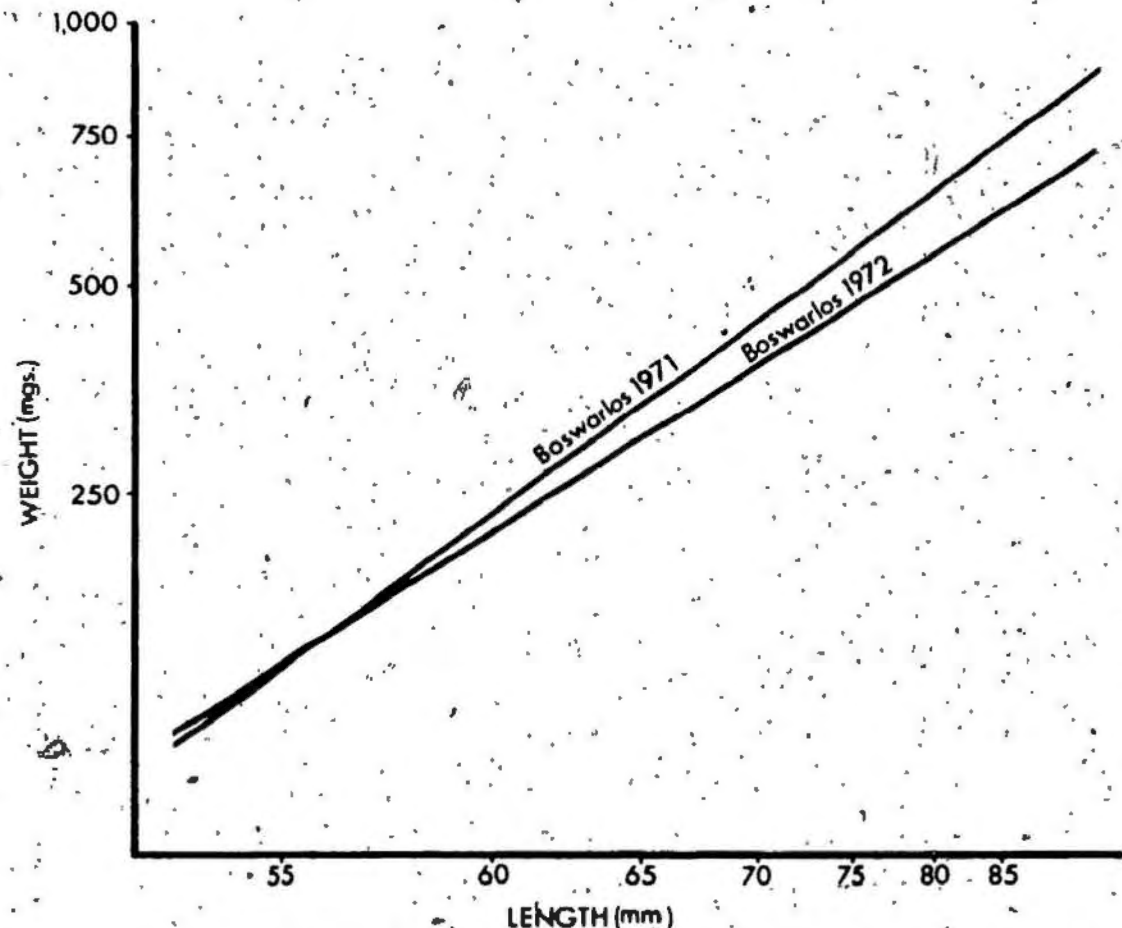
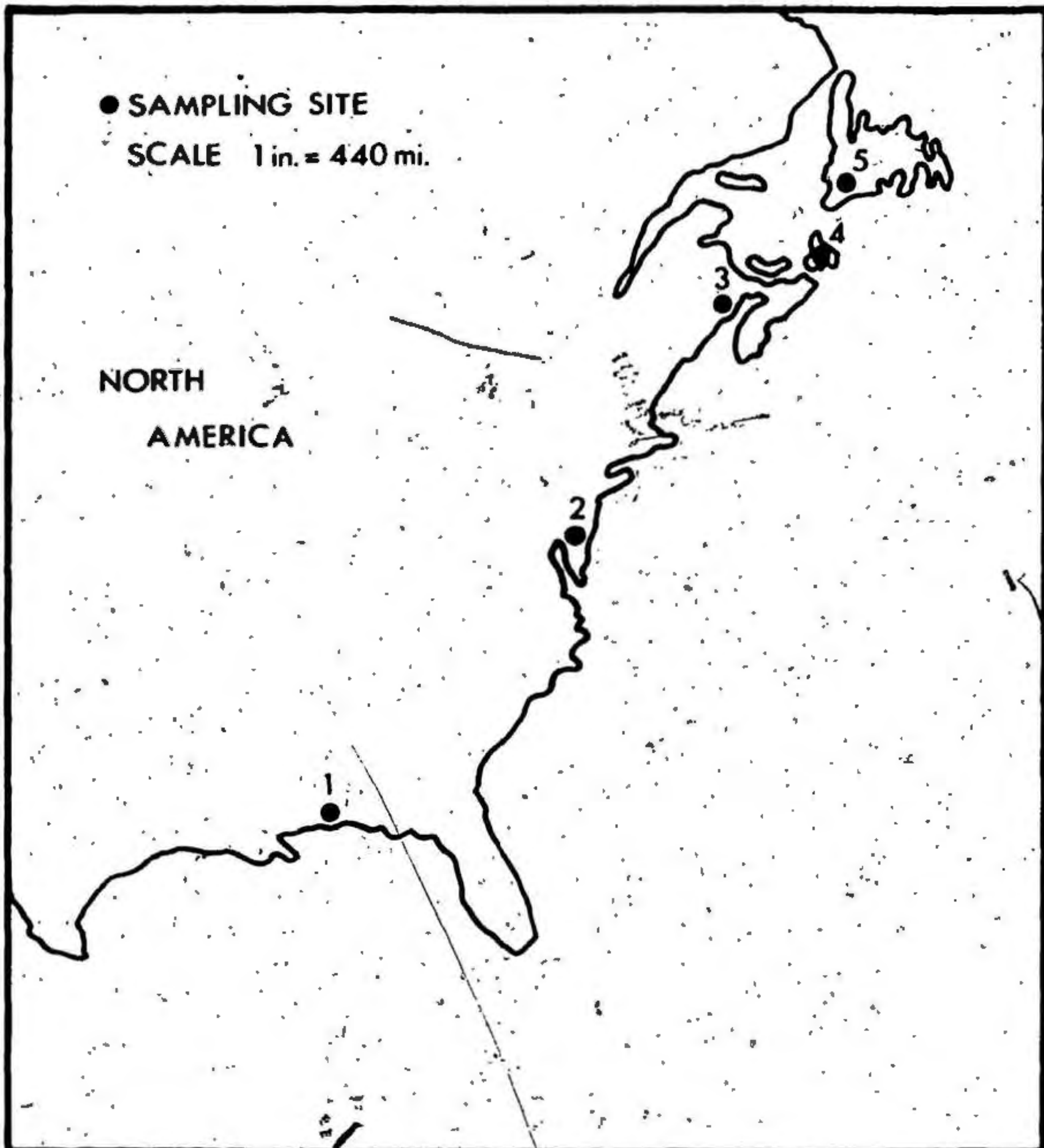
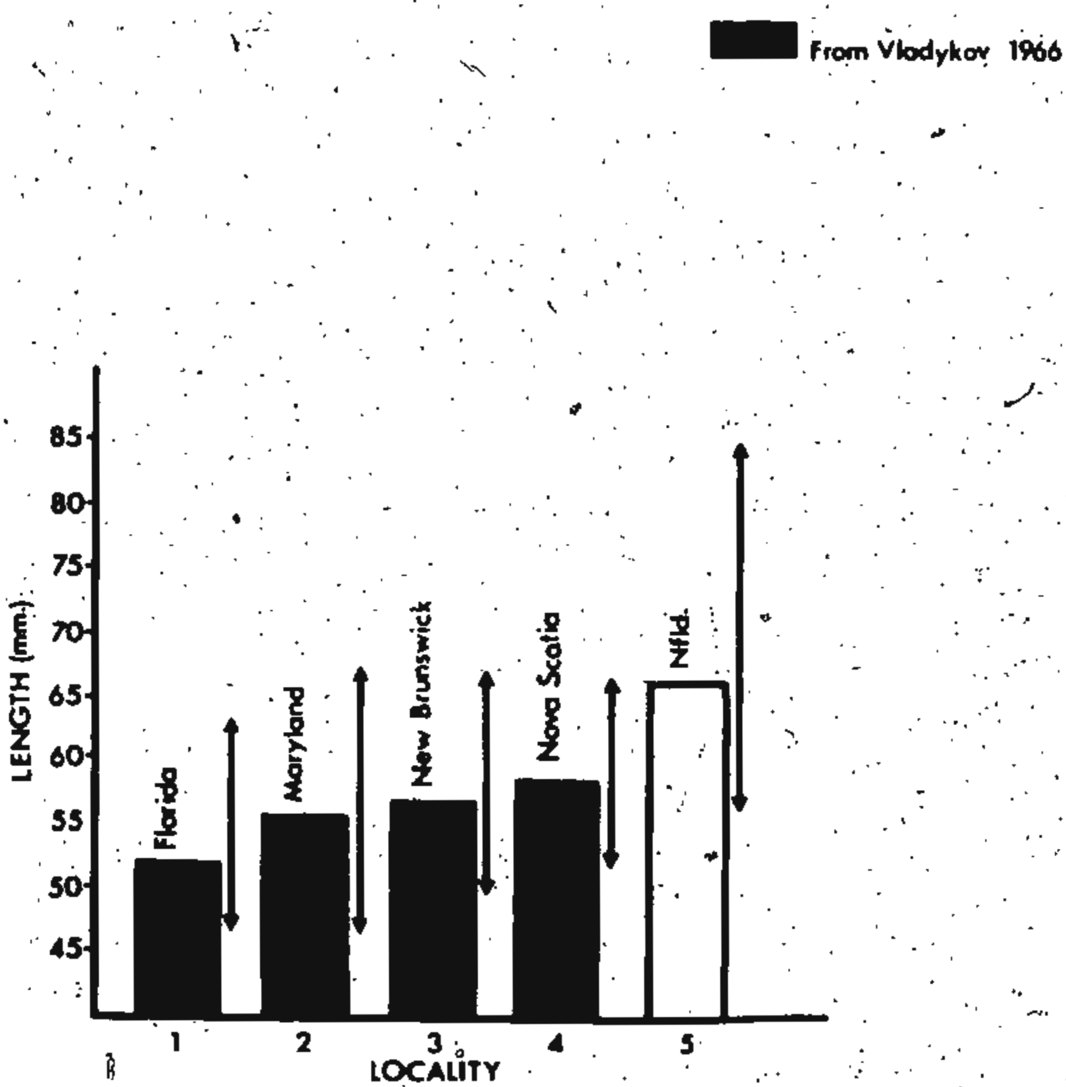

1,000
750
500
250
WEIGHT (mgs.)
Boswarlos 1971
Boswarlos 1972
55
60
65
70
75
80
85
LENGTH (mm)

Figure III: 4. Elver sampling areas along the Atlantic coast of North America.



● SAMPLING SITE
SCALE 1 in. = 440 mi.
NORTH
AMERICA
1
2
3
4
5

Figure III: 5. Mean length and range in length of elvers collected along the Atlantic coast of North America.



From Vladykov 1966
LENGTH (mm.)
85
80
75
70
65
60
55
50
45
Florida
Maryland
New Brunswick
Nova Scotia
Nfld.
1
2
3
4
5
LOCALITY

As shown in the graph (Figure III. 5.) the mean length of elvers increased steadily from south to north. The length range over which Newfoundland elvers were spread is also much greater than for any other locality sampled.

b. Length Frequencies of Elvers Along the Western Atlantic Coast

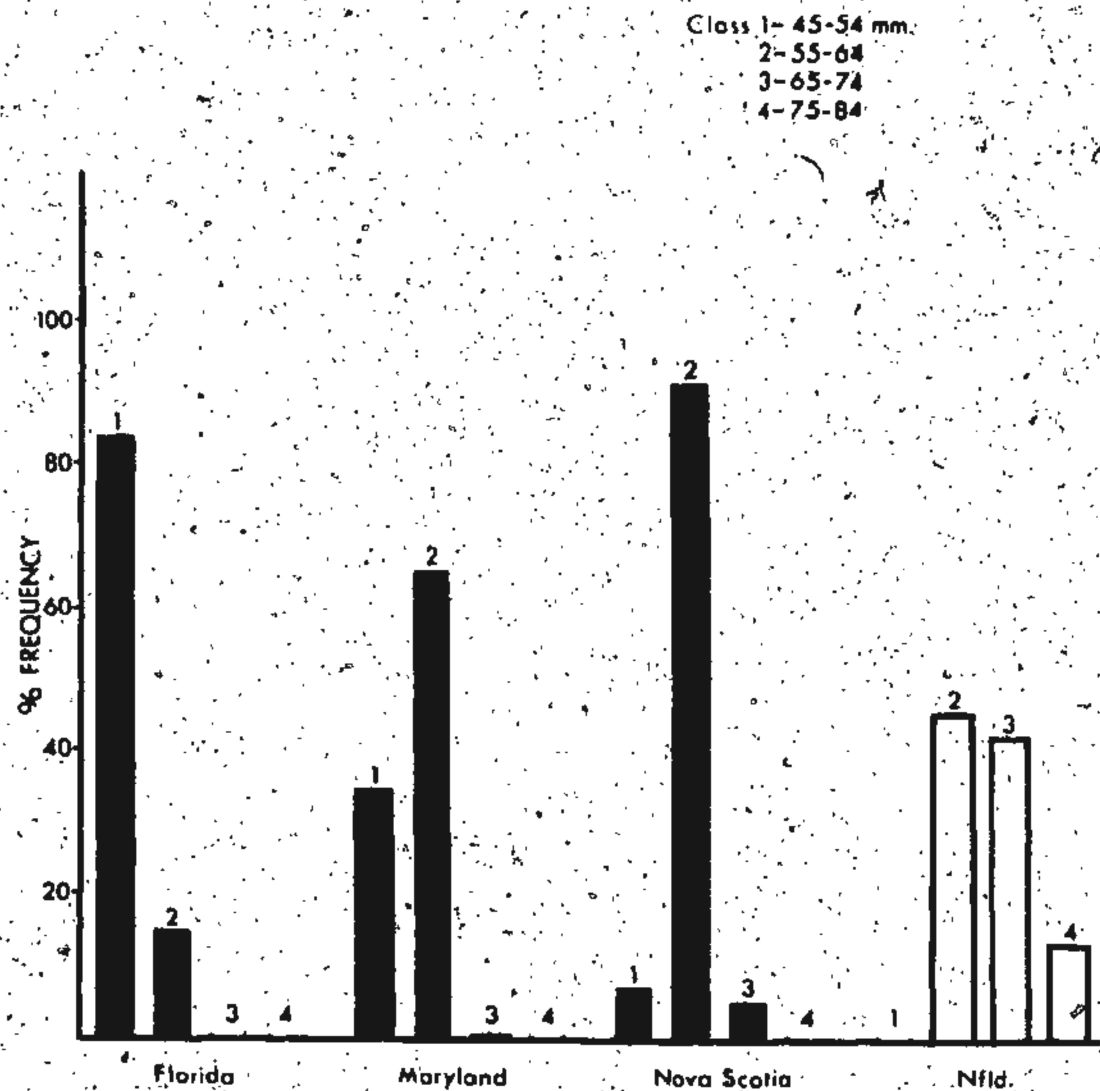
The results of this analysis are shown in Figure III. 6. Florida occupied an extreme position with class I predominating while in the Maryland sample class II was most numerous. In the Nova Scotia sample class II predominated with some class III fish appearing. Class III was the largest group in the Newfoundland sample. This sample also included class IV fish for the first time.

c. Variation in Mean weight of Elvers Along the Western Atlantic Coast

The variations in mean weight for elvers collected from south to north along the Atlantic coast of North America are shown in Figure III. 7.

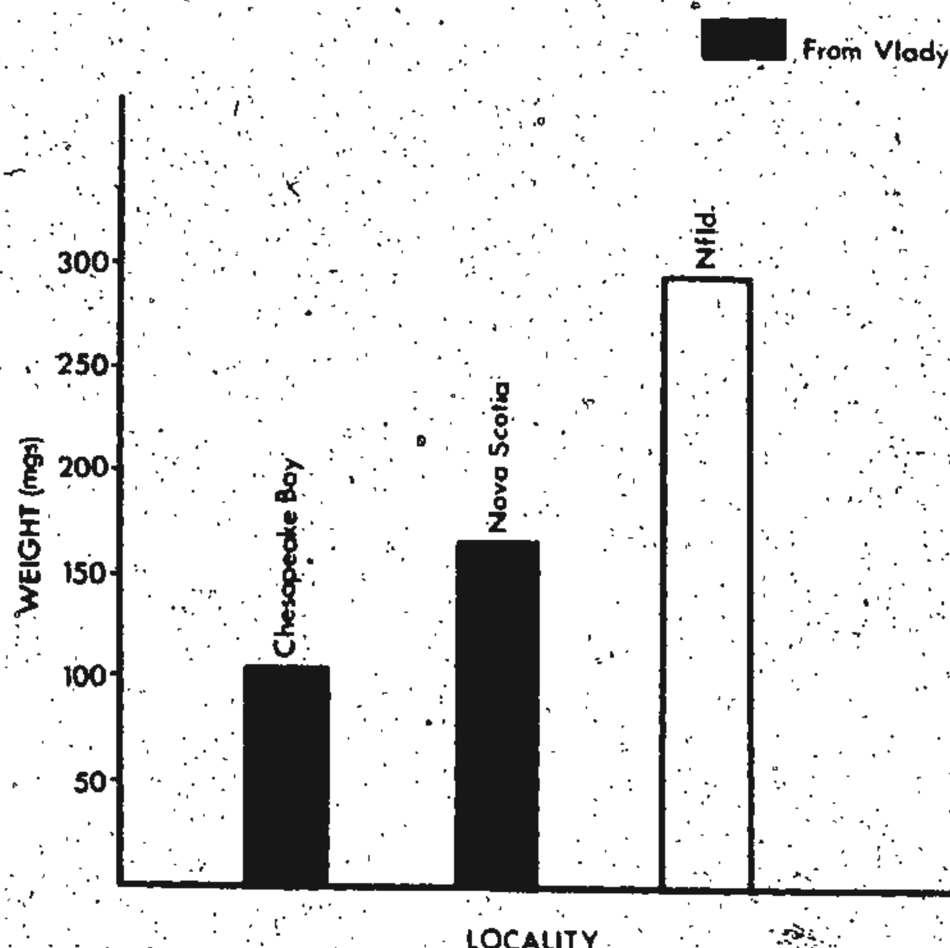
The weight variation with geographical location can be clearly seen as substantial increases in weight are noted from south to north. The mean weight for Chesapeake Bay was 104.0 mg and for Nova Scotia 169.0 mg. This represents an increase of 65.0 mg.

Figure III: 6. Length frequencies of elvers collected along the Atlantic coast of North America.



Class 1- 45-54 mm.
2-55-64
3-65-74
4-75-84
100
80
60
40
20
% FREQUENCY
1
2
3
4
Florida
Maryland
Nova Scotia
Nfld.

Figure III: 7. Variations in mean weight of elvers collected along the Atlantic coast of North America.


From Vladykov 1970
WEIGHT (mgs)
300
250
200
150
100
50
Chesapeake Bay
Nova Scotia
Nfld.
LOCALITY

Newfoundland elvers increased substantially in weight over the Nova Scotia sample with a mean weight of 295.0 mg. This was an increase of 126.0 mg over the Nova Scotia sample.

4. Variation in Elver Size at Progressive Stages of Development

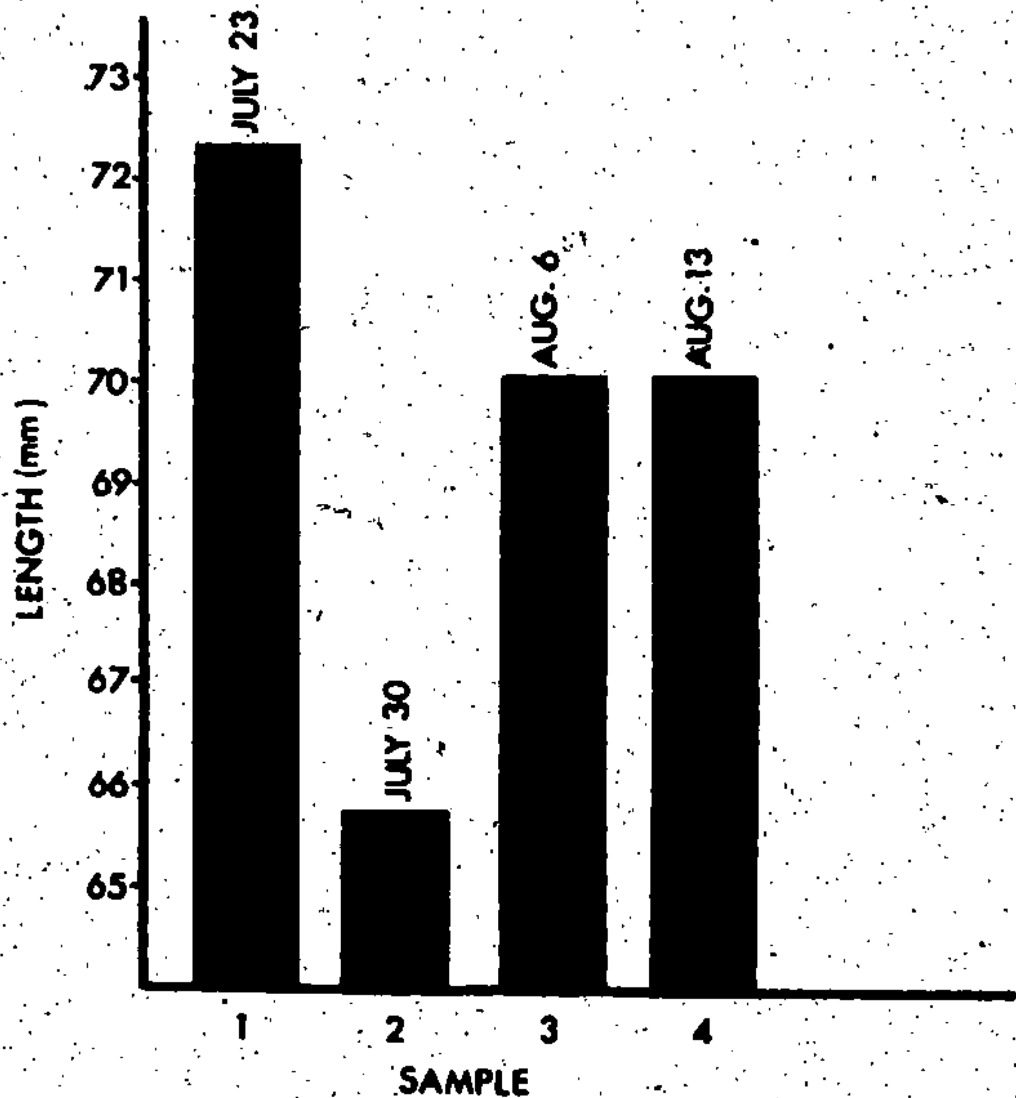
a. Variations in Mean Length and Weight of Elvers Collected in Newfoundland

Differences in length and weight in early and late collections of elvers from Newfoundland are substantial. Elvers from one run were sampled over a period of three weeks beginning at the time of first entry into freshwater. Length variations are shown graphically in Figure III. 8. and weight variations are presented in Figure III. 9.

When the run first entered freshwater the elvers sampled had a mean length of 72.3mm. This dropped substantially within a week to a mean of 65.7 mm. The third week showed a recovery in length to a mean of 70.0 mm which remained stable.

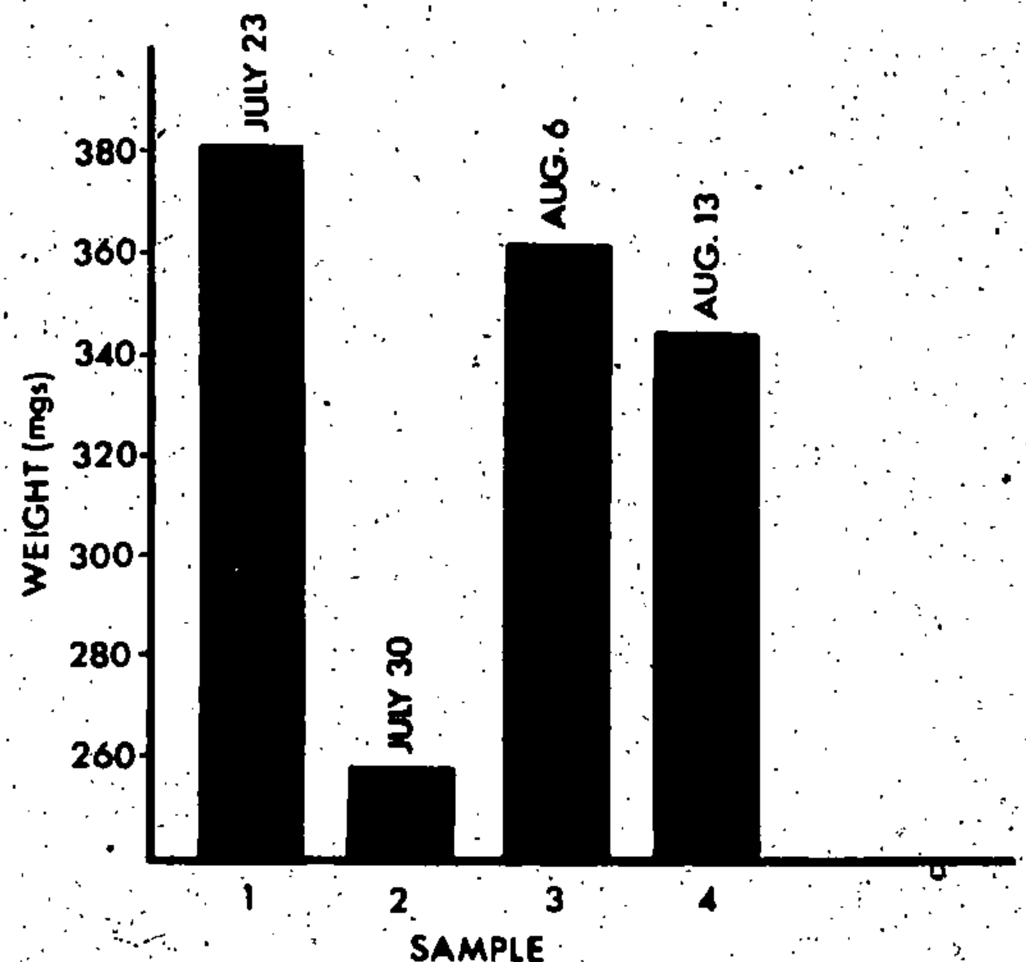
Weight variations also followed this pattern. Upon entry into freshwater the mean weight of the sample was 380.0 mg. This decreased to a low of 255.0 mg during

Figure III: 8. Variations in mean length of Newfoundland elvers due to stages of development.



LENGTH (mm)
73
72
71
70
69
68
67
66
65
JULY 23
JULY 30
AUG. 6
AUG.13
1
2
3
4
SAMPLE

Figure III: 9. Variations in mean weight of Newfoundland elvers due to stages of development.


JULY 23
JULY 30
AUG. 6
AUG. 13
WEIGHT (mgs)
380
360
340
320
300
280
260
1
2
3
4
SAMPLE

the second week. The third week showed a recovery in weight to a mean of 360.0 mg which remained approximately stable.

b. Variations in Length Frequencies due to Stages of Development

Variations in length frequencies over three weeks of sampling are presented graphically in Figure III. 10.

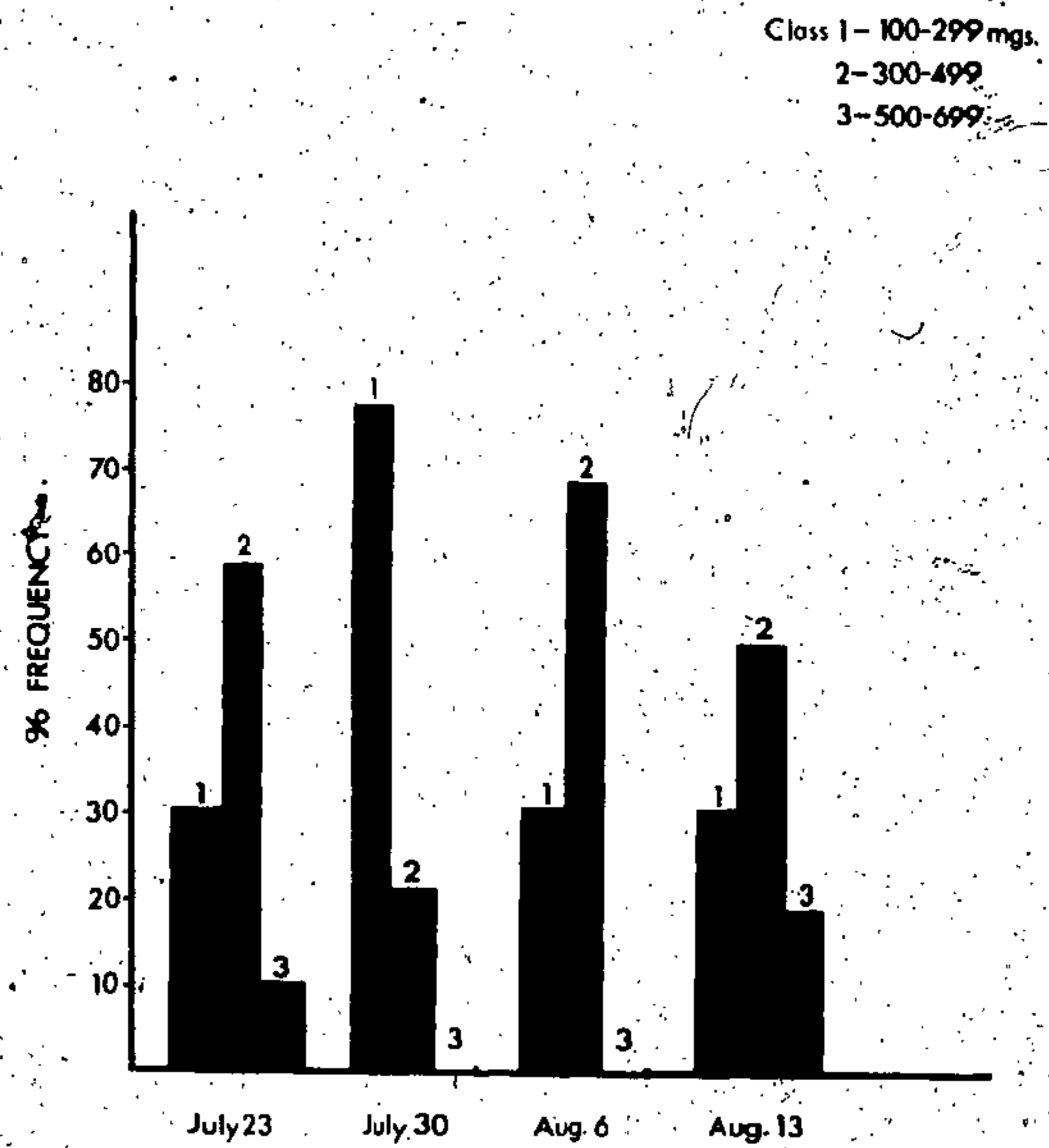
At the time of first entry into freshwater the 70.0 to 79.0 mm class was most numerous. The second week produced a marked change with the 60.0 to 69.0 mm class becoming by far (90.16%) the most frequent. The third week resulted in the 70.0 mm. to 79.0 mm class increasing to 56.25% of the sample. The last sample followed the trend set in the previous week when a further increase to 63.56% was noted in the 70.0 to 79.0 mm class.

c. Variations in Weight Frequencies due to Stages of Development

Weekly samples from a single run of elvers were collected over a three week period. Variations in weight frequencies for the sampling time appear graphically in Figure III. 11.

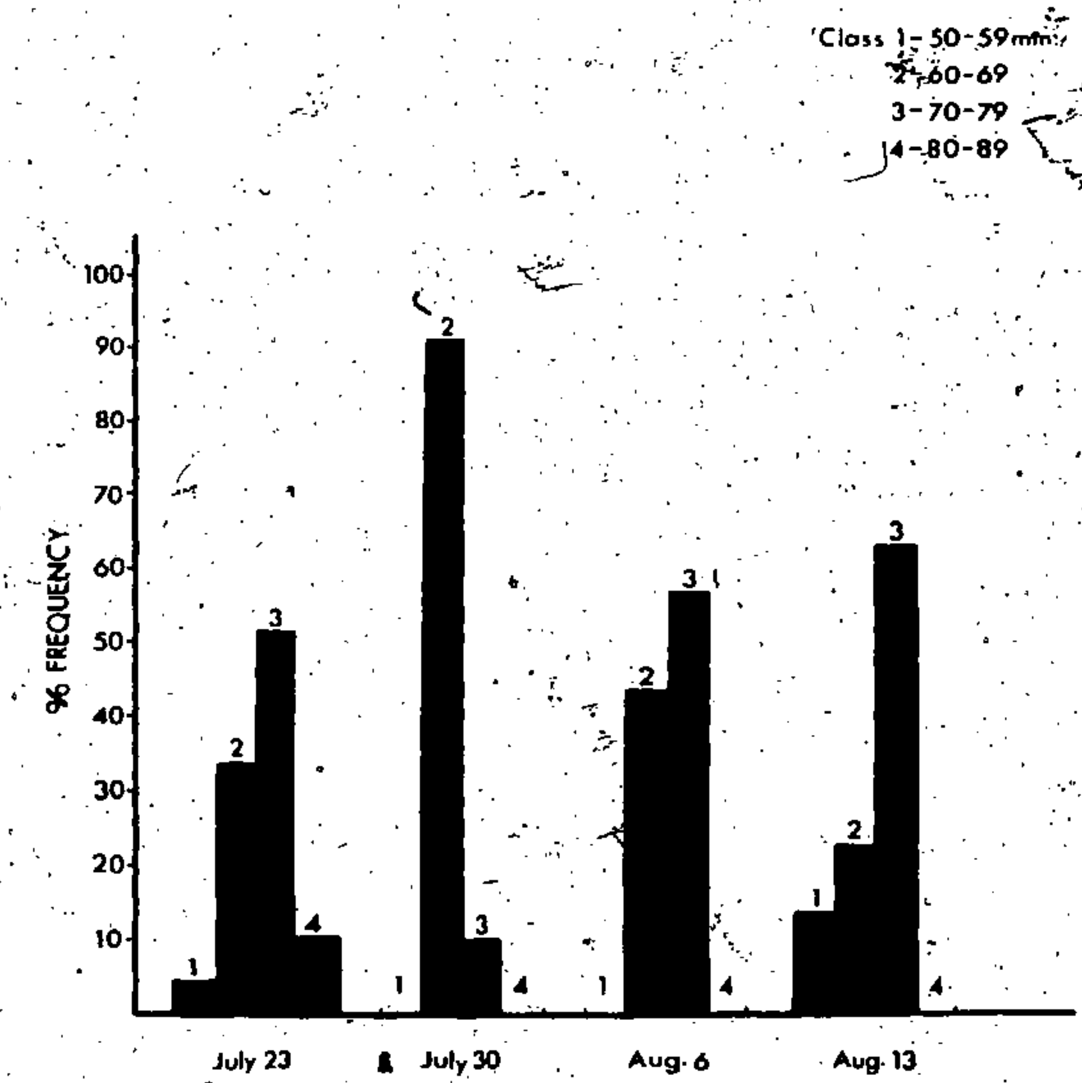
At the time of entry into freshwater the 300.0

Figure III: 10. Variations in length frequencies of Newfoundland elvers due to stages of development.



Class 1 – 100-299 mgs.
2 – 300-499
3 – 500-699
% FREQUENCY
80
70
60
50
40
30
20
10
1
2
3
July 23
July 30
Aug. 6
Aug. 13

Figure III: 11. Variations in weight frequencies of Newfoundland elvers due to stages of development.



Class 1- 50-59mm
2-60-69
3-70-79
4-80-89
% FREQUENCY
100
90
80
70
60
50
40
30
20
10
1
2
3
4
July 23
July 30
Aug. 6
Aug. 13

to 499.0 mg class was most frequent. The second week of sampling produced a sharp change with the 100.0 to 299.0 mg class increasing to 77.25% of the sample. The third week was the opposite of the second with the 300.0 to 499.0 mg class recovering to a frequency of 68.75% while the 100.0 to 299.0 mg class dropped to 31.25% of the sample. In the last sample the 500.0 to 699.0 mg class increased from zero to 18.16% while the 300.0 to 499.0 mg class decreased considerably.

5. ~~Frequency~~ Distributions ~~of~~ Juveniles in Freshwater

Age frequencies for the three areas sampled are shown in Table III. 3. and Figure III. 12.

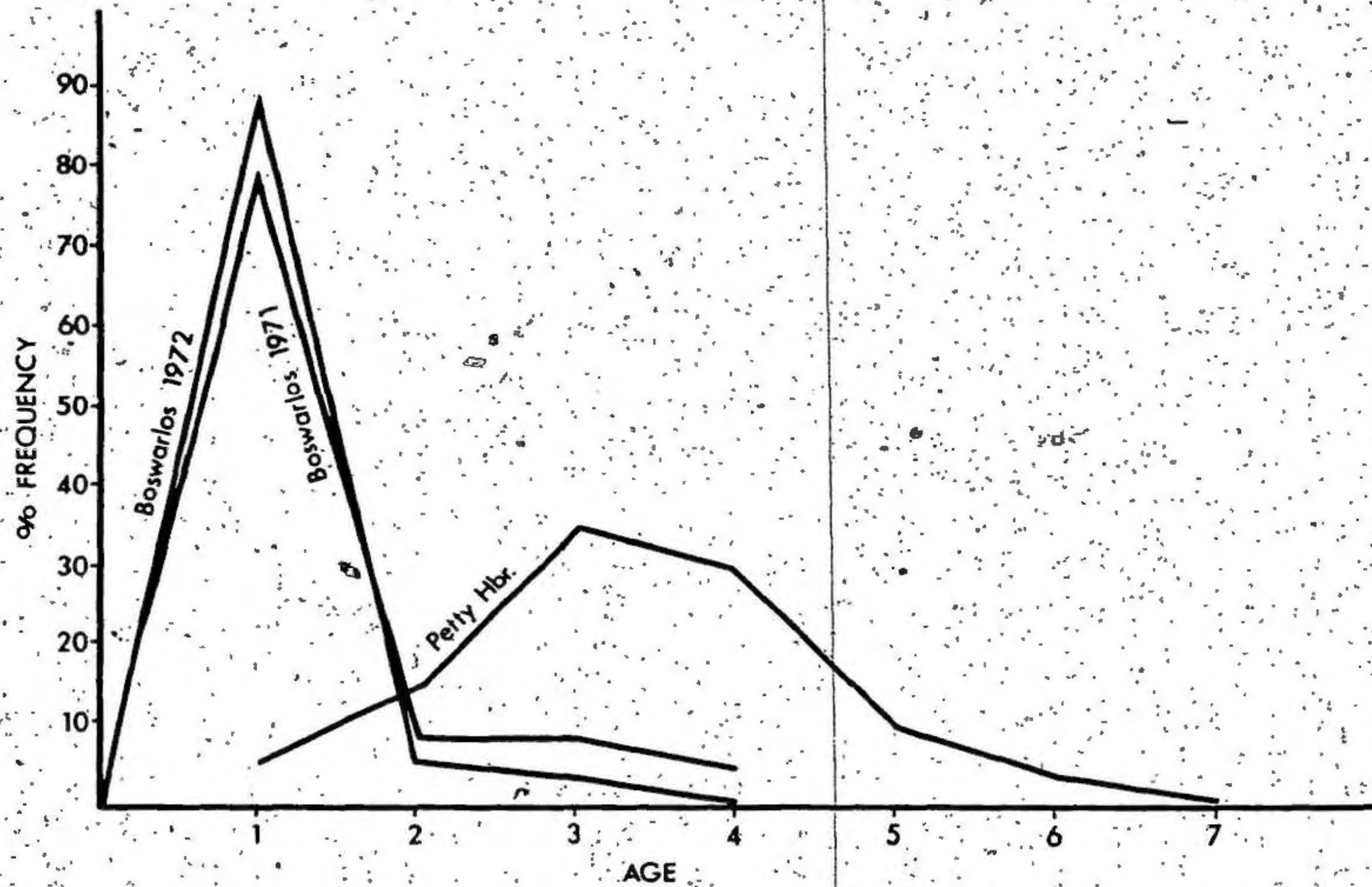
Both the 1971 and 1972 samples of juveniles from the Boswarlos area ranged in age from one to four years. The mean ages of the specimens were 1.39 and 1.17 years respectively. The modal group for both the 1971 and 1972 samples were comprised of one year old eels. Eels of this age-size group were very prevalent in the sampling area while the mid-age group (5 to 10 years) was scarce or absent altogether.

The Petty Harbour sample of juveniles produced a broader age group ranging from one to seven years with

Table III: 3. Percentage age frequency for juveniles of *Anguilla rostrata* (LeSueur) in freshwater.

Location	I	II	III	IV	V	VI	VII	VIII	Total Fish
				Age groups					
Boswarlos 1971	78.12 (18)	8.68 (2)	8.68 (2)	4.34 (1)					23
Boswarlos 1972	89.18 (91)	5.88 (6)	3.92 (4)	0.98 (1)					102
Petty Harbour	5.92 (16)	14.06 (38)	35.52 (96)	29.60 (80)	9.99 (27)	4.07 (11)	0.74 (2)		270

Figure III: 12. Age frequency distributions of juveniles of *Anguilla rostrata* (LeSueur).


% FREQUENCY
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
AGE
Boswarlos 1972
Boswarlos 1971
Petty Hbr.

a mean age of 3.39 years. The modal group consisted of three year old eels.

Length frequencies for the three sampling areas are shown in Table III. 4. and Figure III. 13.

The Boswarlos 1971 sample ranged in length from 56.0 to 87.0 mm. In 1972 the range was from 61.0 to 85.0 mm. The mean lengths of the Boswarlos 1971 and 1972 samples were 67.0 and 73.0 mm respectively. The modal group of the 1971 sample was represented by the 62.0 mm group while the 1972 sample had its mode at the 67.0 mm mark.

The Petty Harbour sample ranged in length from 64.0 to 129.0 mm. The mean length of the sample was 91.0 mm and the mode occured at the 87.0 mm mark.

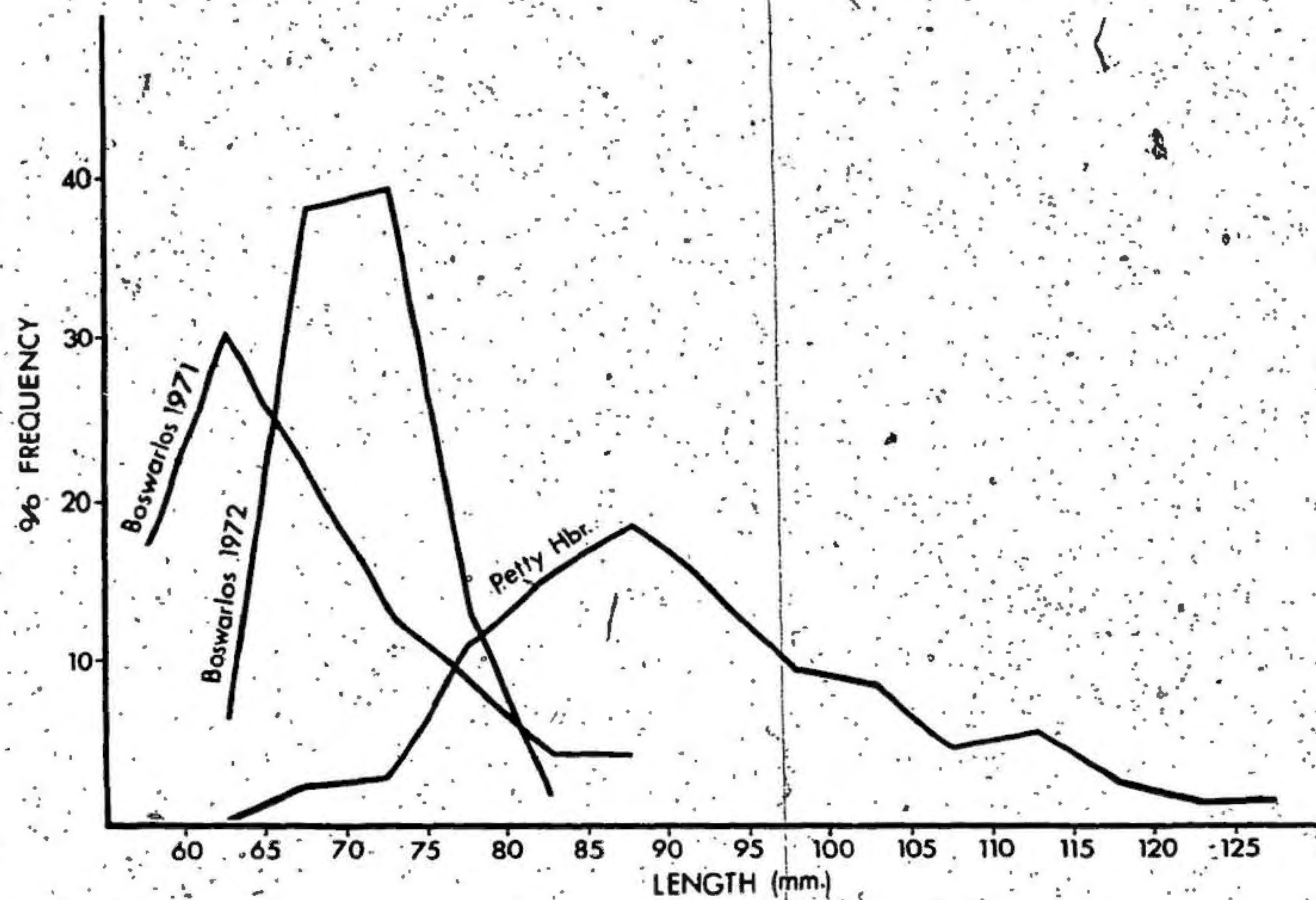
Weight frequencies for the three sampling areas in which juveniles were taken are shown in Table III. 5. and Figure III. 14.

The Boswarlos 1971 sample ranged in weight from 0.17 to 1.07 gms. A sample taken from the same site in 1972 ranged in weight from 0.13 to 0.94 gms. The mean weight of the Boswarlos 1971 juveniles was 0.36 gms and the mode occurred at the 0.245 gm mark. The sample taken at Boswarlos in 1972 had a mean weight

Table III: 4. Percentage length frequency for juveniles of *Anguilla rostrata* (LeSueur) in freshwater.

Locations	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104	105-109	110-114	115-119	120-124	125-129
Petty Harbour		0.37 (1)	2.22 (6)	2.96 (8)	11.10 (30)	15.54 (42)	18.50 (50)	14.80 (40)	9.62 (26)	8.88 (24)	4.44 (12)	5.92 (16)	2.59 (7)	1.48 (4)	1.48 (4)
Boswarlos 1971	17.36 (4)	30.38 (7)	21.70 (5)	13.02 (3)	8.68 (2)	4.34 (1)	4.34 (1)								
Boswarlos 1972	6.86 (7)	38.22 (39)	39.20 (40)	13.22 (14)	1.96 (2)										

Figure III: 13. Length frequency distributions of juveniles of <u>Anguilla rostrata</u> (LeSueur).



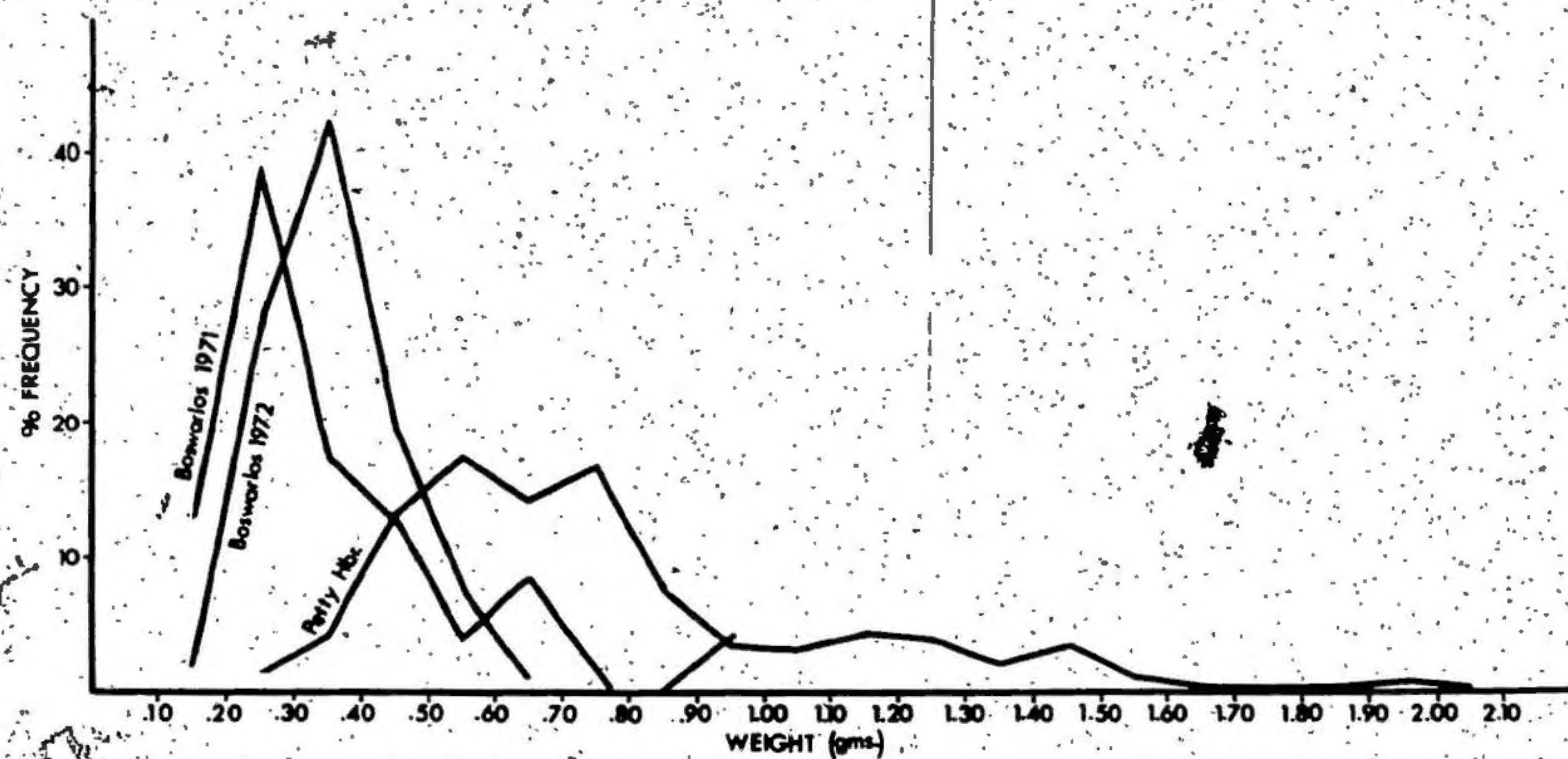
% FREQUENCY
40
30
20
10
Boswarlos 1971
Boswarlos 1972
Petty Hbr.
60
65
70
75
80
85
90
95
100
105
110
115
120
125
LENGTH (mm.)

Table III: 5. Percentage weight-frequency for juveniles of <u>Anguilla rostrata</u> (LeSueur) in freshwater.

Locations	Weight classes (gms.) .10-.19	.20-.29	.30-.39	.40-.49	.50-.59	.60-.69	.70-.79	.80-.89	.90-.99	1.00-1.09
Petty Harbour		1.48 (4)	4.44 (12)	13.32 (36)	17.39 (47)	14.43 (39)	16.65 (45)	7.40 (20)	3.70 (10)	3.33 (9)
Beavarloe 1971	13.02 (3)	39.06 (9)	17.36 (4)	13.02 (3)	4.34 (1)	8.68 (2)	-	-	4.34 (1)	
Beavarloe 1972	1.96 (3)	27.44 (28)	42.14 (43)	19.60 (20)	7.84 (8)	0.98 (1)				

Locations	1.10-1.19	1.20-1.29	1.30-1.39	1.40-1.49	1.50-1.59	1.60-1.69	1.70-1.79	1.80-1.89	1.90-1.99	2.00-2.09
Petty Harbour	4.44 (12)	4.07 (11)	2.22 (6)	3.70 (10)	1.11 (3)	0.37 (1)	0.37 (1)	0.37 (1)	0.74 (2)	0.37 (1)
Beavarloe 1971										
Beavarloe 1972										

Figure III: 14. Weight frequency distributions of juveniles of <u>Anguilla rostrata</u> (LeSueur).



% FREQUENCY
40
30
20
10
Boswarlos 1971
Boswarlos 1972
Petty Hbr.
.10 .20 .30 .40 .50 .60 .70 .80 .90 1.00 1.10 1.20 1.30 1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10
WEIGHT (gms.)

of 0.35 gms and the mode occurred at the 0.345 gm mark.

The Petty Harbour sample ranged in weight from 0.22 to 2.09 gms. The mean weight for this group was 0.77 gms and the modal group occurred at the 0.445 gm mark.

The number of specimens examined are shown in brackets below the percentages in Table III. 3, III. 4 and III. 5.

6. <u>Age-length Relationship of Juveniles</u>

Mean length, calculated length, range in length and annual increments in length are shown in Table III. 6 a-c. The mean length for each age group and annual increments are also shown graphically in Figure III. 15.

After the first year of freshwater life the eels from the Boswarlos 1972 sample showed a slightly faster growth rate than that of the sample taken in 1971. The 1972 sample had a mean length of 71.0 mm at age one while the 1971 sample had a mean length of 66.2 mm. The 1971 sample, however, showed faster growth in the second year of freshwater life with an annual increment of 6.3 mm. The 1972 sample grew slower with an annual increment of 5.1 mm.

Table III: 6a. Mean length, calculated length, range in length and annual increments in length for juveniles of <u>Anguilla rostrata</u> (LeSueur) in freshwater.

Age group	I	II	III	IV
Boswarlos 1971				
Mean length	6.62	7.25	7.75	8.20
Calculated length	6.62	7.36	7.83	8.18
Range in length	5.6	7.1	7.7	8.2
	8.7	7.4	7.8	
Annual increments	-	0.63	0.50	0.45
No. of specimens	18	2	2	1

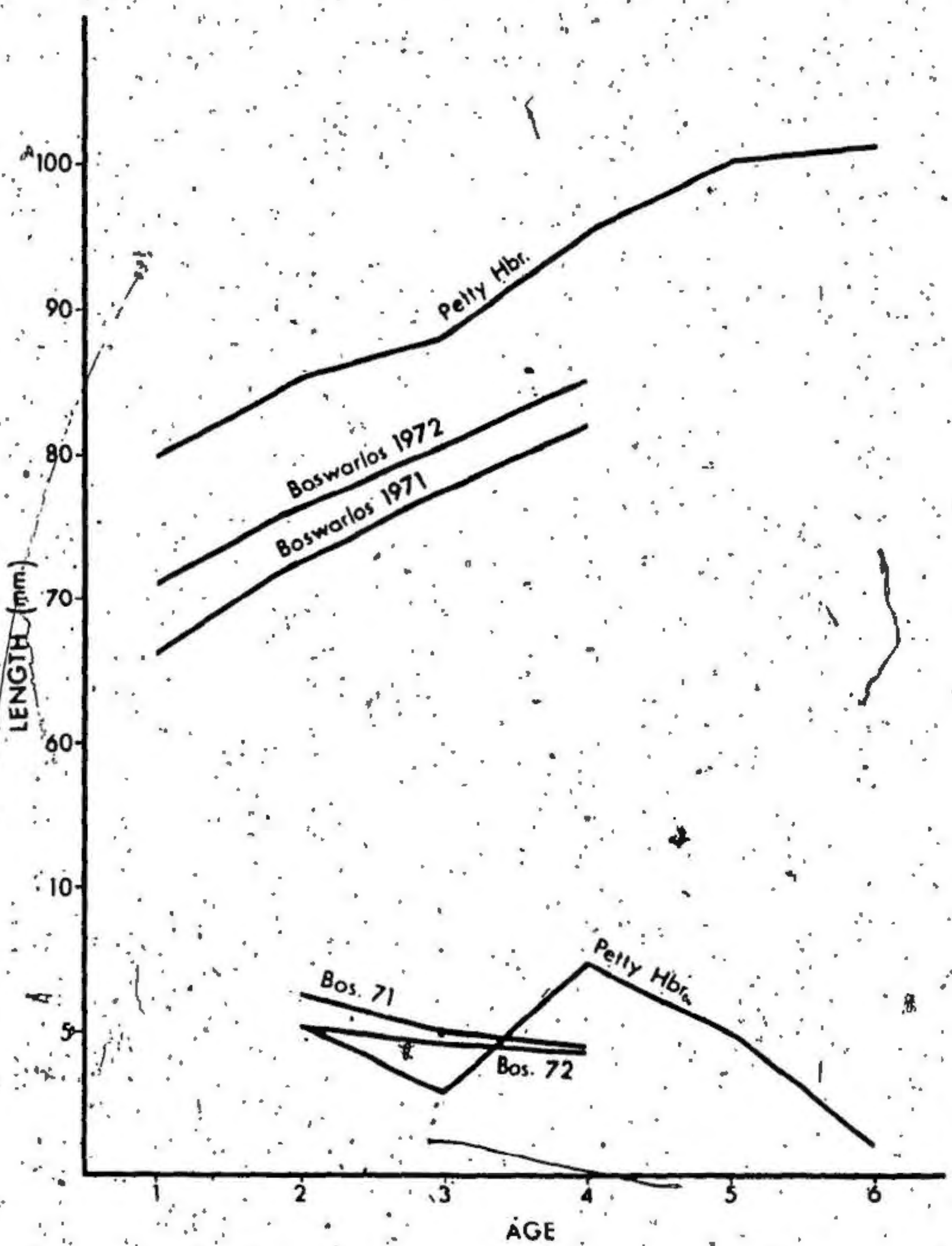
Table III: 6b. Mean length, calculated length, range in length and annual increments in length for juveniles of <u>Anguilla rostrata</u> (LeSueur) in freshwater.

Age group	I	II	III	IV
Boswarlos 1972				
Mean length	7.10	7.61	8.07	8.50
Calculated length	7.10	7.70	8.07	8.35
Range in length	6.1-	7.5-	7.9-	8.5-
	8.1	7.7	8.2	
Annual increments	-	0.51	0.46	0.43
No. of specimens	91	6	4	1

Table III: 6c. Mean length, calculated length, range in length and annual increments in length for juveniles of *Anguilla rostrata* (LeSueur) in freshwater.

Age group	I	II	III	IV	V	VI	VII
Petty Harbour							
Mean length	7.99	8.51	8.80	9.53	10.03	10.14	8.25
Calculated length	7.62	8.51	9.08	9.50	9.85	10.14	10.40
Range in length	6.4–	6.8–	6.5–	6.9–	8.1–	8.6–	7.7–
	9.7	11.0	12.9	12.8	12.3	12.5	8.8
Annual increments	–	0.52	0.29	0.73	0.50	0.11	–
No. of specimens	16	38	96	80	27	11	2

Figure III: 15. Mean length for each age group and annual increments in length of juveniles of *Anguilla rostrata* (LeSueur). The annual increments in length are shown at the bottom of the graph.



100
90
80
70
60
10
5
LENGTH (mm.)
Petty Hbr.
Boswarlos 1972
Boswarlos 1971
Bos. 71
Bos. 72
Petty Hbr.
1
2
3
4
5
6
AGE

Beyond the second year of freshwater life the 1971 sample grew faster than those taken in 1972. At age four, lengths were almost identical. The 1971 sample had a mean length of 82.0 mm while the mean length of the 1972 sample was 85.0 mm. In general growth was irregular and rather slow.

The Petty Harbour sample was larger than the Boswarlos samples after one year in freshwater with a mean length of 79.9 mm as shown by the annual increments, (Table III. 6 a-c). However, overall growth for this sample was slower than for the two Boswarlos samples. In addition, growth of Petty Harbour eels was more irregular than for the other areas sampled.

Calculated growth in length for each area and age group is shown in Table III. 6 a-c and in Figure III. 16.

For easier graphical comparison and to obtain a mathematical expression for growth in length the age-length data was transformed to the log regression form.

$\log L = \log a + b\ (\log A)$ is the logarithmic form of the exponential $L = aA^b$. The calculated age-length relationship is represented by the following equations.

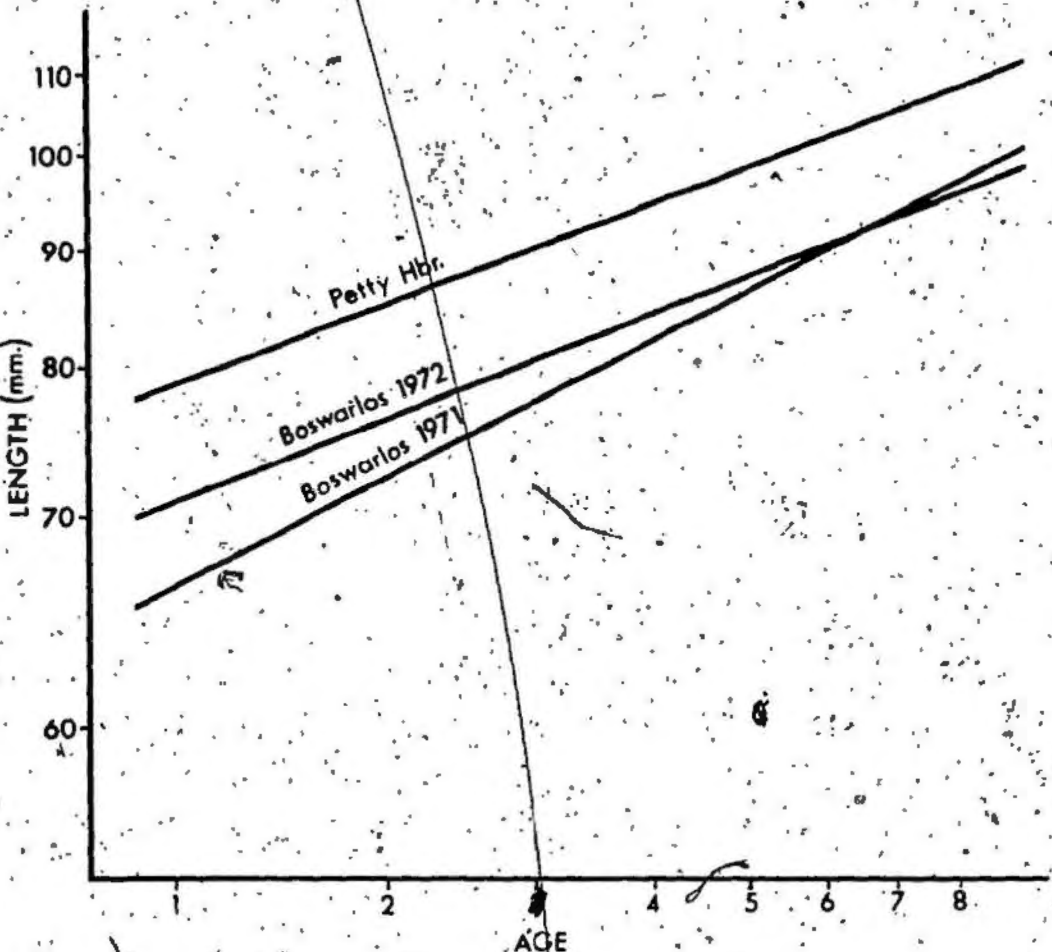
Boswarlos 1971 -

$$\log L = .8209 + .1526(\log A)$$

Boswarlos 1972

$$\log L = .8513 + .1165(\log A)$$

Figure III: 16. Calculated growth in length of juveniles of *Anguilla rostrata* (LeSueur).



110
100
90
80
70
60
LENGTH (mm)
Petty Hbr.
Boswarlos 1972
Boswarlos 1971
1
2
3
4
5
6
7
8
AGE

Petty Harbour -

$$\log L = .8819 + .1595(\log A)$$

The Boswarlos 1971 sample showed the fastest growth pattern followed by the Boswarlos 1972 sample and finally the Petty Harbour group. At age one the Boswarlos 1971 group was 5.2 mm. shorter than the 1972 group but by age seven both groups were the same size.

As shown in the graph (Figure II. 16.) the Petty Harbour population was larger at age one but subsequent growth was slower than the other samples producing a gradual convergence of the growth lines.

7. Age-weight Relationships

Data on mean weight, calculated weight, range in weight and annual increments in weight for the samples of juveniles collected appears in Table III. 7 a-c and in Figure III. 17.

After the first year of freshwater life the Petty Harbour eels were larger than the one year old fish contained in the Boswarlos samples. The fastest growth in weight, overall, was displayed by the Boswarlos 1971 sample. The annual increments for this group were slightly larger than for the Boswarlos 1972 sample and

Table III: 7a. Mean weight, calculated weight, range in weight and annual increments in weight for juveniles of *Anguilla rostrata* (LeSueur) in freshwater.

Age group	I	II	III	IV
Boswarlos 1971				
Mean weight	0.34	0.61	0.89	1.07
Calculated weight	0.34	0.61	0.86	1.09
Range in weight	0.17–	0.57–	0.85–	1.07–
	0.98	0.65	0.93	–
Annual increment	–	0.27	0.28	0.18
No. of specimens	18	2	2	1

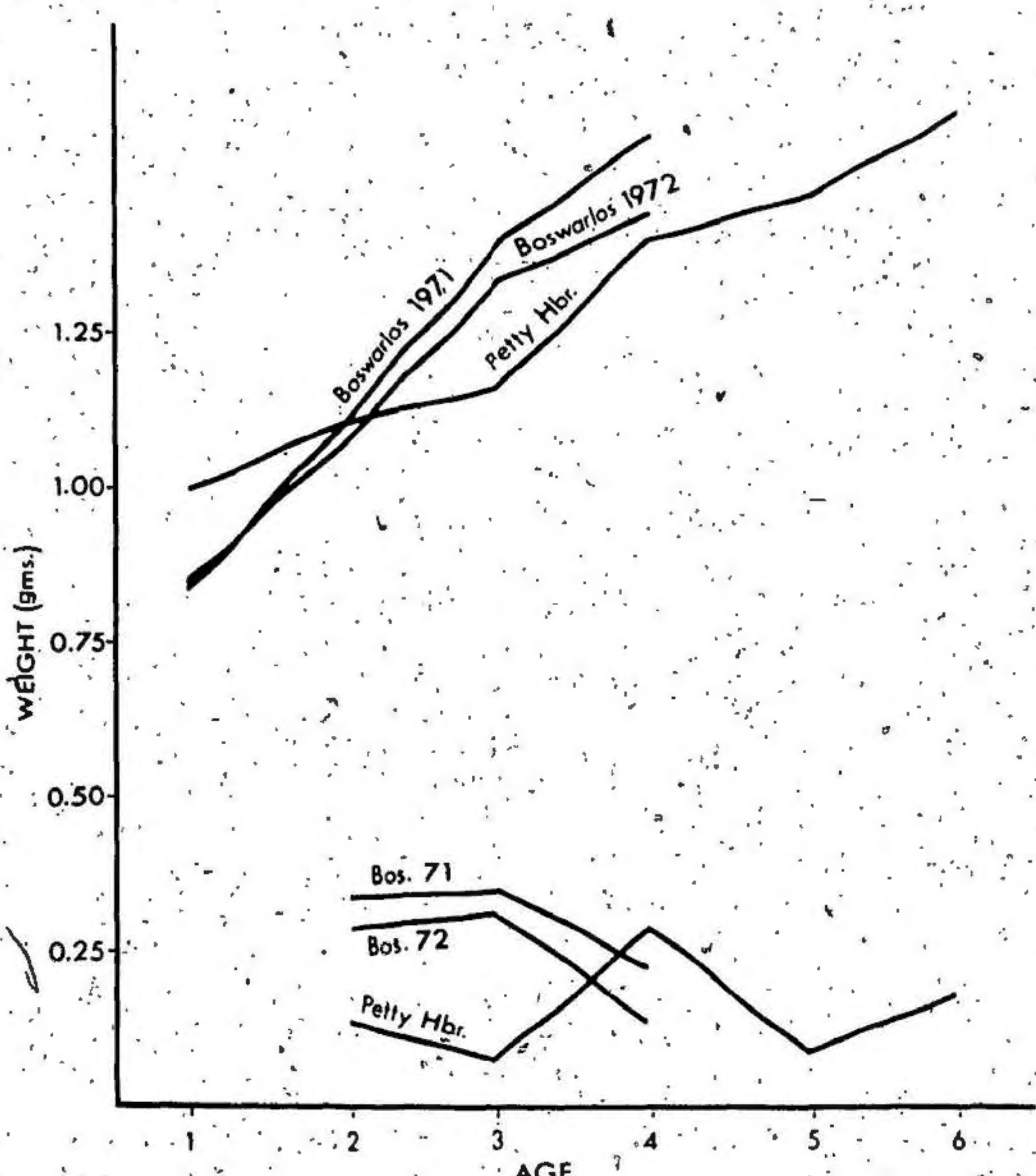
Table III: 7b. Mean weight, calculated weight, range in weight and annual increments in weight for juveniles of <u>Anguilla rostrata</u> (LeSueur) in freshwater.

Age group	I	II	III	IV
Boswarlos 1972				
Mean weight	0.35	0.58	0.83	0.94
Calculated weight	0.35	0.58	0.78	0.96
Range in weight	0.13-	0.51-	0.74-	0.94-
	0.67	0.69	0.85	-
Annual increment	-	0.23	0.25	0.11
No. of specimens	9[illegible]	6	4	1

Table III: 7c. Mean weight, calculated weight, range in weight and annual increments in weight for juveniles of *Anguilla rostrata* (LeSueur) in freshwater.

Age group	I	II	III	IV	V	VI	VII
Petty Harbour							
Mean weight	0.50	0.61	0.67	0.90	0.97	1.11	0.53
Calculated weight	0.42	0.61	0.76	0.89	1.01	1.11	1.21
Range in weight	0.22-	0.31-	0.30-	0.36-	0.45-	0.60-	0.43-
	0.77	1.29	1.59	1.98	1.81	2.09	0.62
Annual increment	-	0.11	0.06	0.23	0.07	0.14	-
No. of specimens	16	38	96	80	27	11	2

Figure III: 17. Mean weight for each age group and annual increments in weight of juveniles of *Anguilla rostrata* (LeSueur). The annual increments in weight are shown at the bottom of the graph.



Boswarlos 1971
Boswarlos 1972
Petty Hbr.
Bos. 71
Bos. 72
Petty Hbr.
1.25
1.00
0.75
0.50
0.25
WEIGHT (gms.)
1
2
3
4
5
6
AGE

considerably larger than for the Petty Harbour eels. Both Boswarlos samples grew rapidly in the I to III year range attaining mean weights of 0.89 and 0.83 gms respectively. The same age group in the Petty Harbour sample had a mean weight of 0.67 gms.

Growth slowed for both Boswarlos samples from age three to four while the Petty Harbour sample showed a rapid increase in weight. At age four the Boswarlos 1971 and 1972 samples weighed 1.07 and 0.94 gms respectively. For the same age group the Petty Harbour eels had increased in weight to a mean of 0.90 gms. As shown by the annual increments the Petty Harbour eels tended to grow more slowly and irregularly than the other populations sampled.

Calculated growth in weight for each age group of juveniles sampled appears in Table III. 7 a-c and in Figure III. 18.

Log regression transformations of the form log W = log a+b (log A) were used to calculate growth in weight. The equations expressing this relationship for the three populations studied are as follows.

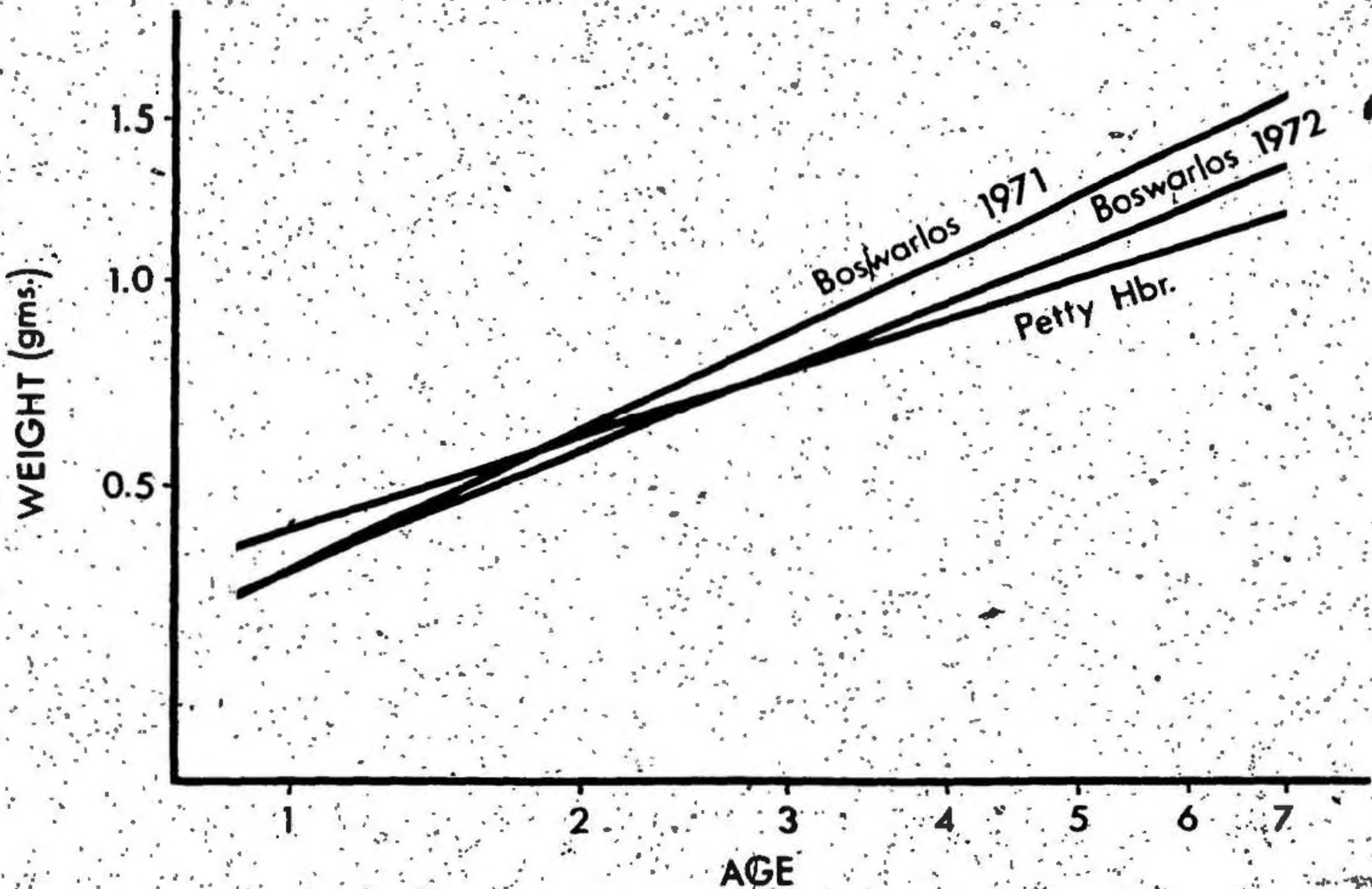
Boswarlos 1971 -

$$\log W = \bar{1}.5315 + \bar{1}.8432(\log A)$$

Boswarlos 1972 -

$$\log W = \bar{1}.5441 + \bar{1}.7286(\log A)$$

Figure III: 18. Calculated growth in weight of juveniles of *Anguilla rostrata* (LeSueur).


WEIGHT (gms.)
1.5
1.0
0.5
Boswarlos 1971
Boswarlos 1972
Petty Hbr.
1
2
3
4
5
6
7
AGE

Petty Harbour -

$$\log W = \bar{1}.6205 + \bar{1}.5476(\log A)$$

The Boswarlos 1971 eels showed the fastest growth rate followed by the Boswarlos 1972 sample and finally the Petty Harbour sample. Up until age three growth in weight was similar for all the populations sampled. In subsequent years, however, the two Boswarlos samples continued to grow at the previous rate while the Petty Harbour sample showed a considerable decrease in its rate of growth in weight.

8. <u>Length-weight Relationship of Juveniles</u>

Length-weight relationships were determined by log regression transformations of the form $\log W = \log a + b(\log L)$. This relationship is expressed by the following equations and is shown graphically in Figure III. 19 and Figure III. 20.

Boswarlos 1971 -

$$\log W = \bar{1}.1320 + \bar{1}.8835(\log L)$$

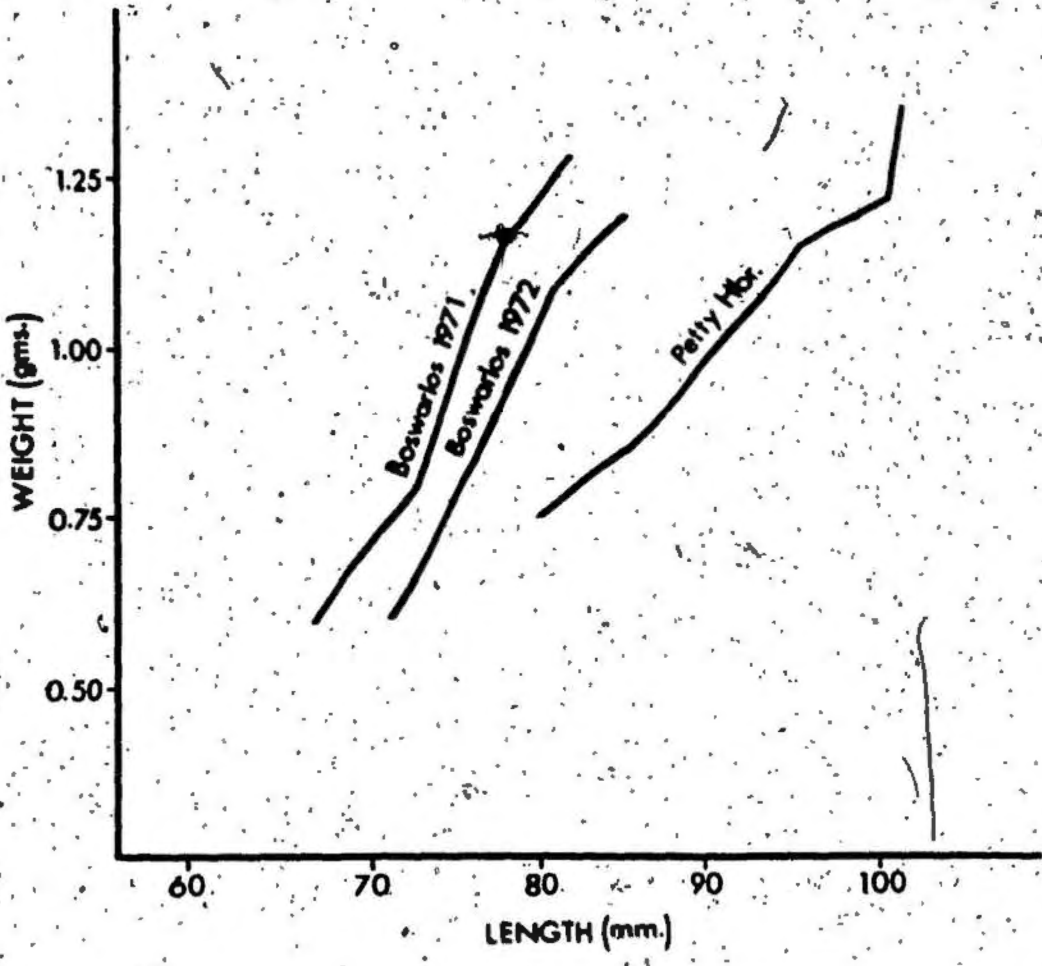
Boswarlos 1972 -

$$\log W = \bar{1}.3424 + \bar{1}.5627(\log L)$$

Petty Harbour -

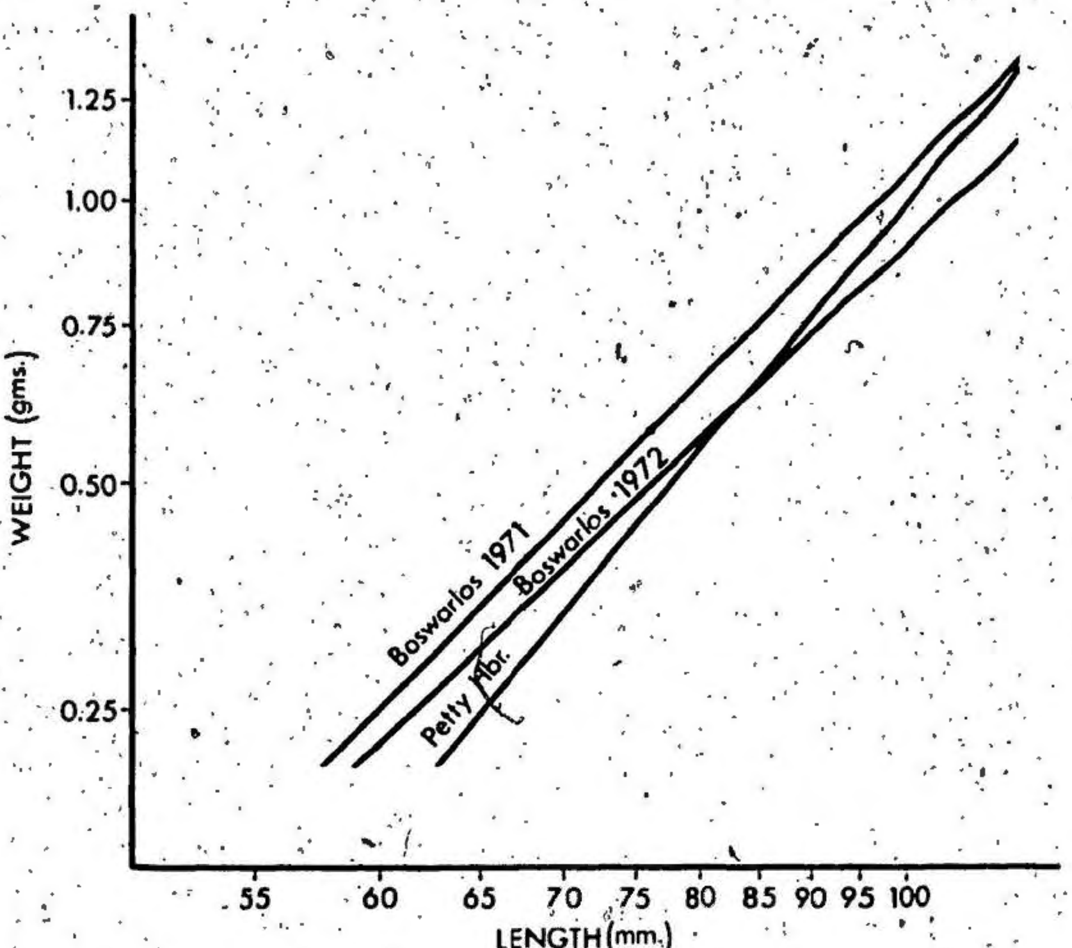
$$\log W = \bar{1}.1501 + \bar{1}.8515(\log L)$$

Figure III: 19. Length-weight relationship of juveniles of _Anguilla rostrata_ (LeSueur).



WEIGHT (gms.)
1.25
1.00
0.75
0.50
60
70
80
90
100
LENGTH (mm.)
Boswarlos 1971
Boswarlos 1972
Petty Hbr.

Figure III: 20. Calculated length-weight relationship of juveniles of <u>Anguilla rostrata</u> (LeSueur).



WEIGHT (gms.)
1.25
1.00
0.75
0.50
0.25
Boswarlos 1971
Boswarlos 1972
Petty Hbr.
55
60
65
70
75
80
85
90
95
100
LENGTH (mm.)

The fastest growth pattern in the observed data was displayed by the Boswarlos 1971 sample followed by the Boswarlos 1972 eels and finally the Petty Harbour sample. As growth progressed the two Boswarlos samples showed a decrease in growth rate while a corresponding increase was noted for the Petty Harbour group.

The fastest growth pattern derived from the calculated relationship occurred in the Petty Harbour sample followed by that of the Boswarlos 1971 group. The growth patterns of the two samples discussed above were approximate but growth of the Boswarlos 1972 population was appreciably slower.

B. <u>Food of Elvers and Juveniles</u>

The food of elvers and juveniles from the various localities is listed in Table III. 8 a-e.

Benthic organisms were the dominant food in all areas sampled. Chironomid larvae were most frequently utilized in all but one of the samples. Lesser food types were leeches (<u>Hirudinea</u>) and caddis flies (<u>Trichoptera</u>). Pelagic fauna was not important in the diet of elvers and juveniles from any of the areas sampled. The most common terrestrial food were adult Diptera. Items such as vegetation and unidentifiable material of

TABLE III: 8a. The food of juvenile eels expressed as percentages of occurrence, number dry weight. Petty Harbour 1971.

	Frequency	% occurr.	Number	%	Wt. (gms.)	% wt.
BENTHIC						
Chironomidae (Larvae)	68	25.16	270	86.40	0.0102	49.98
Hirudinea	1	0.37	1	0.32	0.0007	3.43
TOTAL	--	--	271	86.72	0.0109	53.41
PELAGIC						
Amphipoda	--	0.37	1	0.32	0.0001	0.49
TOTAL	--	--	1	0.32	0.0001	0.49
TERRESTRIAL						
Dolichopodinae	20	7.40	30	9.60	0.0060	29.40
Cercopidae	1	0.37	1	0.32	0.0006	2.94
Culicidae	7	2.59	8	2.56	0.0004	1.96
TOTAL	--	--	39	12.84	0.0070	34.30
OTHERS						
Vegetation	--	--	--	--	--	--
Indistinguishable	30	11.10	--	--	0.0025	12.25
Empty	171	63.27	--	--	--	--
TOTAL	--	--	--	--	0.0025	12.25
GRAND TOTAL	--	--	311	100.00	0.0205	100.00

TABLE III: 8b. The food of elvers expressed as percentages of occurrence, number and dry weight. Boswarlos 1971.

	Frequency	% occurr.	Number	%	Wt.(gms.)	% wt.
BENTHIC						
Chironomidae (Larvae)	108	89.64	1995	99.70	0.0551	97.85
Culicidae (Pupa)	6	4.98	6	0.25	0.0002	0.35
Trichoptera	2	1.66	2	0.05	trace	0.01
TOTAL						
PELAGIC						
----------	--	--	--	--	--	--
TOTAL	--	--	--	--	--	--
TERRESTRIAL						
----------	--	--	--	--	--	--
TOTAL	--	--	--	--	--	--
OTHERS						
Vegetation	1	0.83	--	--	trace	0.01
Indistinguishable	12	9.96	--	--	0.0010	1.78
Empty	8	6.64	--	--	--	--
TOTAL	--	--	--	--	0.0010	1.79
GRAND TOTAL	--	--	2003	100.00	0.0563	100.00

TABLE III: 8c. The food of juvenile eels expressed as percentages of occurrence, number and dry weight. Boswarlos 1971.

	Frequency	% occurr.	Number	%	Wt. (gms.)	% wt.
BENTHIC						
Chironomidae (Larvae)	23	100.00	330	99.90	0.0091	99.97
Culicidae (Pupa)	2	8.68	2	0.10	trace	0.01
TOTAL	--	--	332	100.00	0.0091	99.98
PELAGIC						
------	--	--	--	--	--	--
TOTAL	--	--	--	--	--	--
TERRESTRIAL						
--------	--	--	--	--	--	--
TOTAL	--	--	--	--	--	--
OTHERS						
Vegetation	--	--	--	--	--	--
Indistinguishable	3	13.02	--	--	trace	0.02
Empty	--	--	--	--	--	--
TOTAL	--	--	--	--	trace	0.02
GRAND TOTAL	--	--	332	100.00	0.0091	100.00

TABLE III: 8d. The food of elvers expressed as percentages of occurrence, number and dry weight. Boswarlos 1972.

	Frequency	% occurr.	Number	%	Wt.(gms.)	% wt.
BENTHIC						
Chironomidae (Larvae)	18	18.36	108	—	0.0351	9.44
Enchytraeidae	32	32.64		—	0.1275	34.30
TOTAL	—	—	108	—	0.1626	43.74
PELAGIC						
———	—	—	—	—	—	—
TOTAL	—	—	—	—	—	—
TERRESTRIAL						
———	—	—	—	—	—	—
TOTAL	—	—	—	—	—	—
OTHER						
Vegetation	4	4.08	—	—	0.0004	0.10
Indistinguishable	70	71.40	—	—	0.2087	56.15
Empty	5	5.10	—	—	—	—
TOTAL	—	—	—	—	0.2091	56.25
GRAND TOTAL	—	—	—	—	0.3717	100.00

TABLE III: 8e. The food of juvenile eels expressed as percentages of occurrence, number and dry weight. Boswarlos 1972.

	Frequency	% occurr.	Number	%	Wt.(gms.)	% wt.
BENTHIC						
Chironomidae(Larvae)	19	18.62	129	-	0.0370	9.66
Enchytraeidae	36	35.28		-	0.1283	33.51
TOTAL	--	--	129	-	0.1653	43.17
PELAGIC						
Gammaridae	1	0.92	1	-	trace	0.01
TOTAL	--	--	1	-	trace	0.01
TERRESTRIAL						
Muscidae	1	0.92	2	-	0.0001	0.02
TOTAL	--	--	2	-	0.0001	0.02
OTHER						
Vegetation	4	3.92	--	--	0.0002	0.05
Indistinguishable	74	72.52	--	--	0.2172	56.73
Empty	1	0.98	--	--	--	--
TOTAL	--	--	--	--	0.2174	56.78
GRAND TOTAL	--	--	132	100.00	0.3828	100.00

food value are included under the heading "Other" in Table III. 8 a-e.

1. Petty Harbour (Table III. 8a)

The dominant food organisms in this sample were Chironomid larvae which rated higest in the three types of analysis in the table. Terrestrial fauna were of lesser importance as food with two families of the true adult flies (Diptera) being present in small numbers.

The number of empty stomachs was large with 63.0% of the sample having no stomach contents. The number of stomachs containing no identifiable material was very low.

2. Boswarlos 1971 Elvers (Table III. 8b)

In this sample the dominant food organism was Chironomid larvae which comprised approximately 90.0% of the food taken.

Other food types represented were caddis flies (Trichoptera) and mosquito pupae (Culicidae) but these were quite unimportant, occurring in less than 5.0% of the stomachs examined. The occurrence of indistinguishable gut contents, debris and empty stomachs was very low in this sample.

3. <u>Boswarlos 1971 Juveniles (Table III. 8c)</u>

The most important food in this sample were the Chironomid larvae which occurred in every stomach examined. The only other food type occurring was mosquito pupae (<u>Culuicidae</u>). There were no empty stomachs in this sample.

4. <u>Boswarlos 1972 Elvers (Table III. 8d)</u>

Annelid worms (<u>Enchytraeidae</u>) were the dominant food organism of this sample. These worms occurred in 32.64% of the stomachs examined and were also present in the largest numbers as well as having the largest percentage dry weight (34.30%). Their importance as a food is somewhat biased by the large number of stomachs with indistinguishable contents. It is suspected that this well digested material consists mostly of Annelids but positive identification could not be made.

Chironomid larvae were the next most important food occurring in 18.36% of the stomachs examined.

Vegetation and debris were present in a large number of stomachs. It is suspected that this material was ingested incidentally along with the Annelid worms discussed above.

5. <u>Boswarlos 1972 Juveniles (Table III. 8e)</u>

As in the elver sample discussed above Annelid worms were the dominant food occuring in 35.28% of the stomachs.

Large numbers of stomachs with unidentifiable material in them were characteristic of ~~this~~ sample.

Chironomid larvae were the second most important food. Food organisms were somewhat more varied in this sample. Specimens of the housefly (<u>Muscidae</u>) were present as well as an amphipod. Less than 1.0% of the stomachs in this sample were empty.

C. <u>Competition and Predation</u>

1. <u>A Comparison of the Food of Elvers, Juvenile Eels, Adult Eels and Brook Trout collected at Boswarlos</u>

Table III. 9 lists the foods taken by 79 brook trout (<u>Salvelinus fontinalis</u>) whose stomachs were examined.

Table III. 10. shows the food of 20 adult eels also taken as part of the same investigation. This was compared with the food taken by elvers and juvenile eels (Table III. 8 a-e).

The trout examined ranged in length from 10.0 to 29.0 cms and consisted of 35 males and 44 females.

Table III. 9 The food of 79 brook trout (*Salvelinus fontinalis*) collected at Boswarlos Port au Port Penninsula, Newfoundland.

	Frequency	% occurr.	Number	%	Wt. (gms)	% wt
BENTHIC						
Chironomidae (larvae)	50	63.29	203	27.21	0.0145	0.48
Trichoptera (larvae)	34	43.03	93	12.47	0.1081	3.61
Culicidae (pupa)	21	26.58	27	3.62	0.0024	0.08
Amnicolidae	25	31.64	66	8.85	0.1284	4.29
Ephemeroptera (nymph)	5	6.32	6	0.80	0.0008	0.03
Ceratopogonidae	1	1.26	1	0.13	trace	0.01
Corixidae	7	8.86	7	0.94	0.0146	0.49
Huridirae	1	1.26	1	0.13	0.0060	0.20
Odonata (nymph)	14	17.72	24	3.22	0.1019	3.40
TOTAL	--	--	428	57.37	0.3767	12.59
PELAGIC						
A. rostrata (elver)	11	13.92	17	2.27	0.6505	21.73
G. aculeatus	9	11.39	12	1.61	0.7640	25.52
TOTAL	--	--	29	3.88	1.4145	47.25
TERRESTRIAL						
Formicidae	46	58.22	256	34.32	0.1632	5.45
Arachnida	5	6.32	6	0.80	0.0015	0.05
Culicidae (adult)	3	3.79	3	0.40	0.0004	0.01
Muscidae (adult)	6	7.59	9	1.21	0.0606	2.02
Pyralidoidea	8	10.12	9	1.21	0.0138	0.46
Limacidae	1	1.26	1	0.13	0.0117	0.39
Cercopidae	5	6.32	5	0.67	0.0079	0.26
TOTAL	--	--	289	38.74	0.2591	8.64
OTHERS						
Vegetation	5	6.32	--	--	0.0210	0.70
Indistinguishable	23	29.11	--	--	0.9224	30.81
Empty	10	12.65	--	--	--	--
TOTAL	--	--	--	--	0.9434	31.51
GRAND TOTAL	--	--	746	100.00	2.9937	100.00

TABLE III: 10. Food of 20 eels collected at Boswarlos Port au Port Penninsula, Newfoundland.

	Frequency	% occurr.	Number	%	Wt.(gms.)	% wt.
BENTHIC						
Chironomidae (Larvae)	15	75.00	83	38.60	0.0069	0.95
Trichoptera (Larvae)	15	75.00	59	27.44	0.0591	8.17
Culicidae (Pupa)	3	5.00	3	1.40	0.0001	0.01
Amnicolidae	10	50.00	21	9.78	0.0352	4.87
Odonata (Nymph)	7	35.00	18	8.37	0.0964	13.32
TOTAL	--	--	184	85.59	0.1977	--
PELAGIC						
A. rostrata	6	30.00	11	5.12	0.4210	58.19
S. fontinalis	1	5.00	1	0.47	0.0897	12.40
TOTAL	--	--	8	5.59	0.5107	--
TERRESTRIAL						
Formicidae	7	35.00	19	8.84	0.0128	
TOTAL	--	--	19	8.84	0.0128	1.77
OTHERS						
Vegetation	2	10.00	--	--	0.0001	0.01
Indistinguishable	9	45.00	--	--	0.0022	0.30
Empty	1	5.00	--	--	--	--
TOTAL	--	--	--	--	0.0023	--
GRAND TOTAL	--	--	215	100.00	0.7235	100.00

The eels ranged in length from 17.0 to 79.0 cms.

A comparison of the freshwater life of the eel and brook trout shows that both depend heavily on Chironomid larvae as food. This is especially evident when examined by the frequency of occurrence and number methods. However brook trout take a much greater variety of species from all three food types (benthic, pelagic and terrestrial) than do any of the eel stages. The benthic food of adult eels and trout is very similar with a total of five types of food being common to both species. The strict benthic feeding habits of the eel are apparent, however, when its intake of terrestrial food species (1 species) is compared with that of the trout (7 species).

Elvers and juveniles are unable, because of size to take fish of any kind as food but larger eels and trout commonly utilize sticklebacks (Gasterosteus aculeatus) and elvers themselves as food.

Caddis flies (Trichoptera), snails (Amnicolidae) and dragonfly nymphs (Odonata) were also important food species for adult eels and trout. These species were of very little importance as a food for the elver and juvenile stages of the eel.

In one sample elvers and juvenile eels fed heavily on Annelid worms (Enchytraeidae) but this species had no importance as a food for the larger eels and trout taken in the sample.

2. The Importance of Elvers as a Seasonal Food of Adult Eels and Brook Trout

As shown in Tables III. 9 and III. 10 elvers were important as a seasonal food of adult eels (30.0% occ.) and trout (14.0% occ.).

When analyzed by the number method their importance (5.12% for eels and 2.27% for trout) seems to be somewhat decreased. This decrease is attributable to the large numbers of insects, especially Chironomid larvae and ants (Formicidae) taken as food by the fish examined. However, the dry weight method demonstrated the importance of elvers as a seasonal food as they comprised 58.2% of the dry weight of all food taken by adult eels and 21.3 % of the weight of all food taken by trout.

D. Secondary Upstream Movement

1. Age and Growth

a. Frequency Distributions of Marine Juveniles

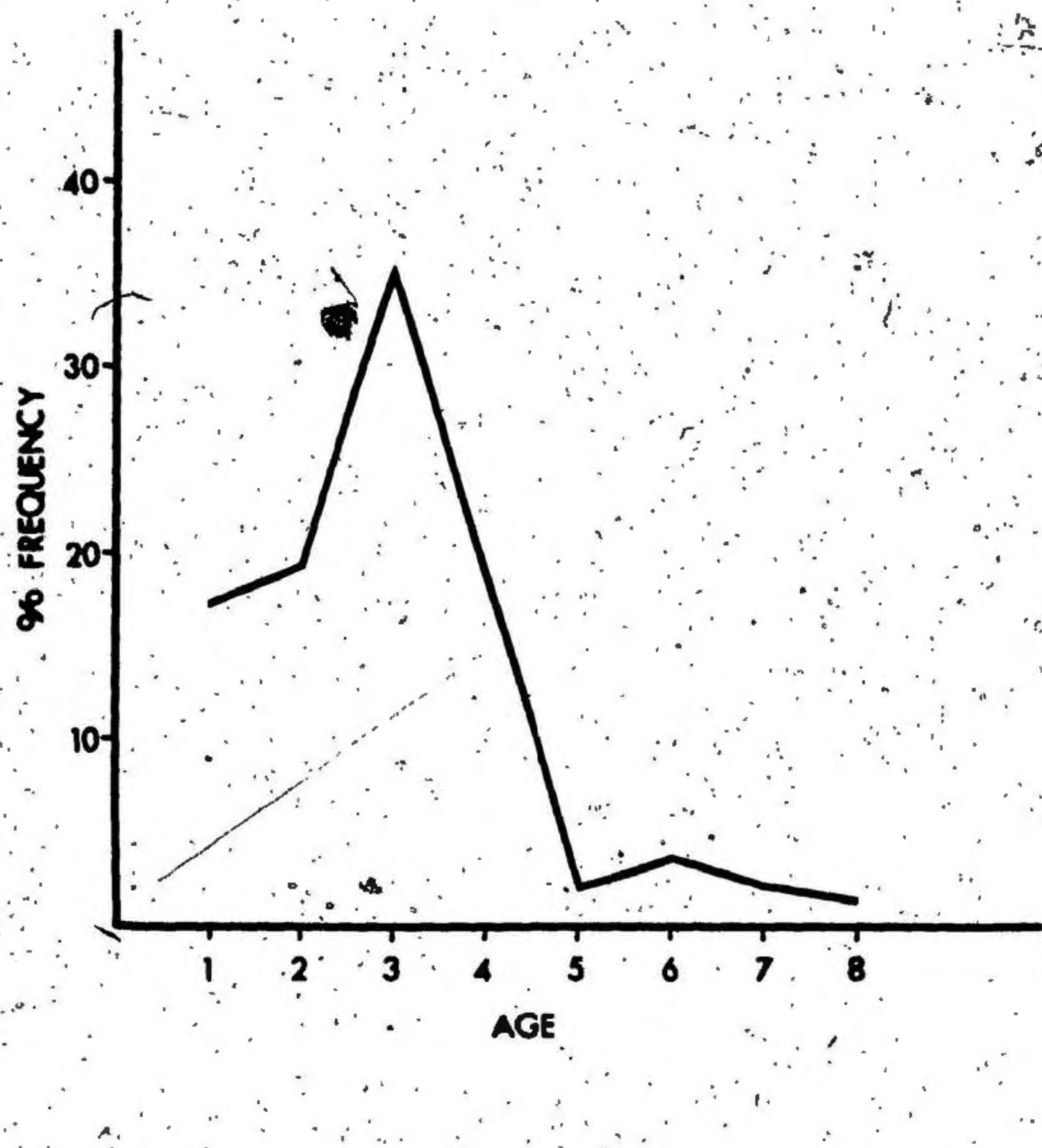
Age frequencies for the Trainvain Brook site (Figure II. 4.) are shown in Table III. 11 and Figure III. 21.

The mean age of eels at this site was 2.94 years and the modal group was comprised of three year old eels. The one to four year old group was prevalent in this sample while the five to eight year olds were scarce and represented only 8.99% of the sample.

Table III: 11. Percentage age frequency for marine juveniles of *Anguilla rostrata* (LeSueur).

Location	I	II	III	IV	V	VI	VII	VIII	Total Fish
	Age groups								
Trainvain Brook	17.25 (25)	19.32 (28)	35.19 (51)	18.63 (27)	2.07 (3)	3.45 (5)	2.07 (3)	1.38 (2)	144

Figure III: 21. Age frequency distributions of marine juveniles of *Anguilla rostrata* (LeSueur).



40
30
20
10
96 FREQUENCY
1
2
3
4
5
6
7
8
AGE

Length frequencies for this sample are shown in Table III. 12 and Figure III. 22.

The eels ranged in length from 67.0 mm to 162.0 mm. The modal group was represented by the 104.5 mm mark and the mean length of the sample was 112.0 mm.

Weight frequencies for the Trainvain Brook sample are shown in Table III. 13. and graphically in Figure III. 23.

The specimens ranged in weight from 0.24 gms to 4.28 gms. The mean weight of the sample was 1.74 gms and the mode occurred at the 1.245 gm mark.

The number of specimens examined are shown in brackets below the percentages in Tables III. 11, III. 12 and III. 13.

b. Age - length Relationship

Mean length, calculated length, range in length and annual increments in length are given in Table III. 24. The mean length for each age group and the annual increments are also shown graphically in Figure III. 24.

Presuming that the elvers which remained in the marine environment and those which migrated to fresh-water were the same size upon arrival in Newfoundland waters this sample (which remained in salt water) showed

Table III: 12. Percentage length frequency for marine juveniles of *Anguilla rostrata* (LeSueur).

Location	Length classes											Total
	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	Fish
Trainvain Brook	0.69 (1)	1.38 (2)	6.21 (9)	12.42 (18)	31.05 (45)	25.53 (37)	9.66 (14)	4.83 (7)	2.76 (4)	3.45 (5)	1.38 (2)	144

Figure III: 22. Length frequency distributions of marine juveniles of *Anguilla rostrata* (LeSueur).

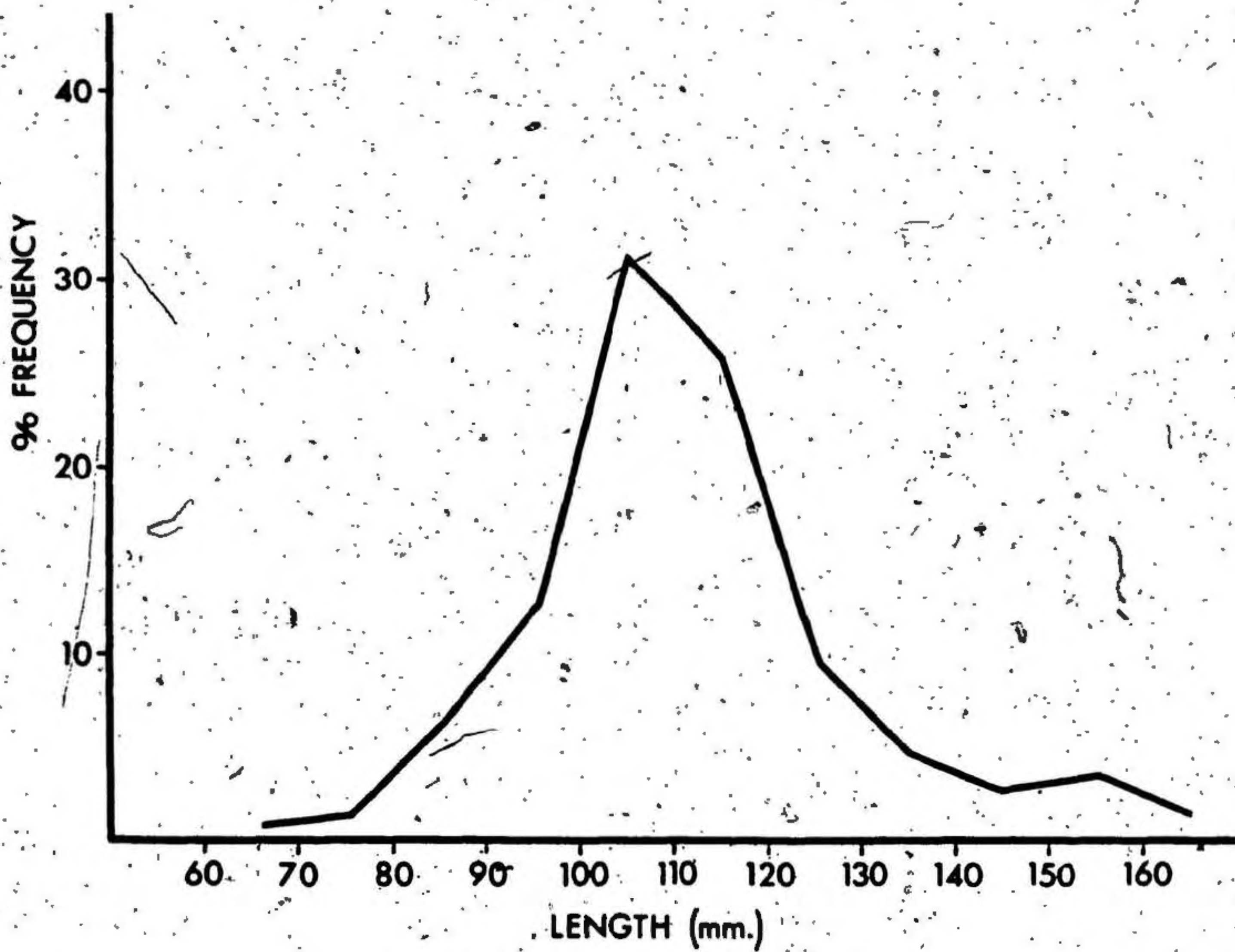
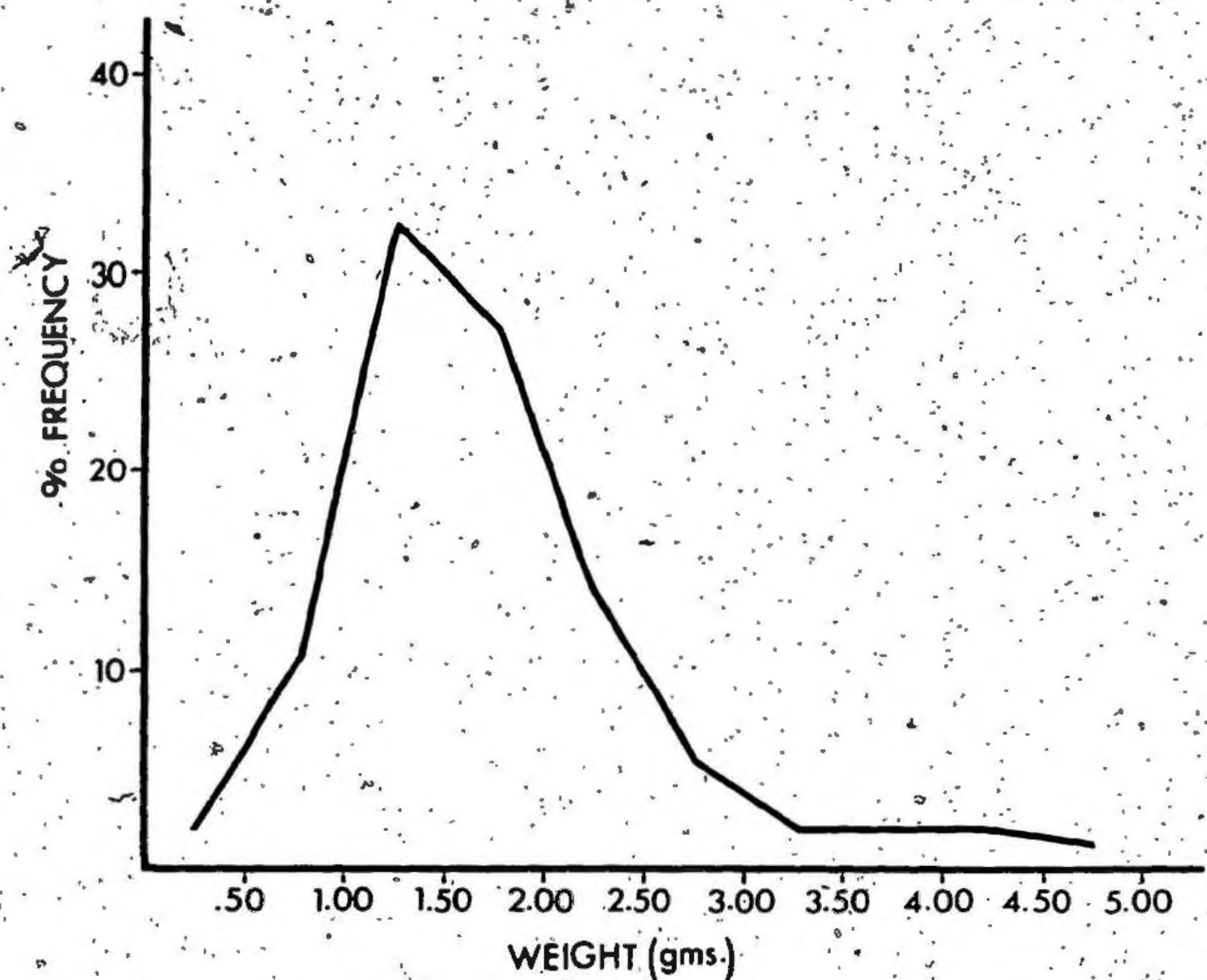

% FREQUENCY
40
30
20
10
60
70
80
90
100
110
120
130
140
150
160
LENGTH (mm.)

Table III: 13. Percentage weight frequency for marine juveniles of *Anguilla rostrata* (LeSueur).

Location	Weight classes										Total
	0-.49	.50-.99	1.00-1.49	1.50-1.99	2.00-2.49	2.50-2.99	3.00-3.49	3.50-3.99	4.00-4.49	4.50-4.99	Fish
Trainvain Brook	2.07	10.35	32.43	27.60	13.80	5.52	2.07	2.07	2.07	1.38	144
	(3)	(15)	(47)	(40)	(20)	(8)	(3)	(3)	(3)	(2)	

Figure III: 23. Weight frequency distributions of marine juveniles of <u>Anguilla rostrata</u> (LeSueur).

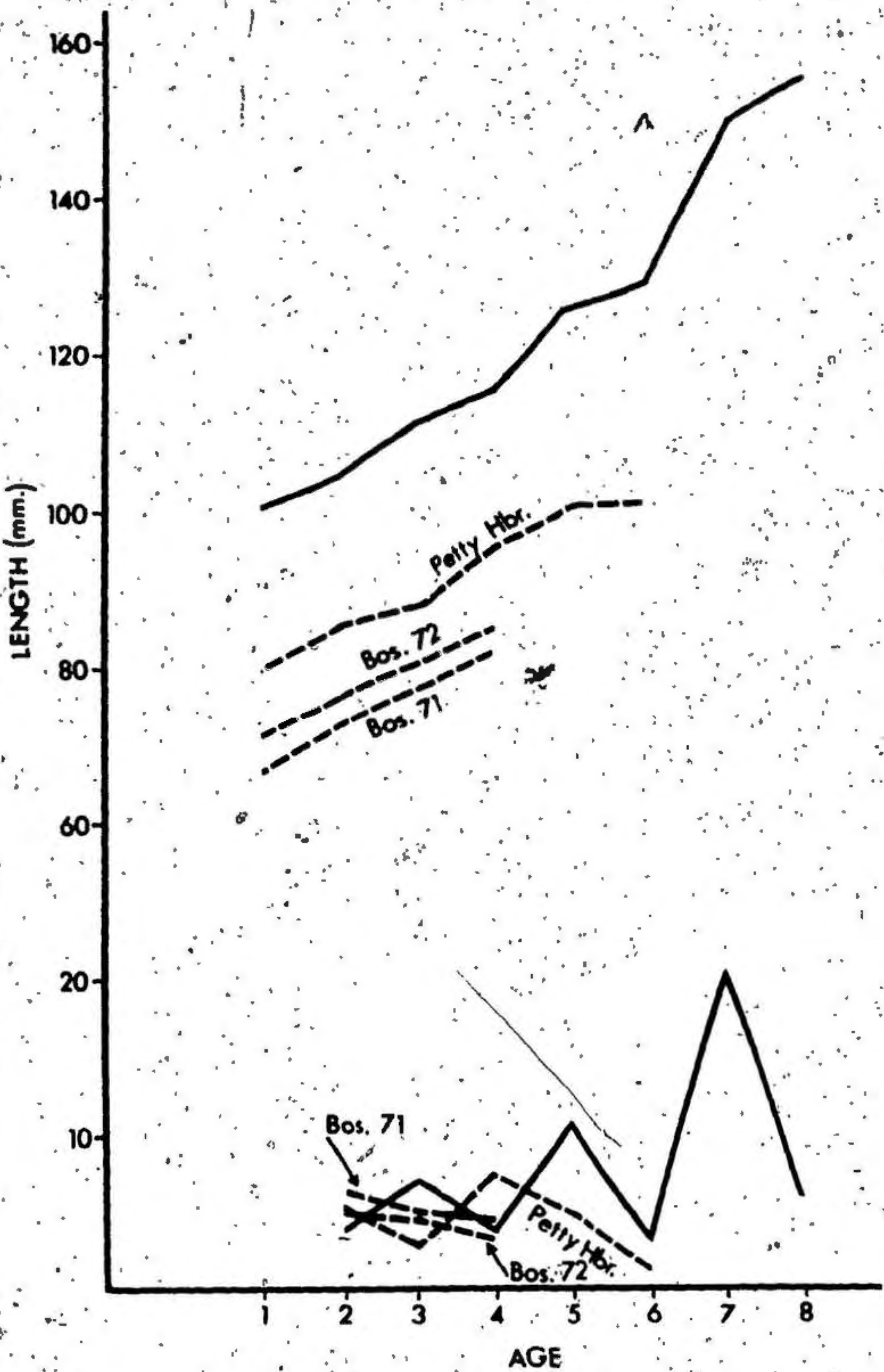


% FREQUENCY
40
30
20
10
.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
WEIGHT (gms.)

Table III: 14. Mean length, calculated length, range in length and annual increments in length for marine juveniles of *Anguilla rostrata* (LeSueur).

Age group	I	II	III	IV	V	VI	VII	VIII
Trainvain Brook								
Mean length	10.06	10.45	11.15	11.54	12.63	12.96	15.03	15.60
Calculated length	8.78	10.21	11.15	11.87	12.46	12.96	13.41	13.80
Range in length	7.0-12.8	8.4-12.7	7.5-13.2	8.8-15.0	10.6-14.0	10.1-15.6	14.2-16.2	15.1-16.1
Annual increments	--	0.39	0.70	0.39	1.09	0.33	2.07	0.57
No. of specimens	25	28	50	27	3	5	3	2

Figure III: 24 Mean length for each age group and annual increments in length of marine juveniles of <u>Anguilla</u> <u>rostrata</u> (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by the use of a broken line.



160
140
120
100
80
60
20
10
LENGTH (mm.)
Petty Hbr.
Bos. 72
Bos. 71
Bos. 71
Petty Hbr.
Bos. 72
1
2
3
4
5
6
7
8
AGE

especially rapid growth in the first year of post-elver life. At age one the specimens in this sample were almost twice as long as that of an average elver at the time of entry into freshwater.

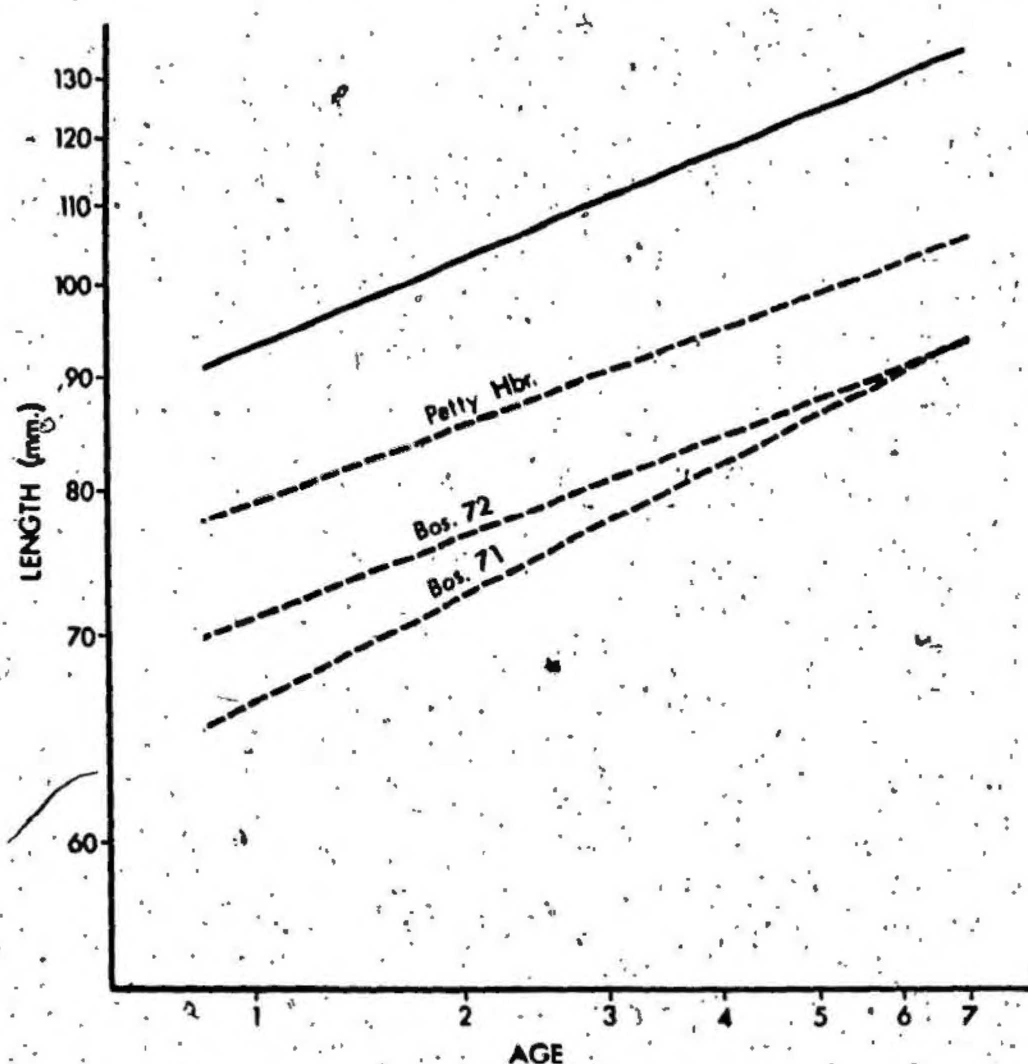
In subsequent years growth slowed considerably and averaged about 5.0 mm per year. As in the freshwater samples growth was irregular with annual increments ranging from 3.3 mm to 20.7 mm per year. Over a period of eight years in salt water this sample increased in length from approximately 50.0 mm to about 155.0 mm. This represented a gain of 105.0 mm over an eight year period.

Calculated growth in length for this sample is shown in Table III. 14 and Figure III. 25. For easier graphical comparison the age - length data was transformed to the log regression form, $\log L = \log a + b(\log A)$. The calculated age - length relationship is represented by the following equation.

$$\log L = .9434 + .2175(\log A)$$

This sample showed a faster growth in length than any of the freshwater populations sampled. At age one the calculated length was 93.0 mm as compared with 79.0 mm for the fastest growing freshwater sample. At age eight the Trainvain Brook eels had increased in length to 138.0 mm while the fastest growing sample of resident

Figure III: 25. Calculated growth in length of marine juveniles of *Anguilla rostrata* (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by the use of a broken line.



LENGTH (mm.)
130
120
110
100
90
80
70
60
Petty Hbr.
Bos. 72
Bos. 71
1
2
3
4
5
6
7
AGE

freshwater eels had a calculated length of 108.0 mm.

While growth in salt water was fastest overall it would seem that the very fast growth ~~in~~ the first year of post elver life was chiefly responsible for the higher length values recorded for this collection as opposed to the freshwater populations sampled.

c. Age - Weight Relationship

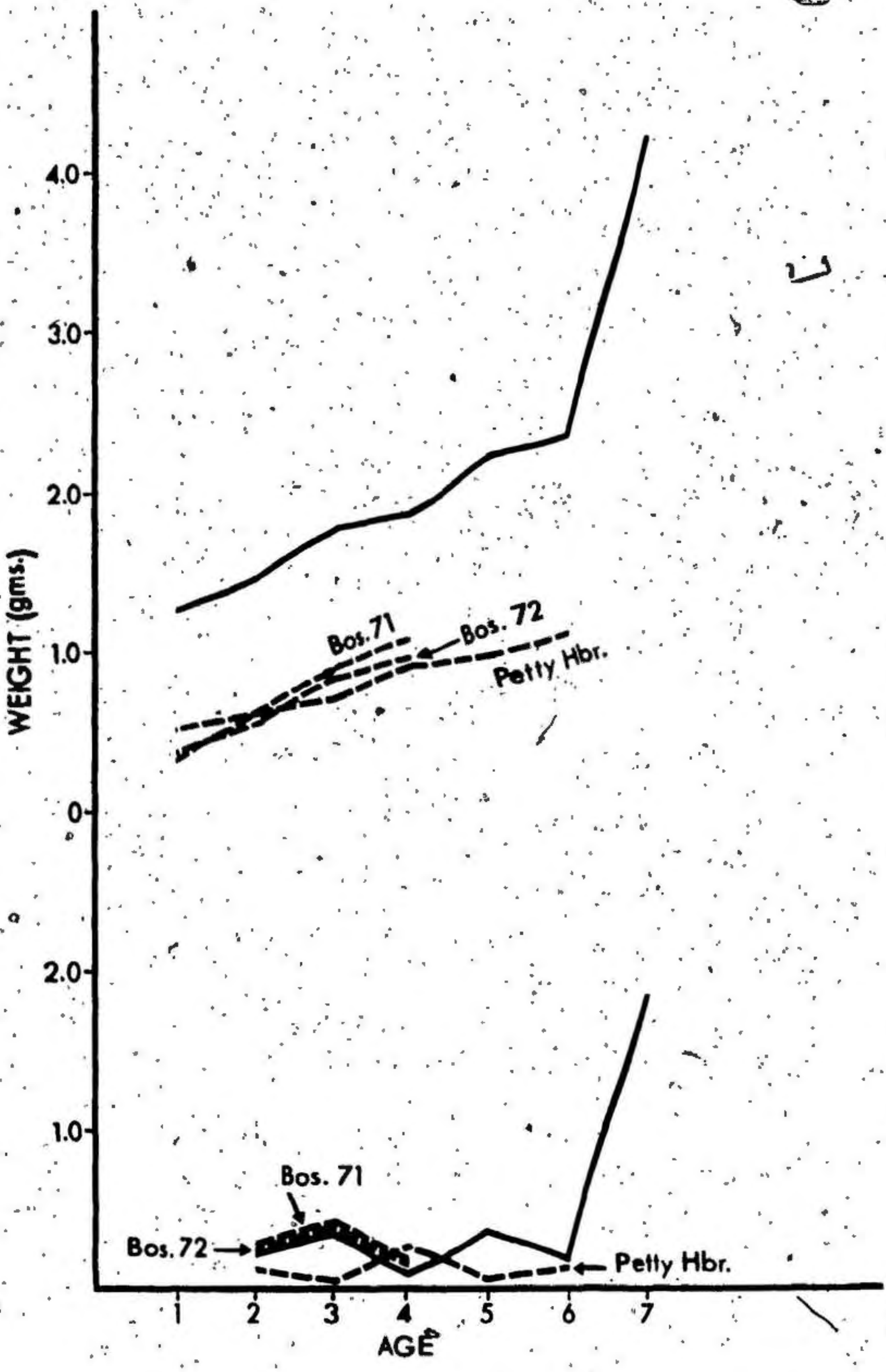
Data on mean weight, calculated weight, range in weight and annual increments in weight for this sample appear in Table III. 15 and are presented graphically in Figure III. 26.

The rapid first year growth of the marine sample is reflected in the weight data with age one specimens having an average weight of 1.25 gms. The fastest growing freshwater sample averaged 0.50 gms for the age one group.

After the first year, however, growth in weight was slower and more irregular, never exceeding 2.0 gms per year and with an average yearly increment of 0.50 gms. Over a period of seven years this sample increased from a mean weight of 1.25 gms at age one to a mean of 4.25 gms at age seven.

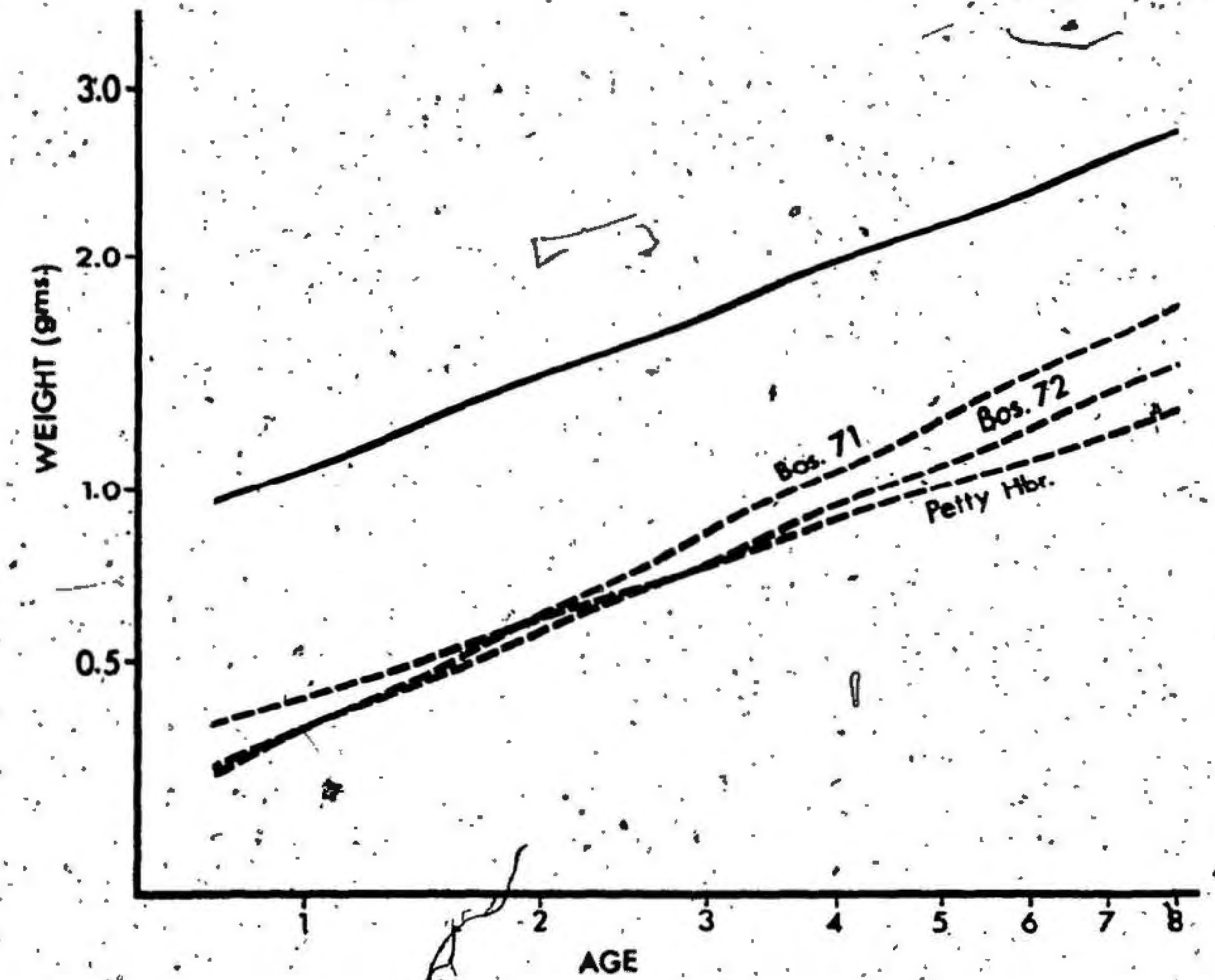
Calculated growth in weight for the Trainvain Brook sample appears in Table III. 15 and Figure III. 27.

Figure III: 26. Mean weight for each age group and annual increments in weight of marine juveniles of Anguilla rostrata (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by the use of a broken line.



4.0
3.0
2.0
1.0
0
2.0
1.0
WEIGHT (gms.)
Bos. 71
Bos. 72
Petty Hbr.
Bos. 71
Bos. 72
Petty Hbr.
1
2
3
4
5
6
7
AGE

Figure III: 27. Calculated growth in weight of marine juveniles of <u>Anguilla rostrata</u> (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by use of a broken line.


3.0
2.0
1.0
0.5
WEIGHT (gms.)
Bos. 71
Bos. 72
Petty Hbr.
1
2
3
4
5
6
7
8
AGE

A log regression transformation of the form log W = loga + b(logA) was used to calculate growth in weight. The equation expressing this relationship is as follows.

$$\log W = .0245 + .4547(\log A)$$

Calculated weight corresponded closely with the observed figures up to the age six group. At this point the observed weights increase sharply, probably due to the fact that the few specimens available for this group were of exceptional weight thus giving higher values than would normally be expected.

This marine population displayed a faster growth in weight than any of the freshwater samples. At age one the calculated weight was 1.06 gms as compared with 0.42 gms for the fastest growing freshwater sample. At age six the Trainvain group weighed more than double that of the nearest freshwater sample with a mean of 2.39 gms as opposed to a mean weight of 1.11 gms for the freshwater group.

Beyond the first year annual increments in weight were similar in both the fresh and salt water groups. This suggests that the fast growth of the marine sample in the first year of post elver life was largely responsible for the higher overall weights in subsequent years.

d. Length - Weight Relationships

Length - weight relationships were calculated by the use of a log regression transformation. The relationship for this sample is expressed by the following equation and is shown graphically in Figure III. 28 and Figure III. 29.

$$\log W = \bar{1}.2492 + 1.3010(\log L)$$

The eels collected at this site displayed the fastest growth pattern in the observed data. Of the freshwater samples the Boswarlos 1971 juvenile group showed only a slightly slower growth rate for all years except the first in freshwater.

The fastest growth pattern derived from the calculated relationships occurred in this sample. The next fastest growth occurred in the Petty Harbour population which was resident in freshwater.

2. Food of Secondary Migrants

Data on the food of the Trainvain Brook sample appears in Table III. 16.

The dominant organism utilized as food in this sample was mayfly nymphs, (Ephemeroptera). This food occurred in 40.71% of the stomachs examined and comprised 68.0% of the total number of food items.

Figure III: 28. Length-weight relationship of marine juveniles of *Anguilla rostrata* (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by the use of a broken line.

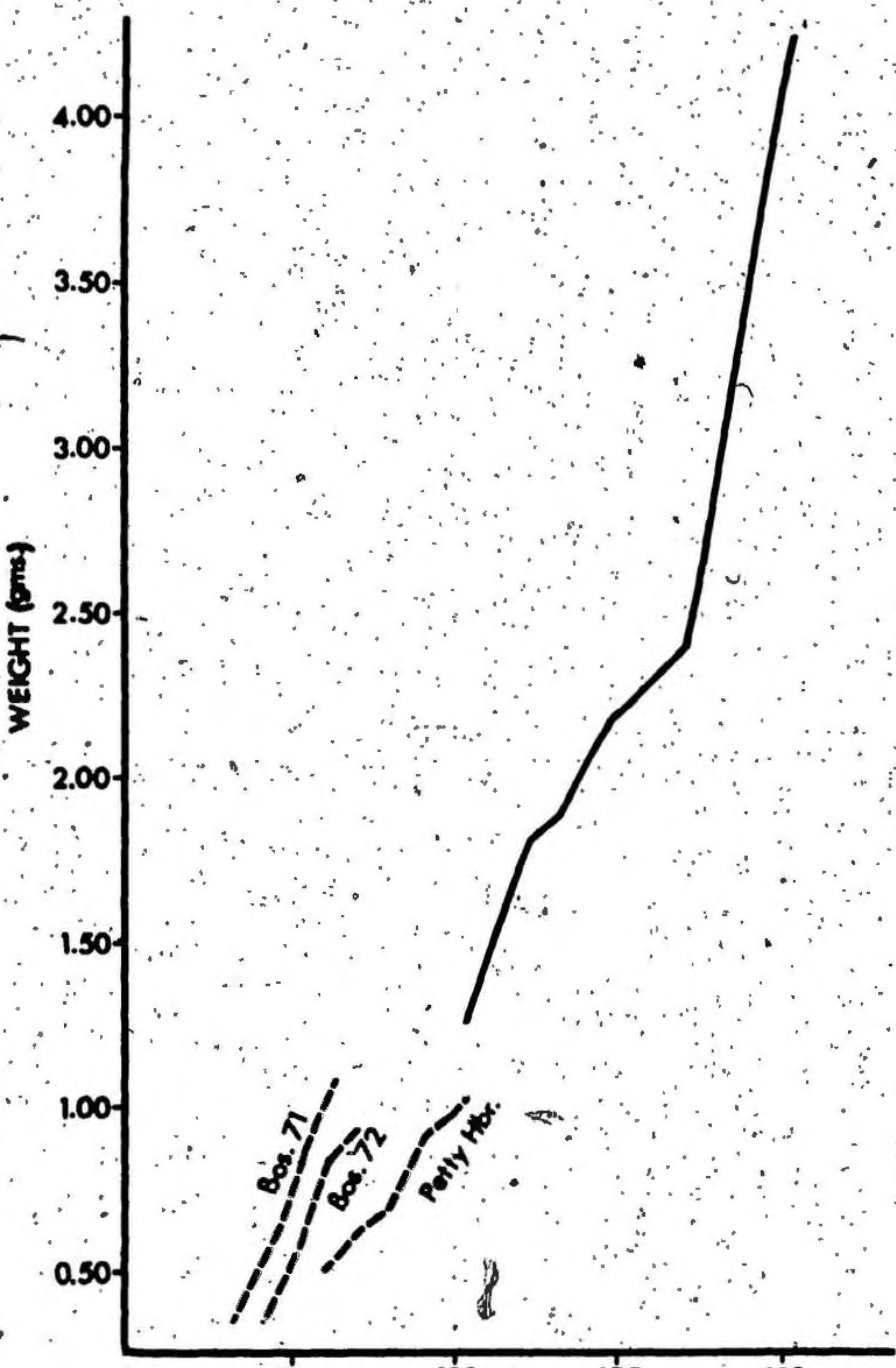

4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
WEIGHT (gms.)
75
100
125
150
LENGTH (mm.)
Bos. 71
Bos. 72
Petty Hbr.

Figure III: 29. Calculated length-weight relationship of marine juveniles of <u>Anguilla rostrata</u> (LeSueur). For comparison purposes similar data is shown for the three freshwater samples examined and is signified by the use of a broken line.

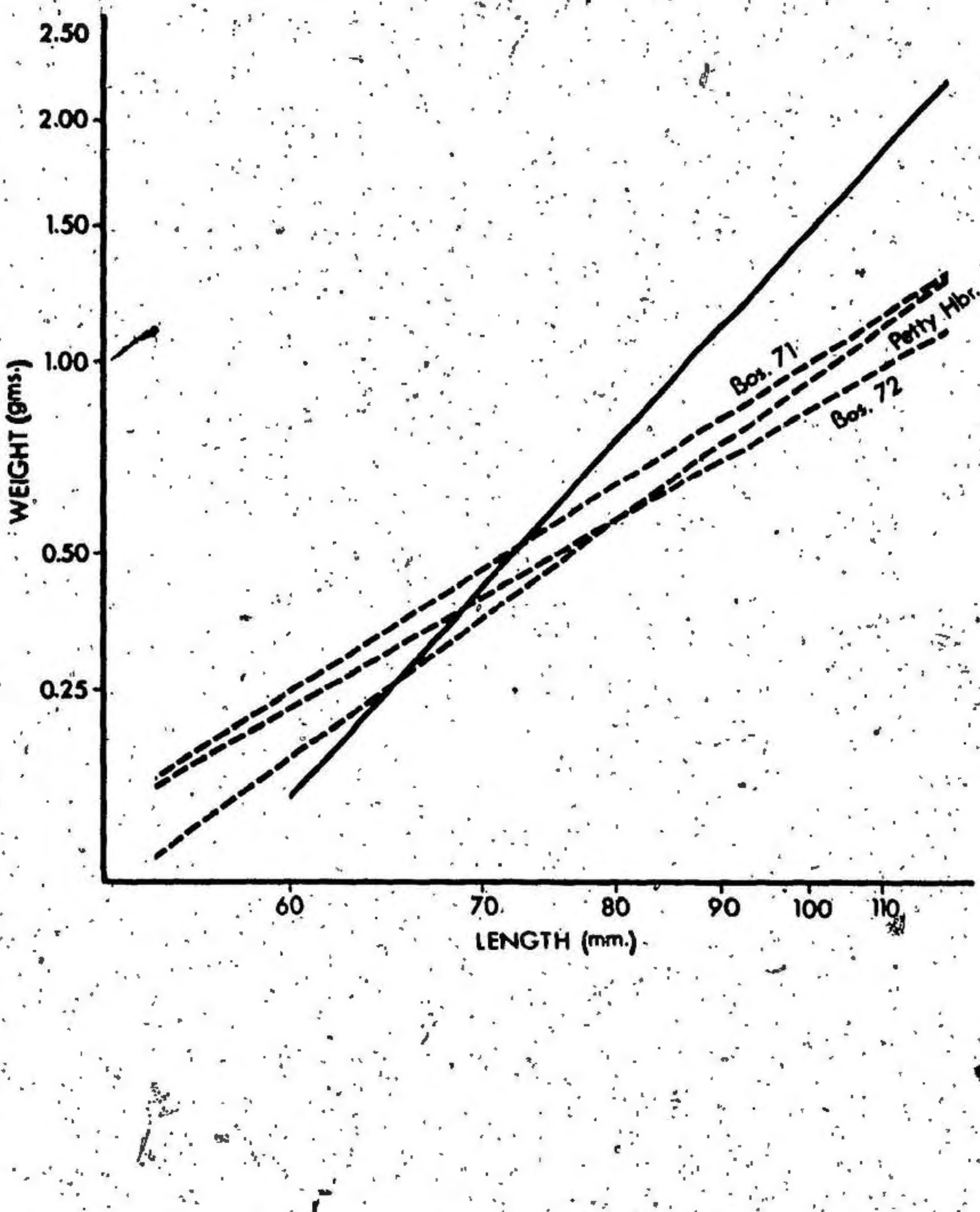

2.50
2.00
1.50
1.00
0.50
0.25
WEIGHT (gms.)
Bos. 71
Petty Hbr.
Bos. 72
60
70
80
90
100
110
LENGTH (mm.)

TABLE III: 16. Food of marine juveniles expressed as percentages of occurrence, number and dry weight.

	Frequency	% occurr.	Number	%	Wt.(gms.)	% wt.
<u>BENTHIC</u>						
Chironomidae (Larvae)	42	28.98	90	30.60	0.0119	3.62
Ephemeroptera(Nymph)	59	40.71	200	68.00	0.3050	92.73
Huridinea	1	0.69	1	0.34	0.0020	0.61
Trichoptera (Larvae)	1	0.69	1	0.34	0.0001	0.03
TOTAL	--	--	292	99.28	0.3190	96.99
<u>PELAGIC</u>						
Coleoptera (Adult)	2	1.38	4	1.36	0.0020	0.61
TOTAL	--	--	4	1.38	0.0020	0.61
<u>TERRESTRIAL</u>						
--------	--	--	--	--	--	--
TOTAL	--	--	--	--	--	--
<u>OTHERS</u>						
Vegetation	--	--	--	--	--	--
Indistinguishable	24	16.56	--	--	0.0079	2.41
Empty	40	33.81	--	--	--	--
TOTAL	--	--	--	--	0.0079	2.41
GRAND TOTAL	--	--	296	100.00	0.3289	100.00

Chironomid larvae were the second most important food group occurring in 28.98% of the stomachs examined and comprised 30.60% of the total of all food organisms taken.

Other benthic fauna taken were leeches, (Hirudinea) and caddis flies, (Trichoptera) but these were unimportant food types comprising less than 1.0% of the total values for all three types of analysis performed on the food.

Terrestrial fauna was not utilized at all as food and only one pelagic group, (Coleoptera) was taken but in small numbers.

Vegetation did not occurr in any of the stomachs examined and debris of no food value occurred only once. Indistinguishable material was found in 15.87% of the stomachs examined. Empty stomachs comprised 33.81% of the total number examined.

3. Tagging of Secondary Migrants

In an effort to determine the effect that an obstruction - such as a waterfall - has on an eel migration a tagging experiment was conducted. This experiment attempted to determine the number of eels that passed the obstruction and if a particular size range was especially successful.

A total of 87 eels ranging in length from 10.0

to 29.0 cms were tagged and released at the base of the fall. The stream was barred and traps were installed in a suitable location about 30.0 meters above the waterfall.

The traps were checked daily but no eels were captured by this method. On the fourth night of the experiment a thorough search was conducted of the area between the waterfall and the traps. Numerous small eels were captured, among them four of the tagged specimens. These fish were 11.0, 12.0, 12.5 and 17.0 cms in length and represented a recovery of 4.60% of the total number tagged.

None of the tagged fish were observed climbing the falls during the four nights that the experiment was in progress. The tagging experiment was discontinued after the fifth night because of heavy rains which caused a marked rise in the water level of the stream.

E. Field Observations on Elvers Entering Freshwater

The observations described in this section were carried out during the 1972 elver run at the Boswarlos sampling site (Figure II. 3) on the west coast of the Island.

In its lower reaches this small stream meanders through a broad sandy beach and empties into the sea. At high tide salt water encroaches into the stream up to a point approximately 25.0 meters inland from its mouth. This creates a brackish pool with a maximum depth of approximately 0.5 meters and a width of about 2.0 meters. At low tide the stream flows rapidly down across the beach having a maximum depth of no more than 20.0 cms. Turbidity in the stream was slight allowing easy observation of incoming elvers. The brackish pool created at high tide provided a suitable area in which samples of elvers could be taken by means of a large dip-net.

In 1972 the first elvers were observed in this stream on the 14th. of July but did not appear in substantial numbers until the 20th. of July. This arrival is substantially later than for other areas of the maritime provinces.

The elvers at Boswarlos entered freshwater only at night. The inward migration occurred always on a rising tide. The first elvers frequently appeared in the mouth of the stream at low tide and the inward movement continued as long as the tide was rising or until most of the elvers in a particular group had entered freshwater.

Elvers entered the stream individually or in small groups swimming actively against the current but keeping close to the sides of the stream. While observations were in progress the density of fish entering freshwater was never more than 10 per minute. Day (1941) observed elver migrations on the Moser River and reported that the eels migrated during the day and in a concentrated run (up to 500 per minute). He reported that they seemed to move into freshwater on the rising tide.

Elvers were observed in salt water near the mouth of the stream. They appeared to be swimming randomly although some elvers were entering freshwater at the time. Large eels were also observed in the area adjacent to the mouth of the stream. It is suspected that they were feeding on the concentration of elvers in the area but efforts to capture a sample were unsuccessful.

Upon reaching the brackish pool described above the elvers remained active until daylight. During the day they remained in the bottom material and when disturbed would immediately seek a new hiding place. This behavour agrees with the findings of Godfrey (1951)

The stomachs of specimens entering freshwater were empty suggesting that they had not fed for some time while at sea. Feeding did not start until a day or two after the elvers had entered freshwater. Benthic invertebrates including Annelid worms and Chironomid larvae provided their first freshwater food.

In the shallows upstream from the brackish pool elvers who were not feeding spent most of the night lying quietly on the bottom. Hundreds were observed on several occasions, at night, lying in large groups in approximately 4.0 cms of water. Predation by adult eels and trout was not observed in the above areas where elvers were concentrated.

IV. DISCUSSION

A. Growth Studies

1. Elvers

From the results of this study it would appear that size variation among elvers of *Anguilla rostrata* at the time of entry into freshwater is due to geographical location. It seems apparent that as you move from south to north along the Atlantic coast of North America the sizes at which elvers enter freshwater increases. This is reflected not only in the mean lengths and weights of specimens taken but also in the marked variation of length classes. The 55.0 to 66.0 mm class is always present although its abundance varies somewhat with locality. From south to north the importance of the 45.0 to 54.0 mm class decreases while the percentage values for the 65.0 to 74.0 mm class are increasing. In the most northerly sample (Newfoundland) a new group, the 75.0 to 84.0 mm class appears for the first time.

Elvers ascend into streams as early as January in Florida (Smith, 1968) and enter freshwater progressively later as you travel north. Elvers ascend the streams of northern Newfoundland as late as early August.

If young eels were in the elver stage when leaving the hatching area in the vacinity of the Sargasso Sea increasing size could be attributed to growth during the northward migration. However, from hatching they are characterized by a series of pre-elver (leptocephalus) stages and remain in these stages until they near the areas where they move into freshwater.

Schmidt (1935) has shown that the leptocephali of the European eel metamorphose into the glass eel and elver stages as they approach the continental shelf of Europe. The arrival of elvers at the coast of Europe becomes more retarded in the areas which are characterized by a wide continental shelf. They arrive at the coast of Spain in October but do not enter the Baltic Sea until the following May. By this time they are completly pigmented elvers or have even developed into juvenile eels.

In the same manner that the North Atlantic current carries the larvae of <u>Anguilla vulgaris</u> to the European coast it is quite possible that the larvae of <u>Anguilla rostrata</u> are carried north-ward along the Atlantic coast by the Gulf Stream.

Smith (1968) studied larval movements of <u>Anguilla rostrata</u> in the Straits of Florida and adjacent waters.

He suggested that the lepotcephali metamorphose into the elver stage when they pass through the edge of the Gulf Stream and enter inshore waters. In more southerly areas where the Gulf Stream passes close to the shore the time interval between metamorphosis and entry into freshwater is relatively short. This could account for the small size and slight pigmentation of southern elvers.

The distance from the edge of the Gulf Stream to the coast increases as it flows north. In the region of Nova Scotia its inward edge varies from 230.0 to 420.0 miles offshore.

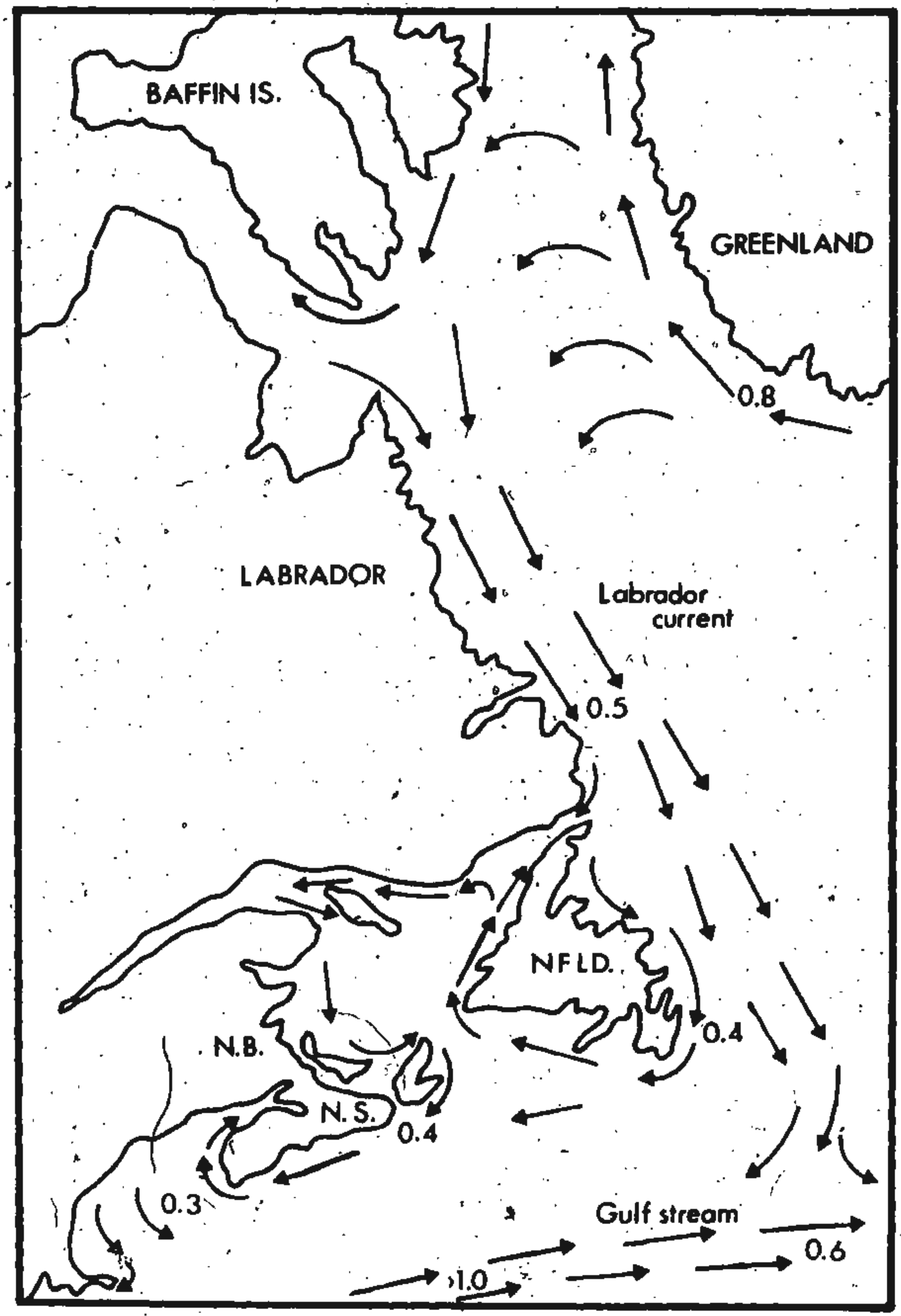
In this area Gulf Stream water breaks away from the main system and mixes with the water masses near the coast. Many forms of marine life associated with more tropical waters are incorporated into these areas of mixed water, (Hachey, Hermann and Bailey, 1954). Elvers could possibly be carried near the coast by these incursions but would, of course, have to travel a greater distance after leaving the Gulf Stream than their more southerly counterparts. The increased traveling time to the coast could account for their greater development if metamorphosis had taken place upon leaving the Gulf Stream as Smith (1968) suggests.

Elvers entering the Gulf of St. Lawrence would have to leave the Gulf Stream in the region of the Laurentian Channel. This would involve crossing the variable currents of the region which are caused by the confluence and subsequent mixing of the Labrador Current and the Gulf Stream (Figure IV. 1). The most likely path of entrance into the Gulf would be on the Newfoundland side of Cabot Strait. In this area an inshore branch of the Labrador Current causes a strong inward movement. Once in the Gulf elvers could be dispersed by the general cyclonic trend of the current within the Gulf itself.

Their migration from the Gulf Stream to the Gulf of St. Lawrence is an extensive movement and possibly accounts for both the retarded arrival of elvers at the coasts bordering on the Gulf and for their large size and advanced pigmentation. This corresponds closely with the pattern described for the European elver in its migration through the English Channel or around Scotland and into the North Sea.

Sklower (1930) examined metamorphosing larvae of _Anguilla vulgaris_ and found that the development of the thyroid gland parallels the stages of metamorphosis. He concluded from this that the determining factor in the metamorphosis of the eel appears to be a thyroid hormone.

Figure IV: 1. Current circulation in the Northwest Atlantic area. The general direction of flow and average current speeds are shown on the map.


BAFFIN IS.
GREENLAND
0.8
LABRADOR
Labrador current
0.5
NFLD.
0.4
N.B.
N.S.
0.4
0.3
Gulf stream
0.6
1.0

It would seem that external factors only retard or accelerate this development.

Stubberg (1913) observed developing elvers of the European eel under varying temperature and salinity conditions. He found that elvers kept in cold water (8.0 to 10.0°C.) developed much more slowly than those kept in warmer water (16.0 to 20.0°C.). Salinity did not effect development so Strubberg concluded that temperature was the most important physical factor influencing metamorphosis.

Low temperatures effecting development of Anguilla rostrata larvae in northern areas could possibly explain the retarded entry of elvers in freshwater. This possibility is doubtful because summer surface water temperatures on the Atlantic coast of Canada and in the Gulf of St. Lawrence range from approximately 10.0 to 20.0°C.

From the data of Sklower (1930) it would appear that this temperature range would not appreciably effect larval development presuming that Anguilla rostrata and Anguilla vulgaris are closely related in this respect.

In any event temperature would not likely produce the large size or advance pigmentation characteristic of northern elvers.

In addition temperature does not adequately explain the retarded entry of Anguilla vulgaris elvers into freshwater in some areas of northern Europe or into the Baltic Sea.

Deelder (1952) who did extensive work on elver migration at sea found no correlation between migration and water temperature. His results were based on studies carried out on the European eel.

Elvers show size differences due to the stage of development through which they are passing. These phases were first investigated and classified by Grassi (1913) for elvers of Anguilla vulgaris and can be applied to elvers of Anguilla rostrata.

Post larval development can be divided into several phases from the "glass eel" stage (Grassi's stage V) to the "early elver" (stage VIa) and "late elver" (stage VIb).

During the VIa stage the elver does not feed and decreases in size. This decrease in size reaches its peak in the early VIb stage but from that point on the elver feeds regularly and rapidly regains its former size. The VIa stage corresponds to the entry of elvers into freshwater thus accounting for the characteristic decrease in size recorded for the early samples examined in Section III. 4. Subsequent samples show a gain in length and weight which corresponds to the VIb stage discussed above.

The early collections were pigmented over the back and sides, above the lateral line. Late collections displayed pigmentation all over the body except parts of the belly. This progressive coloration corresponds to the pattern displayed by <u>Anguilla vulgaris</u> in the VIa and VIb stages.

2. <u>Juveniles in Freshwater</u>

Two factors seem to predominate in the results of the studies on growth of <u>Anguilla rostrata</u> juveniles in Newfoundland. Based on his work Vladykow (1970) concluded that eels in Newfoundland waters are slow growing fish characterized by irregular growth rates. He stated that in many cases eel growth was so slow that specimens of about 600.0 mm (2.0 ft.) could be as old as 15 or 16 years of age.

Gunning and Shoop (1962) reported similar growth conditions for Louisiana eels. Ogden (1970) also reported slow irregular growth for eels in New Jersey streams.

These two factors are also well established for growth in the European eel and are recognized by Bertin (1956) after reviewing data on several thousand specimens of <u>Anguilla vulgaris</u>.

In the present study both these factors are apparent in the data for annual length and weight increments and for the range in length and weight within each age group. Annual increments in length varied from 1.1 to 7.3 mm within the age groups sampled. Annual increments in weight varied from 0.06 to 0.28 gms for the freshwater collections.

Range in length and weight within an age group was highly variable. The freshwater samples had a range of up to 4.0 cms in length and up to 1.0 gm difference in weight.

The data of Vladykov (1970) and Ogden (1970) as well as the results of this study are not consistent with the findings of Gray and Andrews (1971). They reported much faster growth rates for juvenile eels in Newfoundland. However, their study was concerned primarily with adult eels and very few juveniles were examined which could account for the differences.

In the freshwater samples examined in this study the Boswarlos 1971 eels grew slightly faster than those taken in 1972 at the same site. The slowest growth rate was displayed by the Petty Harbour eels. In that the stream from which the Petty Harbour sample was taken was fast-flowing and contained few pools as compared to the stream at Boswarlos the slower growth rate of the

Petty Harbour samples may reflect this condition. Eels appear to favour warmer, slow moving water (Bertin, 1956; Gardner and King, 1922). A still or slow moving water body may favour growth because less energy is expended while feeding. This has been suggested by Bertin (1956) and Sinha and Jones (1967a) for the European eel.

The feeding activity of the eel shows a seasonal cycle which depends on temperature (Bertin 1956). This could account for the faster growth rate of more southerly eel popuations which live in warmer water and have a longer annual feeding period (Gunning and Shoop, 1962). An observation made by D'Ancona (1951) supports this theory. He placed equal numbers of Anguilla vulgaris into two tanks one of which was heated to a temperature of 5.0° C. above the other. Both groups were fed to excess yet the eels in the warmer water showed more rapid growth.

Continous temperature records were not kept for the sampling areas but from temperatures recorded during sampling the Boswarlos stream was warmer than the stream at Petty Harbour. Although the temperature differences between the sampling areas were slight this factor could have had some effect on the growth of the eels inhabiting these areas.

A main factor causing the slower growth rate at Petty Harbour would seem to be food supply. Bottom material consisted of solid rock or large boulders at Petty Harbour. The stream bottom at Boswarlos ranged from gravel to sand to mud providing a much more varied substrate supporting a greater variety and number of insects. This conclusion was reached after bottom samples from the two areas were examined. The incidence of empty stomachs in the Petty Harbour samples was considerably higher than at the other sites.

3. Marine Juveniles

The most obvious feature of growth in the marine collections was the exceptionally fast growth in the first year of post-elver life. Specimens in this age group doubled in length and weight while juveniles living in freshwater displayed, in most cases, very little growth during this period. After the first year, however, growth in the marine environment was much slower but annual increments were still somewhat larger than for juveniles living in freshwater.

Sizes of metamorphosed elvers are approximately the same when they reach coastal waters. This would seem to hold true whether they enter freshwater or remain in the sea.

Therefore the marked differences in growth rate between freshwater and marine juveniles would seem to be environmentally induced. The most likely factors contributing to increased growth in the marine environment would be more food and perhaps more space.

Both factors have been related to the growth of anadromous and sea-run salmonids in several studies, (Wilder 1952 and Green 1955) and may be equally applicable to the American eel. Bertin (1956) has shown, for example, that high density does adversely effect the growth of the European eel. Bellini (1907) and Fidora (1951), however, conducted experiments with *Anguilla vulgaris* and found that the quantity of food much more than the amount of space was the dominant factor in the growth of this species. While no data is available from the present study on the types or amount of food eaten by juvenile eels in the sea, it would seem likely that an increase in living space could cause a decrease in competition for food and this could result in much faster growth. Why this increase in growth would be most apparent in the first year of post-elver life is not known.

In freshwater where densities of small eels are high after an elver run competition for suitable food may occur. This could produce slower growth than in a nearby marine population in which competition is low. In subsequent years the freshwater population may disperse over a wider area and become reduced by predation and other mortality. This could result in somewhat improved growth.

B. Food of Elvers and Juveniles

Food relationships help determine rates of growth, population levels and condition of the fish and as well indicate situations where competition is influencing the factors listed above. For most fish species food habits change with season, age, size of the individual and with the kinds of food available.

Elvers and juvenile eels are almost exclusively bottom feeders. Benthic fauna comprised the most important food in all samples. Within this group Chironomid larvae were by far the most important. Bottom sampling showed that Chironomid larvae were the most numerous insects in the substrate.

Other organisms such as caddis flies, dragon flies and freshwater snails were also present in substantial numbers. These benthic organisms were seldom eaten by small eels but formed an important food of larger eels and trout living in the same stream.

The Petty Harbour sample was distinguished by its high number of empty stomachs but again Chironomids were the single most important food. It is interesting to note that terrestrial species formed a larger proportion of the food of small eels at this site than at the other. This could possibly indicate that the small eels were using terrestrial insects as an alternate food due to the lack of benthic organisms.

The dependence of small eels on Chironomids as a principal food corresponds with the findings of Elson (1940b). He reported that the food of eels in two Nova Scotia streams contained up to 82.5% Chironomid larvae by volume.

In some samples examined in this study the majority of material listed under debris was sand. This was apparently ingested along with food organisms as the eel captured prey among the material on the bottom of the stream. The presence of this material further demonstrates the benthic feeding habits of elvers and juvenile eels.

C. Predation and Competition

1. Predation on Elvers by Larger Eels and Trout

There are various records in the literature reporting instances of salmon, trout and large eels feeding upon elvers and juvenile eels. Frost (1950) has described heavy feeding by trout upon small resident European eels. Carins (1942b) and Hobbs (1948) have also reported predation by brown trout upon long-finned eels in New Zealand. The most important fish predator upon elvers is perhaps the adult eel. Large eels have been reported by Day (1941) feeding heavily on elvers during their ascent into freshwater.

In the present study it was found that adult eels and trout feed commonly on elvers. Their importance as a food of trout was insignificant when examined by the number method. The occurrence and dry weight methods more accurately expressed their importance as a food.

Elvers formed an important part of the diet of large eels constituting well over 50.0% of the weight of all food consumed.

Elver runs can extend over a period of up to two months and the density of elvers in streams could be high for a much longer period after actual migration from the sea into freshwater ceases. In view of the duration of elver runs it is apparent that elvers are an important seasonal food of adult eels and brook trout.

2. Competition for Food by Elvers, Adult Eels and Trout

The role of the eel as a competitor for the food of trout has been described by Sinah and Jones (1967b) for the European eel. Hobbs (1948) and Carins (1942b) have reported similar results for the long-finned eel. Elson (1940b, 1941) has reported that eels compete very seriously with salmon fingerlings and parr for food.

Competitive relationships between organisms are usually highly complex and difficult to determine. The results of this investigation reveals a considerable overlap in the types of food taken by elvers, adult eels and trout. This was especially true of the food of adult eels and trout and applied more specifically to the benthic portions of their diets.

Chironomid larvae were much utilized as food by elvers, large eels and trout. This group had a frequency of occurrence of 100.0% in elvers and up to 60.0% and 75.0% in trout and large eels respectively. Other benthic organisms utilized, especially by adult eels and trout, were caddis fly larvae (Trichoptera), true fly pupae (Culicidae), snails (Amnicolidae) and dragon fly nymphs (Odonata). Two fish species, the three-spine stickleback and the elver, were also taken frequently by both adult eels and trout. Terrestrial insects were taken regularly by brook trout but were insignificant as food of either elvers or adult eels.

Competition is largely dependent upon the availability of food and upon population densities. Numbers of elvers, adult eels and trout were high in the stream investigated, at least for part of the year. The area was also subject to rapid increases in fish populations due to new arrivals of elvers and the return of sea-run brook trout. The environment, in this case a small stream, was limited by size as well as other factors in the amount of suitable food that could be produced. Because of these factors eels and trout could possibly compete for food, especially benthic organisms at least for part of the year.

D. Secondary Upstream Movement of Young Marine Eels

The eel is catadromous and in general, eel movements have been described as adhering to relatively simple patterns. Elvers migrate into freshwater and sexually mature adults migrate to the sea. The results of eel investigations by several authors however, have led them to conclude that eel movements are much more complex than this (Smith and Saunders 1955, Medcof 1969).

With reference to the simple catadromous migration of the eel Smith and Saunders (1955) after extensive work on the eel populations of the Maritime provinces of Canada stated, " Certainly such movements are inherent in the life history of the eel, yet, as shown from the data that we have presented, these exhibit much diversity with respect to intensity and time and in relation to the environmental factors effecting them and do not appear to include all large movements of eels observed in our waters."

Medcof (1969) in a publication describing fresh-water and salt water migrations of eels in Nova Scotia suggested that eels migrate between fresh and salt water more commonly than the literature indicates. In addition he stated that these migrations were of sufficient interest to warrant further investigation.

One of the most intriguing of these migrations involves the regular secondary movement of small eels from the sea. Godfrey (1951) reported such a migration on the Pollett river in mid-August. He observed numerous small eels varying from approximately 15.0 to 25.0 cms. in length swimming upstream during a hot summer afternoon. Carins (1942a) observed similar movements of small long-finned eels and has described this movement as a well defined migration, which in certain localities, being anticipated annually, is observed with constant regularity.

Secondary upstream movements have been observed for three successive years at Trainvain Brook near the south-west corner of the Island. The migration consists primarily of juvenile eels and should not be confused with the fall migration of adults into freshwater seeking suitable areas in which to spend the winter. In 1970 the eels appeared on August 1st., in 1971 on August 2nd. and in 1972 on August 5th.

Two days before the arrival of the 1972 migrants the brook between the waterfall and the sea as well as the shallow water along the beach adjacent to the outlet of the brook was examined for the presence of eels. Very few were found in the brook (11) or along the salt water beach (4). Once the migration was in progress - in addition to those gathered below the waterfall - large numbers of eels were present in the brook and were also found hiding among the rocks in the beach near the outlet of the stream. The eels seemed to appear suddenly and in large numbers. The concentration of eels below the waterfall could be estimated at several thousand.

Large numbers of eels were actively engaged in climbing the cliff face at the waterfall both day and night. For the most part they followed two faults in the rock which led from the water to the crest of the fall. The eels were, at times, 5 or 6 deep in these cracks and formed a more or less continous band up to 10 eels wide (6.0 to 8.0 cms). Smaller eels (10.0 to 20.0 cms in length) seemed to be more successful in attempting to climb the falls while large individuals (up to 30.0 cms long) were only observed lying on the wet rocks no more than 0.5 to 1.0 meters above water level.

The sample ranged in age from one to eight years but the great majority of the specimens were in the one to four year age groups. Eels ranging in length from 10.0 to 15.0 cms were most numerous but larger eels (up to 30.0 cms) were also represented.

The eels fed actively immediately upon arrival into freshwater. Subsequent bottom sampling showed them to be the most numerous benthic insect present in that section of the stream. Empty stomachs were numerous but this may have been due to heavy feeding on the insect population of this area of the stream by such a large influx of predators.

The tagging experiment coupled with observations would seem to show that these eels were migrating to the upper reaches of the stream system.

It seems apparent that this migration could not be classed as a minor movement of eels into freshwater as is common in brackish estuarine areas.

Most of the literature has described the annual elver run as the sole means by which eels populate inland waters. If secondary migrations of the type described in this section are common, and they appear to be in some areas, they could contribute substantially to freshwater eel populations.

In some streams of the Maritime provinces resident eels have been removed and elvers denied access in an attempt to increase salmonid production. In spite of these measures, eels especially juveniles, rapidly move into such areas. It is quite possible that secondary migration is responsible for the repopulation of these apparently eel-free streams.

More extensive observations of secondary eel migrations could lead to increasingly effective controls of this species in areas where their absence is beneficial to the production and growth of more valued fish.

V. SUMMARY AND CONCLUSIONS

1. In most areas of the province elvers enter freshwater from early July to early August. At entry into freshwater they average about 65.0 mm in length and weigh approximatley 250.0 mg.

Young eels grew slowly in the freshwater areas sampled. Mean length was approximately 100.0 mm and mean weight about 2.0 gms for a seven year old fish. Samples of juveniles from salt water displayed a faster growth rate, especially in the first year of post-elver life.

2. Gut contents were analysed by three methods; occurrence, number and dry weight. Generally the constitutents of the diet of elvers and juvenile eels is similar in the areas studied even though their relative importance may vary with locality.

A heavy dependence on bottom insects especially Chironomid larvae and Annelid worms was evident. The diet of elvers consisted almost entirely of Chironomid larvae. Juveniles utilized a more varied diet which included caddis fly larvae and dragonfly nymphs. Very few terrestrial or pelagic organisms were eaten.

As the eel grows larger its diet becomes more varied, (Gray, MS, 1970). Large eels regularly take sticklebacks, small trout and elvers as food. Use is also made of a greater variety of benthic insects. All through its growth, however, the eel appears to utilize benthic insects most frequently as food.

3. Elvers are eaten in substantial numbers by brook trout and adult eels. From the data presented in this study it would appear that elvers form an important seasonal food for trout and large eels.

The food of elvers, juvenile and adult eels and brook trout overlap substantially, especially in summer. If sufficient numbers of insects - especially bottom species - were not available competition for food could occurr between these two species.

4. Late summer movements of juveniles from salt to freshwater are common in some areas of the Island. These migrations usually take place in early August. Large numbers of small eels move into streams from the sea adding substantially to the eel populations of the area. These young eels have been, up to this time, strictly marine and this would appear to be their first entry into freshwater.

5. In Newfoundland elvers usually enter freshwater in July. In Northern Newfoundland, however, this may

be retarded until early August. In the areas studied elvers always enter freshwater at night and on a rising tide. It appears that they do not feed for some time before entering freshwater. Once in freshwater they commence feeding after a two to three day period.

LITERATURE CITED

Ancona, U. d' 1951. Tentativi di deviazione essuale nell'anguilla. Boll. Zoll. 18, (Turin, 1951).

Bellini, A. 1907. Experience sur l'elevage de l, Anguille en stabulation a Commancchio. Bull. Soc. Cantr. Aquicult. Peche 27: 81, 141, 186, 215.

Bertin, L. 1956. Les Anguilles; Payot, Paris.

Cairns, D. 1942a. Life history of the two species of New Zealand freshwater eel. Part I: Taxonomy, Age, Growth, Migration and Distribution. N. Z. Jour. Sci. Tech. XXIII; 2B: 53B-72B.

__________.1942b. Life history of the two species of New Zealand freshwater eel. Part II: Food and inter-relationship with trout. N. Z. Journ. Sci. Tech. XXIII; 4B: 132B-148B.

Christensen, J. M. 1964. Burning of otoliths, a technique for age determination of soles and other fish. Journal du Conseil. 29(1): 73-81.

Day, L. R. 1941. A preliminary report on elver migrations into Moser River, N. S. Mas. Rept. Biol. Sta. No. 213.

Deelder, C. L. 1952. On the migration of the elver (Anguilla vulgaris Turt) at sea. Journ. du Conseil. 18(2): 187-218.

Elson, P. F. 1940a. Predators of salmon fingerlings in Goldmine Brook. Fish. Res. Bd. Can. MS Rep. Biol. Sta. No. 210(6): 13p.

________. 1940b. Food of salmon, trout and eels in Goldmine Brook. Fish. Res. Bd. Can. MS Rep. Biol. Sta. No. 210(8): 18p.

________. 1941. Eels as a limiting factor in salmon smolt production. Fish. Res. Bd. Can. MS Rep. Biol. Sta. No. 213(16): 9p.

Fidora, M. 1951. Influenza dei fattori ambietale sull' accrescimento e sul differenziamento sessuale delle anguille. Nova Thalassis. 1(9): 1-37.

Frost, W. E. 1950. The growth and food of young salmon (Salmo salar) and trout (S. trutta) in the River Forss, Caithness. J. Anim. Ecol. 19; 147-158.

Gardiner, J. A. and G. King. 1922. Respiratory exchange in freshwater fish. Part V. Eels. Biochem. J. 16(6): 736-738.

Gerking, S. D. 1949. Urethane (Ethyl carbamate) in some fishery procedures. Prog. Fish. Cult. 11(1): 73-74.

Godfrey, H. 1951. A report on eel investigations for 1950-51. Fish. Res. Bd. Can. Manuscript Rep. #439.

__________. 1957. Feeding of eels in four New Brunswick salmon streams. Fish. Res. Bd. Can. Atlantic Progr. Rep. 67: 19-22.

Grassi, B. 1913. Metamorfosi dei Murenoidi: Ricerche sistematiche ed ecologicle. (Jena, 1913).

Gray, R. W. 1970. A contribution to the Biology of the American eel (Anguilla rostrata (LeSueur) in certain areas of Newfoundland. Unplublished M. Sc. thesis, Dept. Biol. Mem. Univ. of Nfld. 147p.

__________. and C. W. Andrews. 1970. Sex ratio of the American eel (Anguilla rostrata(LeSueur)) in Nfld. waters. Can. Jour. Zool. Vol. 48: 3 p. 483-87.

__________. and C.W. Andrews: 1971. Age and growth of the American eel (Anguilla rostrata(LeSueur) in Newfoundland waters. Can. Jour. Zool. Vol. 49:1 p. 121-128.

Greene, A. F. C. 1955. Will stunted brook trout grow? Prog. Fish-Cult. 17(2): p91.

Gunning, G. E. and C. R. Shoop. 1962. Restricted movements of the American eel (_Anguilla rostrata_, (LeSueur)) in freshwater streams, with comments on growth rate. Tulane Studies in Zoology, Vol. 9(5): 265.

Hachey, H. B., F. Hermann and W. B. Bailey. 1954. The waters of the ICNAF convention area. Ann. Proc. ICNAF Vol. 4: 1953-54.

Hobbs, D. 1948. Trout fisheries in New Zealand, N.Z. Mar. Dept. Fish. Bull. 9: 1-175.

James, D. T. and V. D. Vladykov. 1967. A method of preparing eel otoliths for age determination. Annales de l' ACFAS, 33: 69.

Jensen, A. C. 1965. A standard terminology and notation for otolith readers. ICNAF research Bulletin #2: 5-7. Dartmouth, Canada.

Lagler, K. F. 1952. _Freshwater Fishery Biology_. W. C. Brown Company, 421p.

Medcof, J. C. 1969. Fishermens reports of freshwater and salt water migrations of Nova Scotia eels (_Anguilla rostrata_). Can. Field. Nat. Vol. 83(2): 132.

Needham, J. G. and P. R. Needham. 1962. _A Guide to the Study of Fresh-water Biology._ Comstock Publishing Co. New York. 89p.

Odgen, J. C. 1970. Relative abundance, food habits and age of the American eel in certain New Jersey streams. Trans. Amer. Fish. Soc. 99(1): 54.

Pennak, R. W. 1953. _Fresh-Water Invertebrates of the United States_. The Ronald Press Co., New York. 769p.

Schmidt, J. 1935. Danish eel investigations during 25 years (1905-1930), (Text from "Dana's Fogt Omkung Jorken 1928-1930, "Copenhagen, 1932). Carlsberg Foundation, Copenhagen: 16p.

Sinha, V. R. P. and J. W. Jones. 1967a. On the age and growth of the freshwater eel (Anguilla anguilla). J. Zool., London 153: 99-117.

__________. 1967b. On the food of the freshwater eels and their feeding relationship with the salmonids. J. Zool., London 153: 119-137.

Sklower, A. 1930. Die Bedeutung der Schilddrüse für die Metamorphose des Aales und der Plattfische. Fortschr. nat. Forsch. Vol. VI, Berlin, 1930.

Smith, D. G. 1968. The occurrence of larvae of the American eel Anguilla rostrata in the straits of Florida and nearby areas. Bull of Marine Sci. Vol. 18: 280-93.

Smith, M. W. 1948. Improved trout angling in a small lake after poisoning undesireable fish. Can. Fish. Cult. 3(4): 3-6.

__________. 1952a. Fertilization and predator control to improve trout production in Crecy Lake, New Brunswick. Can. Fish. Cult. No. 13: 33-39.

__________. 1956. Further improvement in trout angling at Crecy Lake, New Brunswick. Can. Fish. Cult. 19: 1-4.

__________. and J. W. Saunders. 1955. The American eel in certain freshwaters of the Maritime provinces of Canada. J. Fish. Res. Bd. Can. 12(2): 238-269.

Strubberg, A. 1913. The metamorphosis of elvers as influenced by outward conditions. Medd. Komm. Hav. Fish. Vol. IV, No. 3 (Copenhagen, 1913).

Usinger, R. L. 1963. Aquatic Insects of California: With Keys to American Genera and California Species. Univ. of California Press. Berkeley and Los Angeles.

Vladykov, V. D. 1966. Remarks on the American eel (Anguilla rostrata LeSueur). Sizes of elvers entering streams; the relative abundance of adult males and females; and present economic importance of eels in North America. Verh. Internat. Verein. Limnol. 1966(16): 1007-1017.

________. 1970. Progress Repr. #1-5 of the American eel (Anguilla rostrata) studies in Canada. Ind. Dev. Branch - Fish. Ser. - Dept. of Fish. and Forestry. Ottawa.

Ward, H. B. and G. C. Whipple, 1959. Fresh-Water Biology. Second Edition, W. T. Edmondson (ed.). John Wiley and Sons Inc. New York.

Wilder, D. G. 1952. A comparative study of anadromous and freshwater populations of brook trout, Salvelinus fontinalis (Mitchell). J. Fish. Res. Bd. Can. 91(4): 119-203.